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GLOBAL DISASTER EARLY WARNING SYSTEM POLICY PLANNING

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1.0 EXECUTIVE SUMMARY

At the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, (UNISPACE 82), held in Vienna, Austria in August 1982, the United States delegation presented several 'initiatives', to be pursued with other interested governments in an effort to further apply space technology to problems on Earth. One such initiative was proposed by the United States Office of Foreign Disaster Assistance, in the U.S. Agency for International Development. The description of the initiative, as it appeared in the paper presented by the U.S. Delegation is as follows:[1]

> In order that the use of Outer Space Technologies in assessing and reacting to natural disasters of varying natures and dimensions may be examined, the United States proposes to sponsor a five-day conference by the U.S. Agency for International Development, Office of Foreign Disaster Assistance in Washington, D.C., in the spring of 1984. This conference would address problems in areas such as global drought assessment, agroclimate, famine early warning, tsunami and severe storm early warning, and considers how satellite based data and communication systems can be of assistance in these areas. Current operational systems, Systems under development and future applicable technologies would be examined.
>
> Such a conference would make more generally available information on those technologies and their applications currently existing and suitable for operational implementation worldwide. The conference would help to focus international consideration of this important topic and assist in definition of future systems requirements. Opportunity would be given for participants, especially from developing countries, to examine new advance technologies available to them. Participants at the expert level would discuss concrete mechanisms, including relatively sophisticated environmental monitoring systems which can mitigate the impact of natural disasters and save lives through preparation and early warning using current and future satellite-based early warning systems and data collection platforms.

As a precursor to the conference, the Office of Foreign Disaster Assistance initiated the current study to lay the planning groundwork for the conference. The purpose of this study is to review current satellite (and associated) technology and related programs with applications to disaster warning. In addition, this study addresses the policies and issues with developing the conference agenda and the future direction of US technical agencies which could contribute to the development of a global disaster early warning system. To this end a tentative conference agenda has been drawn up and an interagency program committee for that conference suggested.

1.1 Disaster Management and Information: A Framework For Understanding

Disaster management can be categorized in a variety of ways. This study utilizes the catagories adopted by USAID's Office of Foreign Disaster Assistance (OFDA) and adds to them. The study includes, as elements of Disaster Management, Early Warning, Emergency Decision Making, Country Preparedness, Emergency Relief, and Rehabilitation. While this study is primarily concerned with Early Warning of Natural Disasters, it is useful to consider the information requirements for early warning in the context of overall disaster management.

1.1.1 Early Warning

Early warning of natural disasters involves several steps. These include (1) the collection of relevant information regarding conditions which might portend a disaster; (2) the collection of such data in a central location with the capabilities to process and analyze it; (3) forecasting, based on that information and analysis, the location, timing, probability and extent of the disaster; and (4) the dissemination of that forecast to relevant agencies responsible for responding to a natural

disaster and to those areas where the natural disaster may occur. Once the forecast has been disseminated to the relevant relief agencies and to the local officials in the area of impact, then decisions must be taken as to how best to respond.

Disasters, and hence disaster forecasts, can be described by looking at them along four dimensions. First, when are they expected to take place? A drought or food shortage may be years in the making, while a Tsunami or Hurricane may be only hours in developing. Second, what is the potential impact of the disaster? This can only be judged by the location in which the disaster is expected to occur and the magnitude of the disaster. If a large magnitude disaster hits an area of low population and low economic value then it will have a low impact. On the other hand, a disaster of small magnitude in a densely populated and/or high economic value area may have high impact. Third, what is the vulnerability of the area concerned? Is it an area which is easily accessible with disaster management/relief equipment? Is it an area in which little or nothing can be done to mitigate against the disaster? What plans are already in place for evacuation of people, or for disaster related communications while trying to manage disaster assistance? Fourth, what is the probability of the disaster occuring. In particular, timing and impact both result from forecasting models and any predictions about them are, by nature, probabilistic.

1.1.2 Emergency Decision Making

Perhaps the most intractible of all of the aspects disaster management is the manner in which decisions are made. Because, forecasting models and early warnings are, by nature, probabilistic, decision rules for making decisions to take action, based on those

probabilistic forecasts, vary from country to country and culture to culture. Efforts have been made in several projects sponsored by the Office of Foreign Disaster Assistance (OFDA) in USAID to build "decision models" into disaster forecasts, however these models are influenced heavily by the personal importance the modeller gives to various decision criteria. For instance, if one forecasts that a hurricane will strike with some probability in the next several hours, an estimate of economic, human and political costs must be made for a decision to either evacuation or do nothing. Different decision makers will weigh the various costs and benefits (human lives, economic impact, etc) of particular actions differently.

The point here is that the decision to take action based on a probabilistic warning is a key step in any disaster management effort. In addition, it raises another key point which is that any system to produce early warnings of natural disasters will be useless unless there are institutions and trained people to act on those warnings. This implies that the development of any satellite based early warning system must take into account the need for training and institutional development.

1.1.3 Country Preparedness

Country preparedness involves "activities that develop plans to save lives and minimize disaster damage, or enhance disaster response operations. Examples include the development of analytical methods such as models for predicting the effectivenss of disaster response operations, training exercises installing warning systems, stockpiling

vital food and medical supplies, and mobilizing emergency personnel on a standby basis. Preparedness plans go into action during the warning period."[2] Essentially then, country preparedness involves preparing a country to mitigate the effects of a disaster once it occurs.

1.1.4 Emergency Relief

Emergency relief includes "post-disaster activities designed to provide emergency assistance for casualities, to reduce the probability of secondary damage, and to speed recovery operations. Examples include evacuation and/or sheltering of the population at risk, search and rescue, emergency medical care and damage assessment."[3]

1.1.5 Rehabilitation

Rehabilitation includes "short-term post-disaster activities (rehabilitation) designed to return vital life-support systems to minimum operating standards; and long-term post-disaster activities (reconstruction) designed to return life to normal or improved levels (for example, redevelopment and community planning)."[4] The line between emergency relief and rehabilitation is hard to dra as emergency relief usually phases naturally into rehabilitation.

1.2 Characteristics of Natural Disasters and Data Requirements

In order to understand the applicability of satellites to disaster warning and management, one must first characterize natural disasters. From these characteristics one can then determine the data requirements necessary for early warning and management of disasters with particular characteristics. Only after outlining the data requirements associated with early warning and management of various disasters can one determine the applicability of satellites and satellite acquired data.

As an initial effort to characterize disasters, this study suggests that the following variables are central to understanding the data requirements of disaster management: location; impact area; disaster development time; frequency of occurence; numbers of people effected; severity of impact; and visibility of indicators.

The study's analysis of these variables suggests several key points about the application of satellite remote sensing to meeting the data requirements for disaster warning and management.

1. There are a number of characteristics of disasters which have little to do with satellite data and information. In fact, many of these characteristics are more important to apriori planning of disaster early warning and management systems, than they are to the types of data required by those systems. For instance, location of disasters, area of impact, the frequency of occurrence, numbers of people effected and severity of the disaster have more to do with planning for disaster management (including early warning) systems, than they do with the types of data to be collected once a decision has been made to implement a system.

2. Once a decision has been made to develop an early warning and mangement system, then decisions are required as to how frequently data observations are required and what type of data is to be collected. Frequency of data observations varies primarily with the time it takes a disaster to develop. Shorter lead time requires more frequent, if not continual, observations while longer lead time allows less frequent data collectin. The type of data collected (whether it be satilite data, aerial photography, in-situ monitors, human observations, etc.) depends in large part on the size and visibility of the indicators of a particular disaster.

3. Particular disasters have characteristics which are peculiar to that type of disaster. As such it is difficult to generalize the requirements of disasters for data and information. In fact, because of the differences in disasters and their characteristics it may be difficult to integrate disaster warning information systems.

1.2.1 Communications Requirements for Disaster Early Warning

The same characteristics of disasters outlined above effect the planning of the communications aspects of any disaster early warning and management system. Possible locations of particular types of disasters dictate where communications facilities will likely be required. The area of impact will have an effect on whether mobile or stationary communications is required. Disaster development time also effects the type of communciations facility required. If a disaster develops rapidly then mobile or in-place communications is essential. If a disaster is slow to develop then longer term communications may be required and established. If a disaster is occurs frequently in a particular area, it may justify a permanent communications link, however, if a disaster is a rare occurrence then a permanent link is hardly justified. Obviously, the numbers of people effected and the severity of the disaster will also influence the priority attached to the need for communications facilities for a particular disaster type.

These characteristics of disasters generate a need for voice, data and video (television) communications. The role of the human in the use of each of these communications media is critical. In each case, none of the human sources using these transmission types is disengaged from the medium. That is, the use of each of these system types requires a knowledgable, rationally-thinking and skilled person with

organized approaches to information use and transmission. While this provides the chance for misinterpretation and judgement error, universal and perfectly useful automatic sensing and reporting will never exist.

In general, voice is useful for all disaster management stages, although not always best; data collection and reporting is useful to authorities for warning stages, and only if interpreted and rebroadcast by other general media is it worthwhile to the general public; data is also especially useful in latter, rehabilitation stages; and television has its place for the public in early warning and country preparedness, and for authorities in post-event assessments.

1.2.2 Applicability of Satellite Telecommunication to Disaster Management

To understand the importance of satellite communications to disaster warning and management, it is necessary to observe the unique generic, characteristics of satellites. In addition to its obviously unique technologies, the geosynchronous satellite used for communications has the following special properties:

1. Networks using satellites are distance-insensitive to user who are within view of the satellite. In the vast majority of cases (except for rare instances of below-surface communications needs and thick or wet foliage), satellite communications can be conducted without being hampered by the local environment. There may be special instances where high hills and low elevation angles from the terminal to the satellite prevent a line-of-sight path, but these are at least statistically infrequent.

2. The relatively small size of satellite voice terminals results in total physical control. This personal handling, particularly in difficult environments and without mechanical aids, can be important for emergency use and in control against damage of the terminal itself. Effects of

earthquake, flood, and high winds will not affect satellite communications as long as the terminal itself (which, even for multi-channel sized antennas, occupies a relatively small amount of real estate) and a power source either can be reasonably protected from the environment, or restored after the threat diminishes. In some cases, such small satellite terminals have survived difficult environments where cables, wires, terrestrial microwave towers have not.

3. Overall power requirements for satellite terminals are small in comparison, for instance, to the operation of an entire long-distance wire and microwave network. They therefore are amenable to use under stored-power and efficient-generation conditions where otherwise communications would be precluded or traded off against other operations needing power for health and safety.

4. A communication satellite system, with an on-site operator using a hand-held, battery-powered camera and a small terminal, can bring relatively high resolution, real-time, color imagery to damage and rescue analysis personnel located remotely for purposes of control and assessment. The implementation of voice feedback from remote observers to the cameraman can further enhance the observational value. Even storage on a portable cassette recorder for playback through a satellite system can be useful.

5. Instantaneous restoration of full capability to a central location for control at the moment the terminal becomes operational is much quicker than having to rewire a terminal or set up a relay chain via microwave or cable.

6. Because it is centrally controlled, a satellite communication system is flexibly convertible from regular commercial use to a disaster voice network, permitting (1) a spread of whole-system costs over a much larger and generally profitable base, (2) avoiding the duplicative costs of

a separate network's acquisition, maintenance, and training, and (3) availability of regular equipment maintenance, spares, fuel, and trained operations personnel to assure network utility when needed for an emergency.

7. Standardization, in general, of satellite frequencies, bandwidth, and transmitted power permit the interchangeability in some cases of one satellite for another. This provides not only reliability against failures and dispersion of facilities against physical loss, but the opportunity in some cases to apply competition to the costing of the emergency service.

In large part disaster communication requirements have characteristics such as: "infrequent but urgent, anytime, anywhere, and affordable." The satellite system's characteristics meet these in large extent as proven by many experiments, but they have been minimally exploited to meet communication needs of disaster warning and management.

1.2.3 Institutional Requirements For The Use of Satellite Technology in Developing Countries

In discussing any type of system for the early warning and management of natural disasters, it is essential to remember that a system includes not only technology, but also institutions, procedures and trained personnel. In fact, it is in the routine use of data and information, rather than in the technology for the collection of data, that the operational use of most high (including satellite) technology meets its toughest test.

There is a need therefore, to understand and develop the users institutional environment in addition to the technologies which make up any satellite based-system. One might develop a very efficient satellite based early warning system but without the institutions and people who know how to use it, it would be useless. This suggests that

with regards to satellite applications to disaster warning and management, that along with efforts to introduce satellite technology into developing countries, one must also focus on institutional development which is essential to the effective use of that technology.

1.3 Satellite (and Associated) Technology Applicable To Disaster Early Warning

There are a range of satelllite technologies applicable to disaster management including early warning. These include (1) meteorological satellites, (2) earth resource sensing satellites, (3) communications satellites. In addition, this study discusses the applicability of (4) computer technologies related to geographic information systems (GIS).

1.3.1 Geostationary Meteorological Satellites

Meteorological satellite data has been collected and disseminated since the launch of the first United States TIROS polar-orbiting satellite in 1960. At the present time, the US operational weather satellite system consists of both polar orbiting satellites and geostationary meteorological satellites. These systems provide data to national and foreign stations, as well as contributing to international programs such as the Global Telecommunications System (GTS) of the World Meteorological Organization (WMO). In addition there are three other geostationary meteorological satellite programs in existence today (European Space Agency, Japan and India) and one other polar orbiting system (Soviet Union). The instruments on these satellites have developed in such a manner as to be almost completely complementary.

1.3.2 Earth Resource Sensing Satellites

Current national programs for remote sensing of earth resources from outer space are in various stages of development. Figure 1.1 provides an overview of the countries involved with the space segment of satellite remote sensing, and the current status of their programs.[5] In general, it appears that there will be upwards of six national remote sensing programs operating by the end of the 1980's. While they will not be as complementary as the meteorological satellite system, and some of them will be commercially oriented, they do form an international earth observations capability.

FIGURE 1.1

NATIONAL EARTH RESOURCE SENSING SATELLITE PROGRAMS

	Stage of Implementation			
Country	Operating	Under Construction	Designed	Concept
United States	Landsat-3 Landsay-4 Landsat-4′	OSTA-3 LFC/MAESS	MLA	MAPSAT Space Station
Union of Soviet Socialist Republics	Meteor Salyut-7 Cosmos Series	Space Station		
India	Bhaskara-2			IRS-1
China		Chinasat-10	Chinasat-11 Chinasat-12	
France		SPOT-1 SPOT-2	SPOT-3 SPOT-4	
European Space Agency		SPAS-01 Spacelab 1	ERS-1	AERS Spacelab D
Canada			RADARSAT	
Germany, Federal Republic of			MOMS	
Japan			MOS-1	ERS-1
Brazil				Equatorial
Netherlands/ Indonesia				TERS

1.3.3 Overview of Communications Satellite Technology

From the variety of satellite communications capabilities now existing and expected to be operational in the next few years, there are a number that could be applicable to emergency and disaster communications. The regulatory environment classes satellite communications in two ways: government (mostly military uses) versus non-government (commercial use); and fixed, mobile, or broadcast according to the type of service provided. Of these, broadcast does not apply to the military category, but all others are identifiable as valid service-type combinations. An examination of these produces a thorough coverage of the types being used, and prompts further depth of inquiry in some areas where they might find utility in disaster mitigation communications.

Fixed service satellites relate to point-to-point services from fixed earth stations, and includes domestic (national), regional, and true international services. Five U.S. domestic satellite carriers are now operational, and many more have applied to the FCC for permission to construct and operate fixed service satellites. The Intelsat organization handles the vast majority of international satellite traffic because of national treaty signatures that tend to assure its exclusivity. There are, however, regional satellite services that are performed exclusive to Intelsat by domestic satellite systems. Recently, even the U.S. has seen some bidders for permission to handle international traffic outside the Intelsat network.

Today, with the proliferation of not only these fast-growing U.S. domestic, regional, and Intelsat services, but other countries' developments of domestic programs and improved technology, there

are over 90 communications satellites in operation around the World. Clearly, the satellite operators and users will continue to expand their investments in this efficient, distance-insensitive medium.

Initial satellite communication services for many foreign countries were provided by the use of a whole or partial Intelsat transponder. Those services are continuing, but in some areas are diminishing because of the advent of other satellites which are set up specifically for international communications under control of a more local body. A first example was the Indonesian satellite system, Palapa, which now provides service to other nearby countries. A second example is the ECS, or European Communications Satellite, used among several participating countries. Another example is Arabsat, the product of a 22-country Arab consortium's efforts to communicate under their own operational rules and tariffs, and nearing launch readiness. While these systems show the fruits of much cooperative effort where political difficulties cannot be surmounted, concepts such as the Andean countries' regional satellite system have not progressed beyond a start-and-stop situation for many years.

Although users worldwide are operating communications satellites to relay a wide variety of information between relatively large systems, only a few of these are used for television broadcast directly to users' premises. They are mostly serving either telephone (two-way) systems with relatively large terminals at multiple-trunk centers, or are distributing television to a variety of cable head-ends using fifteen-foot receiving antennas. Other users in a variety of service areas use satellites for data transmission, teleconferencing, electronic mail, and other uses. Foreign countries have begun building high-powered DBS

satellite technology, and several U.S. operators also are preparing the development of this new direct-to-home service using small and inexpensive terminals.

The expectation for DBS system growth is that within only a few years, there will come into being -- at least for developed countries -- high-powered satellites which will be used principally for television broadcasting directly to homes using antennas of diameters less than one meter. The associated receivers will have descramblers which are individually addressable in real time from the satellite itself, and will be connected to ordinary television sets and monitors. The entire home system up to the television set is expected to retail for less than $300.

In a few years, millions of these personally-owned small earth stations will be pointed toward satellites. For the broadcast industry, this direct contact with hitherto unserved markets will bring increased opportunities in TV programming, entertainment, advertising, and sales.

But DBS also could open the way for the innovative delivery of specialized, on-demand information. Coupled with other evolving information systems, this distance independent broadcast medium could alter plans for information storage, delivery and access. Under subscription services, innovative information services are envisioned, such as the dissemination of high-fidelity audio, high-speed data for access to information bases, and perhaps even interaction by means of low-speed return links.

Land mobile communicatoins also offer tremendous potential for disaster related communications. Some of the original satellite two-way voice experiments were done via mobile, walkie-talkie

type radios using NASA VHF transponders with portable wire-frame antennas about ten feet in size. While the U.S. military has pursued mobile communications by satellite, only limited progress has been made toward satisfying the much-discussed potential market for voice using small terminals through a large satellite. Such a concept was looked upon as only having a potential for technical demonstrations, because it was not seen how the commercialization of this technology could be supported through a large enough user set at affordable subscriber prices to justify a several hundred-million dollar satellite. That is, while the mobile equipment capital costs would be moderate, in order to pay for the satellite itself, the operational lease of a channel would still have to be much higher than current mobile telephone usage prices.

1.4 Computer Technology For Geographic Information Systems

The production of early warnings of natural disasters consists of three critical steps--data acquisition, data manipulation, and information dissemination. Both data acqusition and information dissemination are directly tied to satellite communications and remote sensing technology. Data manipulation, on the other hand, is tied more directly to computer technologies and models or algorithims for manipulating data. During the last decade or so, much has been made of the development of Geo-based (or Geographic) Information Systems (GIS).

A GIS is a collection of procedures, computer programs, human resources, and hardware devices that supports the acquisition, storage, manipulation and display of geographically referenced data. In other words, various types of information can be coded to geographic points or areas. This is critical to all resource development and planning activities as well as to disaster warning and management. Any disaster warning or effort to manage a disaster relief program has a strong spatial

component. Without data and information being coded to a spatial location, that data and information becomes useless. The importance of a computerized GIS system is pointed up by the fact that the amount of data is likely to be quite large; one satellite image of the Earth can contain from tens of millions to hundreds of millions of bytes of data, and when one begins layering data from a variety of sources (several different satellites, aircraft, ground truth, socio-economic variables, etc.), the amount of data grows enormously. Handling this much data manually is physically impossible. In addition, data (as indicated directly above) comes from a wide range of sources. Varied data sets must be converted into a common structure. Again, manually it is very difficult to work with or justify maps of varying scale and size. A computer, working digitally, can make these adjustments quickly and accurately. Finally, many of the data manipulation functions required by disaster warning planners and managers require complex computer analysis. In order to use data from a variety of sources in complex prediction models, computer applications are often necessary.

A GIS, to be used as an effective spatial analysis and modelling tool, must be interlinked with a Data Base Management System (DBMS), Image Processing System (IPS) and statistical system. The data base management system is used for manipulating data depending on the characteristics or definitions of the user; the image processing system takes images from a variety of input sources and processes them for input into the geo-coded reference system, and a statistical system allows for data to be

statistically analyzed or modelled for a specific purpose. A full study of GIS systems is being conducted by the Office of Federal Disaster Assistance concurrently with this study, and it is expected that that study will be used in conjunction with this one.

1.5 Satellite Applications To Disaster Warning and Mangement

There have been a range of applications made of satellite remote sensing and communications technology to disaster early warning and management. This include operational systems for severe storm warning and highly experimental systems for earthquake prediction. Satellite data have been successfully used to monitor and forecast various weather relted phenomena with good success. The use of Data Collection Platforms to relay data from remote areas to central processing facilities via satellite has greatly enhanced our capabilities in the area of disaster warning.

This study's brief overview of satellite and associated technologies applicable to disaster warning and management suggests that the use of satellites in various disaster management systems has only begun to be tapped. It also suggests that there are already a wide range of operational and experimental programs which are rapidly becoming globally oriented and which are establishing global information and communications systems. Satellite data will be used as input to these systems and satellite links will be used to transmit data around the world. It is important to point out, however, that satellites make up only part of any such system--and as satellite capabilities grow, they will have to fit into on-going p ograms and early warning and management systems to be truly effective. Appendix 1 covers in some detail a wide range of on-going programs which are potentially related to disaster early warning.

1.6 Challenges to an Operational Satellite-based Early Warning System For Natural Disasters

This study has discussed satellite applications to disaster warning and management. It is clear from those sections that there will be an ever increasing number of operational remote sensing and telecommunications satellites and that there already exist a number of globally oriented disaster warning systems. Any effort to develop a globalized early warning system based on satellite technology will, however, encounter a range of political issues, both domestic and international.

1.6.1 Senarios For U.S. Iniatives in Development of a Global Early Warning System

In the following discussion of domestic and international policy issues regarding an operational early warning system, the following scenarios for US initiatives in the globalization of early warning systems, the following scenarios should be kept in mind:

1. Scenario 1: The United States initiates a program for the development of a global early warning system for natural disasters based on US technology and institutions. This system begins with a focus on developing a US government response network and the globalization of forecasting models and early warning programs within the US government. International participants would be invited to join this iniative, at first as users of the system and then later as contributors of technology and institutional support. This would be a US system with international participation after the initial structure of the system was established. The decision of whether to integrate existing disaster warning programs for different type of natural disaster would be made by an interagency group of the US government. This is the "US Initiative" scenario.

2. Scenario 2: The United States proposes that an international effort be made to establish a global early warning system for natural disasters. The system would be based on the interests of a variety of international participants and would take include many of the internatioanl disaster warning program already in existence. Decision making would be undertaken through an informal/international body convened on an annual basis. Efforts would be made to establish focal points for various types of disaster warning information in existing programs. This system would be based largely on technologies and programs already in existence in a variety of countries and would be apolitical to the extent that international relationships would develop prior to the development of any formal international institution. This is the "International" scenario.

3. Scenario 3: The United States would propose that a new international agency/organization be established to develop/implement a global early warning system for natural disasters. The US would contribute to this system on a par with its current capabilities and would expect like participation from other developed and developing coutries around the world. Such a system could be used to upgrade the status of the United Nations Disaster Relief Organization (UNDRO) or by the creation of a new agency for disaster warning. Such an agency might follow the model of Intelsat or the World Meteorological Organization. System decisions would be made by this international organization. This is the "International Organization" scenario.

These scenarios are illustrative of the manner in which the US could approach the development of a global system for disaster warning. However, inherent in any of these scenarios are numerous challenges/issues which confront any US effort to utilize satellites on a

global/operational basis. These challenges to US decision makers can be divided into two seperate but extremely interactive types--domestic and international.

1.6.2 Domestic Policy Issues

There are a wide range of interconnecting policy issues involved with the establishment of an operational satellite early warning system for natural disasters. These include (1) Inter-agency responsibility and funding; (2) Private sector versus public sector concerns; (3) Military versus Civil government concerns; and (4) Domestic policy concerns versus foreign policy concerns including commercial needs versus international scientific cooperation and humanitarian policies and commercial/private sector needs versus US reliance on international data sources.

1.6.2.1 Interagency Responsibility

The development of a satellite system for early warning of natural disasters will involve both budget and legislative implications. The establishment of such a system (including technology, people and institutions) will require time, money and manpower from those agencies which are required to participate in the system.

There are two levels at which an operational system must be developed--first the actual system for implementing disaster warnings and second the mechanisms by which those warnings are disseminated to appropriate agencies who are expected to respond. Agencies involved in the generation of disaster warnings would likely include those involved in data collection (NASA, NOAA, Agriculture, Navy, Interior, etc.) while agencies involved in response would include further data collection but also those capable of providing disaster relief and technical assistance (USAID, Corps of Engineers, Coast Guard, Military, etc.) All of these agencies, in the development of an operational early warning systems would

have to make a budgetary and manpower contribution, and one would have to be given the authority and budget to organize and manage the system. Some of them--for instance many of the data collection agencies--would claim that they are alrady providing hundreds of millions of dollars to finance satellites and extensive ground truth. Others will claim that they have no legislative mandate to provide operational assistance to such a program, and will therefore require a change in legislative mandate to participate actively. Therefore, the development of such a system will have both budget and policy/legislative components.

Another component of this issue involves the development of forecasting and early warning programs for specific disasters, for example the development of earthquake prediction technology, tsunami early warning systems or agricultural crop forecasting models. This issue is largely a technology transfer issue--that is, how is the technology transferred from an experimental/developmental stage to an operational system, and most importantly, who will pay for that transition and the eventual operational system?

In sum then, there are three key interagency issues involved with the development of an operational early warning system for natural disasters--budget, legislation and technology transfer.

1.6.2.2 Private vs. Public Sector Interests

Within the United States several key satellite technologies are owned and operated by the private sector while others are operated by the government. Satellite communications is a private venture, while the Meteorological satellites are owned and operated by the US

government. Landsat and earth resource sensing satellites are in the process of being transferred from government to private sector ownership and operation.

This raises a set issues involved with the development of an operational satellite early warning system for natural disasters. First, will data be availale from commerical remote sensing systems for use in an international disaster warning system and if so, how much will it cost, how hard will it be to obtain it, will private companies be able to stagger their pricing schemes in order to accomodate "humanitarian" uses of the data, and will those same private companies be willing to pre-empt on-going data collection to focus their sensors on a particular region where a natural disaster is developing or has struck? Second, if this type of data is "for sale" to international users, will the US be able to obtain timely and affordable data from other countries operating satellite systems? If not, will there be efforts to stem the flow of international resource data to the US include not only satellite data but also other types of data collected from in-situ platforms and ground agents? Will this have an impact on weather satellite cooperation and the international meteorological system which has developed so effectively?

1.6.2.3 Civil/Military Interface

There are two key issues involved in the realm of civil/military interface with respsect to early warning of natural disasters. First, is the issue of civilian access to military data and the use of military facilities, and second is the issue of the data and information itself, which might be of military value.

The military has access to data and information which is unavailable to the civilian side of the government for purposes such as the early warning of ntural disasters. It is important for those interested in developing such a global system to explore the possibility of utilizing military sources. In addition, any global system will likely have to coordinate with the Defense Department in order to ensure that US national security interests are not compromised.

1.6.2.4 Domestic Policy vs. Foreign Policy

As has been the case with the US space program since its inception, the dictates of domestic policy and the use of space technology in the area of foreign policy often come into conflict. This conflict takes the form of a strong desire of parts of the foreign policy community to use space technology to support US foreign policy objectives and to live up to the initial goal of the civilian space program to be open to foreign cooperation and to be conducted for "benefit of all mankind," as opposed to domestic interests which are strongly in favor of protecting US high technology from enemies and competitors and commercializing that technology rather than using it in a cooperative mode. While these goals and objectives are not necessarily in conflict, they often seem at odds. In any effort to develop a space-based system for early warning of natural disasters this conflict is ilkely to arise.

1.6.3 International Policy Issues

At the International level, any such effort must confront a range of issues, some of which are directly tied to those domestic issues listed above. These include (1) transborder data flow and international free flow of information; (2) dependence and accountability; (3) training and technology transfer; and (4) System Sturcture/Integration

1.6.3.1 Transborder Data Flow

The emergence of Landsat sparked a heated controversy in the United Nations regarding the distribution of satellite data and information. Over the last decade the United States has disseminated data collected from the Landsat series openly and at minimal cost to all interested parties, domestic and foreign. This policy, in line with the US traditional policy regarding the free flow of information, mitigated many of the objections of developing countries regarding access to information about their countries. However, any program which will collect information about one country and distribute openly to the international community will raise serious political questions. In sum, many countries are simply uncomfortable with the open dissemination of any data and information about their country.

1.6.3.2 Training and Technology Transfer

In order for any early warning system to be effective on an international basis, training and technology transfer will have to play a big part in the development of the system. In-country personnel who will be handling the dta and information, and who will have to make decisions regarding whether to order a warning and how to respond to warnings, will hvae to be trained not only in the technical aspects of disaster prediction and warning but also in disaster management. Such training could be incorporated into other aspects of training in-country such as remote sensing training efforts in the fields of hydrology, agriculture, civil engineering, geology, etc. This is obviously a key area for continued support by agencies such as USAID. This will also have an impact on the down-stream funding for any international disaster early warning system.

1.6.3.3 Dependence and Accountability

The issues of dependence and accountability are closely related to the international character of satellite information and global information systems. In this regard any international early warning system will, by definition, be international in scope and character. As such it will most likely be subject to the issues of dependence and accountability. These issues are summed up in the following quote:[6]

> Should remote sensing technology fulfill its promise, it will become indispensible for many countries. User nations will have made siognificant investments in facilities of various kinds. They will have geared their dta gathering and decision making processes, both in the public and private sectors, to the peculiar characteristics and assured availability of satellite imagery. Their interest in the stability and continuity of the service on which their domestic systems will have come to rely will consequently be considerable.

In other words, developing countries will come to rely heavily on US or other developed country technology. With that reliance will come a desire to have an input into the further development and continued availabiltiy of data. Because the system would be designed largely to alleviate suffering from natural disasters in developing countries, it seems that input from those countries might well be appropriate. This raises the central issue, then, of whether any international system for disaster early warning can or should be run solely by the United States or any other country? This issue takes on particular importance in that any international satellite based system will rely not only on satellite data from international sources but also on other international data sources and programs of other developed countries. In addition, many developing countries are also developing sophisticated

satellite programs which would be integral to any such international system. This suggests the obvious question of whether the planning of any such system should include international participants.

1.6.3.4 System Structure/Integration

The above discussion leads to a final issue which will confront the developers of any global early warning system for natural disasters. That is, there currently exist a number of global disaster monitoring systems in the US and abroad. In addition they exist for a wide range of disaster, some of which are closely related (such as Earthquakes and Tsunami's) and others which are not closely related at all (earthquakes and drought). Any effort to develop a global system will have to determine whether or not it is useful and effective to integrate existing systems into a single network or whether it is better to maintain seperate networks for distinct disaster phenomena.

1.6.4 Summary

There are a number of domestic and international issues which are raised by the possibility of developing a global early warning network for natural disasters. The potentials of such a system are great, but the domestic and international political realities of space technology and applications require that the political problems likely to arise with the advent of such a system be dealt with at the outset.

One can look at the three system development scenarios described earlier in this section and weigh them against the various issues which are outlined above.

Scenario 1 (the US Initiative Scenario) would simplify decision making for the overall system because it wold limit decision makers, at least at the outset, to domestic agencies. However, this scenario would

not eliminate the difficult domestic problems associated with system development--particularly those revolving around budget, legislation and technology transfer. In addition, the decision to proceed with Scenario 1 would be the subject of extensive debate between those agencies in favor of a domestic approach and those with a more international outlook. Finally, such an approach would undoubtably raise the ire of international participants, both those with the capability of contributing to the system and those wishing to use it.

Scenario 2 (the International Scenario) would encourage international participation, but would do it in such a way as to develop informal contacts and agreements prior to any formal international structure being developed. It has the advantage of bringing international participants into the picture early on and developing a system based on user needs as well as current capabilities. However, it would not ameliorate the domestic issues facing US decision makers and might very well slow down overall progress on an international system due to the difficulties inherent in any international project. One can envision, however, that an approach similar to Scenario 2 could be used to bring international participants together early on and informally begin building international programs and networks with the implied, if not actual, consent and participation of the international community.

Scenario 3 (the International Organization Scenario) would serve to exacerbate international issues as it would thrust any such initiative into the international political arena. While such an initiative might ameliorate any policy issues arising out of a lack of international participation it would focus attention on international political issues which are inherent in satellite technology and data acquisition. Domestically, issues facing US decision makers would not be resolved and

increasing international political visability would generate increased domestic debate over foreign policy issues. Scenario 3, while having the attraction of mitigating international concerns over a US dominated system, would likely exacerbate other political issues such that little or no progress would likely be made on system development.

In sum then, Sceario 1 would likely make domestic decision making easier at the cost of irritating and perhaps alienating international particpants while Scenario 2 might complicate system decisions but would ameliorate international participants. Scenario 3 would likely cause the system to become overly politicized and to be stillborn.

It is hoped that the proposed conference and proposed interagency program committee (discussed in the following section) will provide the beginnings of a dialogue to deal with domestic and international political (as well as other) aspects of a global system, as well as the broader development context of disaster warning and management.

1.7 A Conference on Satellite Applications to Early Warning of Natural Disasters

The proposed conference is a response to a US initiative at Unispace 82 which promised to make available information on existing satellite technology and its applications to disaster warning which are suitable for operationalization.

The United States Office of Foreign Disaster Assistance is planning to hold such a conference in Spring of 1985. Current plans call for a two-three day conference focused on applications of satellite technology in four basic areas in which research and applications are already being supported by USAID/OFDA. These include:

1. global drought assessment, agroclimatic, and famine early warning systems.
2. Tsunami early warning and monitoring systems
3. Severe storm forecasting and early warning systems
4. Regional seismic networks
5. Satellite-based data transfer and disaster telecommunications

In order to develop the interagency interaction which will be necessry to implement this conference and to build toward the globalization of satellite-based disaster early warning an intergency conference program coordinating committee has been identified and set up. The nature of the conference and its subject material dictates that USAID/OFDA, NOAA, the USGS, and USDA be involved in planning for the conference. The fact that space technology and technology transfer will play such an important role implies strongly that NASA should be a participant as well, particularly as longer term plans for a potential operational system develop, and as needs for computer and distributed data processing network capabilities become defined and understood. In addition, the the Department of Defense must be included due to its wide-ranging capabilities and requirements.

An initial meeting of the program committee was held on April 26, 1984. A presentation was made to the committee, with an outline of the needs for a Global Early Disaster Warning System, with background information on the role and charter of OFDA, and a review of the UNISPACE initiatives. A second meeting of the program committee was held on June 4, 1984. Based on the discussions of that group and meeting held individually with the members of the program committee, this study recommends that the conference be structured around the ideas that natural disasters are costly to the nations involved, that aid from the U.S. and other donor nations

will decline as population demands increase and resources are stretched, and that new technology which allows for forecasting of disasters can ameliorate the economic consequences, to the benefit of all. The agenda presented here is an example of how the meeting can be arranged, and is a recommended approach. Additionally, should there be a desire for more detailed presentation, the panel presentation format can be replaced by individual papers. The current time for each panel is about one and one half hours, giving time for each panelist to give a ten minute statement (assuming four panelists) and leave ample time for a well guided discussion for the panel. Selection of panel moderators will be crucial to this end. Speakers have not been named in this agenda.

TENTATIVE CONFERENCE AGENDA

Opening Day:

8:00 - 9:30	Registration and Coffee
9:30 - 9:40	Welcome
9:40 - 10:10	Overview and Charge for the Conference
10:10 - 10:30	Coffee Break
10:30 - 12:00	World Economics of Natural Disasters Panel Discussion by IMF, Bankers, Economists and Insurance representatives
12:00 - 1:30	Lunch - Keynote Speaker
1:30 - 3:00	Tsunami Forecasting - New Techniques Panel Discussion including some foreign Participants
3:00 - 3:20	Coffee Break
3:20 - 4:50	Earthquake and Volcano Forecasting and Monitoring - Panel Discussion
4:50	Close

Day Two:

8:30 - 10:00	Flood and Hydrologic Applications Panel Discussion
10:00 - 10:20	Coffee Break
10:20 - 11:50	Tropical Wind and Severe Storm Strike Forecasting - Panel Discussion
11:50 - 1:30	Lunch - Independant Arrangements
1:30 - 3:00	Agroclimate and Crop Production Forecasting Technologies - Panel
3:00 - 3:20	Coffee Break
3:20 - 4:50	"Social and Economic Costs of Disaster Warnings - Can We Afford Them?"
4:50	Close

Day Three:

8:30 - 9:00	Overview of Communications System Technologies for Disaster Warning and Monitoring
9:00 - 9:30	Overview of Data Processing and Display Technologies for Disaster Warning and Monitoring
9:30 - 9:50	Coffee Break
9:50 - 10:20	Future Earthquake and Volcano System Capabilities
10:20 - 10:50	Future Crop Yield Forecasting System Capabilities
10:50 - 11:20	Future Flood and Hydrology Systems Capabilities
11:20 - 11:50	Future Severe Storm and Tropical Wind Wind Strike Capabilities
11:50 - 1:30	Lunch
1:30 - 2:00	Training Programs Available for New Earthquake and Volcano Technologies at USGS
2:00 - 2:30	Training and Assistance for Agroclimate and Crop Yield Forecasting Technologies at NOAA
2:30 - 3:00	Training and Assistance for Severe Storm Warning Technologies NOAA
3:00 - 3:20	Coffee Break
3:20 - 5:00	Panel Discussion - Information Needs of Developing Countries - Panelists to be Selected from Attendees

1.7.1 Illustrative Budget

The illustrative budget for the conference makes the following assumptions:

1. The US Government will pay for the air fare and per diem of all developing country international participants and speakers.
2. Members of US agencies and memebers of developed countries and/or international organizations will pay their own way.
3. The conference will be held in the Department of State at little or no cost. Coffee and refreshments will be catered by the Department of State.
4. One conference banquet dinner will be held at a Washington area hotel or restaurant.
5. A private company will serve as technical manager of the conference, including coordination and review of papers, development of any needed position papers, provision of honorarium to speakers/session chairman, and publishing of the proceedings.
6. The private company organizing the conference will be under contract 8 full months before the conference is scheduled. The following is a very tentative, illustrative budget.

ILLUSTRATIVE CONFERENCE BUDGET

SATELLITE APPLICATIONS TO DISASTER WARNING

I. TECHNICAL ASSISTANCE CONTRACT (Conference Management)

DIRECT LABOR	DAYS	RATE	COST
TECHNICAL COORDINATOR	80.00	160.00	12800.00
ADMINIS. ASSISTANT	160.00	112.00	17920.00
TECHNICAL EXPERTS	80.00	200.00	16000.00
SUBTOTAL SALARIES			46720.00
OVERHEAD (125% of salaries)		125.00	58400.00
OTHER DIRECT COSTS			
Air Travel			6000.00
Local Travel			1000.00
Per Diem			2100.00
Publishing Proceedings			10000.00
Printing Invitations/etc.			7500.00
Communications			1600.00
Shipping/Postage			1000.00
Miscellaneous			800.00
Banquet			5000.00
SUB-TOTAL ODC			35000.00
TOTAL COSTS			140120.00
FEE			14012.00
TOTAL COSTS, TECHNICAL ASSISTANCE			154132.00

II. TRAVEL AND PER DIEM, INTERNATIONAL PARTICIPANTS

TRAVEL	50 Round Trips @ $3000	150000.00
PER DIEM	6 days/person @ $75/day	22500.00

III. SPEAKER HONORARIUM, TRAVEL AND PER DIEM

SPEAKER HONORARIUM	10 persons @ 400.00/day	4000.00
SPEAKER TRAVEL	25 Round Trips @ 1000.00	25000.00
SPEAKER PER DIEM	5 days/person @ $75/day	3750.00
TOTAL COSTS. SPEAKERS AND INTERNATIONAL PARTICIPANTS		205250.00

TOTAL CONFERENCE COSTS	359382.00
10 % CONTINGENCY	35938.00
TOTAL CONFERENCE BUDGET	395320.00

1.7.2 Steps To Holding The Conference

During the course of this study several key steps were taken to holding the subject conference. These included:

1. Identification of key policy issues associated with the globalization of disaster early warning systems;
2. Identifying and convening a an interagency program committee for the conference;
3. Through that committee, gaining general consensus over the type of conference to be held (largely informative) and securing the cooperation of several US agencies in conference planning;
4. Developing a tentative conference outline;
5. Developing an illustrative budget for the conference.

There are a number of steps which must be taken prior to the holding of the conference as discussed directly above. These involve the following, not necessarily to be undertaken in the order presented:

1. Formalization of program committee meetings;
2. Develop and agreement on conference agenda;
3. Determine budget and funding inputs from other agencies;
4. Once a conference date has been agreed on, put under contract a technical assistance firm to manage the conference;
5. Solicit papers and secure speakers;
6. Review papers and disseminate, if appropriate, to discussants;
7. Secure conference room and facilities for reception/banquet and hotel accomodations for visiting participants;
8. Line up publishing firm and secure camera ready copies of papers presented;
9. Disseminate conference invitations to selected participants and solicit participation of desired persons.
10. Prepare State Department and other agency international offices for participation in the conference, if necessary.

1.7.3 Summary

This study has developed a framework for understanding the data and information requirements for disaster management including disaster early warning systems (Section 2.0). It has described a wide range of satelltie technologies applicable to disaster management and early warning (Section 3.0) and has offered a range of examples of satellite applications to disaster management (Section 4.0). It then outlined various scenarios for a US initiative in the holding of an international conference on satellite applications to disaster early warning and identified policy issues associated with the conference and any efforts to globalize disaster warning systems (Section 5.0). Finally, this study outlined a conference agenda and illustrative budget, as well as steps required to achieve the conference in the Spring of 1985. With appropriate and timely action, a conference on satellite technology applications to disaster early warning could be held in the Spring of 1985 and continue the process of bringing satellite technology to bear on problems on Earth.

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2. P.B. Richards, et. al., "Recommended Satellite Imagery Capabilities For Disaster Management", 33rd Congress of the Internatioanl Astronautical Federation, September 27-October 2, 1982, p.1.

3. Ibid., p.1.

4. Ibid., p.1.

5. Adapted from Frederick Doyle, "Status of Satellite Remote Sensing Programmes", Washington D.C., Department of the Interior, 1982, mimeo; see also "Study on the Implications of Establishing an International Satellite Monitoring Agency", A/AC.206/14, August 1981.

6. Remote Sensing From Space, Prospects For Developing Countries, National Academy of Sciences, Washington D.C., 1977, pp. 149-150.

2.0 Global Disaster Early Warning System Policy Planning

At the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, (UNISPACE 82), held in Vienna, Austria in August, 1982, the United States delegation presented several 'initiatives', to be pursued with other interested governments in an effort to further apply space technology to problems on Earth. One such initiative was proposed by the United States Office of Foreign Disaster Assistance, in the U.S. Agency for International Development. The description of the initiative, as it appeared in the paper presented by the U.S. Delegation is as follows:[1]

> In order that the use of Outer Space Technologies in assessing and reacting to natural disasters of varying natures and dimensions may be examined, the United States proposes to sponsor a five-day conference by the U.S. Agency for International Development, Office of Foreign Disaster Assistance in Washington, D.C., in the spring of 1984. This conference would address problems in areas such as global drought assessment, agroclimate, famine early warning, tsunami and severe storm early warning, and considers how satellite based data and communication systems can be of assistance in these areas. Current operational systems, Systems under development and future applicable technologies would be examined.
>
> Such a conference would make more generally available information on those technologies and their applications currently existing and suitable for operational implementation worldwide. The conference would help to focus international consideration of this important topic and assist in definition of future systems requirements. Opportunity would be given for participants, especially from developing countries, to examine new advance technologies available to them. Participants at the expert level would discuss concrete mechanisms, including relatively sophisticated environmental monitoring systems which can mitigate the impact of natural disasters and save lives through preparation and early warning using current and future satellite-based early warning systems and data collection platforms.

As a precursor to the conference, the Office of Foreign Disaster Assistance initiated the current study to lay the planning groundwork for the conference. The purpose of this study is to review current satellite (and associated) technology and related programs with applications to disaster warning. In addition, this study addresses the policies and issues with developing the conference agenda and the future direction of US technical agencies which could contribute to the development of a global disaster early warning system. To this end a tentative conference agenda will be drawn up and an interagency program committee for that conference suggested.

The study begins by developing a framework for understanding disaster warning and management. This will put the technologies and programs then reviewed into a proper context. Following that, we review existing and future space and related technologies which are or will be applicable to global early warning of natural disasters. This includes a review of current remote sensing satellites, communications satellites and computer technology related to geographic information systems. The study also describes a variety of programs related to satellite applications to disaster warning.

2.1 Disaster Management and Information; A Framework For Understanding

Disaster management can be categorized in a variety of ways. This study utilizes the categories adopted by USAID's Office of Foreign Disaster Assistance (OFDA) and adds to them. The study includes, as elements of Disaster Management, Early Warning, Emergency Decision Making, Country Preparedness, Emergency Relief, and Rehabilitation. While this

study is primarily concerned with Early Warning of Natural Disasters, it is useful to consider the information requirements for early warning in the context of overall disaster management.

2.1.1 Early Warning

Early warning of natural disasters involves several steps. These include (1) the collection of relevant information regarding conditions which might portend a disaster; (2) the collection of such data in a central location with the capabilities to process and analyze it; (3) forecasting, based on that information and analysis, the location, timing, probability and extent of the disaster; and (4) the dissemination of that forecast to relevant agencies responsible for responding to a natural disaster and to those areas where the natural disaster may occur. Once the forecast has been disseminated to the relevant relief agencies and to the local officials in the area of impact, then decisions must be taken as to how best to respond. This study, however, is focused primarily on the applications of space technology to the generation of early warning forecasts and the dissemination of those forecasts; not on policy decisions once forecasts/warnings are received.

Disasters, and hence disaster forecasts, can be described by looking at them along four dimensions. First, when are they expected to take place? A drought or food shortage may be years in the making, while a Tsunami or Hurricane may be only hours in developing. Second, what is the potential impact of the disaster? This can only be judged by the location in which the disaster is expected to occur and the magnitude of the disaster. If a large magnitude disaster hits an area of low population and low economic value then it will have a low impact. On the other hand, a disaster of small magnitude in a densely populated and/or

high economic value area may have high impact. Third, what is the vulnerability of the area concerned? Is it an area which is easily accessible with disaster management/relief equipment? Is it an area in which little or nothing can be done to mitigate against the disaster? What plans are already in place for evacuation of people, or for disaster related communications while trying to manage disaster assistance? Fourth, what is the probability of the disaster occuring. In particular, timing and impact both result from forecasting models and any predictions about them are, by nature, probabilistic.

It is also important to note that early warnings take two distinct forms. First, actual a priori prediction of natural disasters and second the tracking of disasters as they occur. For example, efforts to predict earthquakes are on-going, however once an earthquake occurs it's effects are immediate. On the other hand, severe storms and tsunami's are difficult to predict a priori, however once they are spotted they can be tracked and warnings issued. This distinction is important in that a priori prediction and disaster tracking may well require different types of data acquisition.

2.1.2 Emergency Decision Making

Perhaps the most intractible of all all of the aspects of disaster management is the manner in which decisions are made. Forecasting models and early warnings are, by nature, probabilistic. In addition, rules for making decisions to take action, based on those probabilistic forecasts, vary from country to country and culture to culture. Efforts have been made in several projects sponsored by the Office of Foreign Disaster Assistance in USAID to build "decision models" into disaster forecasts, however these models are influenced heavily by the

personal importance the modeler gives to various criteria upon which to base decisions. For instance, if one forecasts that a hurricane will strike with some probability in the next several hours, an estimate of economic, human and political costs must be made for either evacuation or doing nothing. Different decision makers will weigh the various costs and benefits (human lives, economic impact, etc) differently. As another example, if one were to predict a massive earthquake in Los Angeles, California sometime in the next ten years with a probability of 80%, what action should be taken?

The point here is that the decision to take action based on a probabilistic warning is a key step in any disaster management effort. In addition, it raises another key point which is that any system to produce early warnings of natural disasters will be useless unless there are institutions and trained people to act on those warnings. This implies that the development of any satellite based early warning system must take into account the need for training and organization development.

2.1.3 Country Preparedness

Country preparedness involves "activities that develop plans to save lives and minimize disaster damage, or enhance disaster response operations. Examples include the development of analytical methods such as models for predicting the effectivenss of disaster response operations, training exercises installing warning systems, stockpiling vital food and medical supplies, and mobilizing emergency personnel on a standby basis. Preparedness plans go into action during the warning period."[2] Essentially then, country preparedness involves preparing a country to mitigate the effects of a disaster once it occurs.

2.1.4 Emergency Relief

Emergency relief includes "post-disaster activities designed to provide emergency assistance for casualities, to reduce the probability of secondary damage, and to speed recovery operations. Examples include evacuation and/or sheltering of the population at risk, search and rescue, emergency medical care and damage assessment."[3]

2.1.5 Rehabilitation

Rehabilitation includes "short-term post-disaster activities (rehabilitation) designed to return vital life-support systems to minimum operating standards; and long-term post-disaster activities (reconstruction) designed to return life to normal or improved levels (for example, redevelopment and community planning)."[4] The line between emergency relief and rehabilitation is hard to draw as emergency relief usually phases naturally into rehabilitation.

2.2 Characteristics of Natural Disasters and Data Requirements

In order to understand the applicability of satellites to disaster warning and management, one must first characterize natural disasters. From these characteristics one can then determine the data requirements necessary for early warning and management of disasters with particular characteristics. Only after outlining the data requirements associated with early warning and management of various disasters can one determine the applicability of satellites and satellite acquired data.

As an initial effort to characterize disasters, this study suggests the following variables: location; impact area; disaster development time; frequency of occurence; numbers of people effected; severity of impact; and visibility of indicators.

2.2.1 Location

The location of a disaster refers to areas of the world where a disaster might take place. It may be that a particular disaster can occur anywhere in the world, or it may be restricted to a particular area or region. For instance, one would plan for disaster management of Tsunami's only in coastal areas while planning for flooding primarily in river basins. Droughts occur primarily in desert regions while tornadoes may occur over a wide variety of locations. This characteristic of disasters is critical for disaster warning and management in that the effective establishment for an early warning and management system must be focused in the areas of likely occurence.

Once the potential locations for a particular type of disaster are determined, satellite technology may well become part of an early warning system or monitoring system for disaster management. However, satellite data is not particularly useful for the initial determination of where different types of disasters are most likely to occur.

2.2.2 Impact Area

Impact area refers to the coverage of a particular type of disaster, varying from a widespread to a very localized impact area. For example, a tornado has a fairly localized impact area while a hurricane may cover an extremely large area. A drought leading to famine might cover a huge geographic area as would the process of desrtification. Landslides, however, are most likely to have very localized impact.

As with the location of disasters, impact area dictates, in part, the type of disaster data and information network which is required for early warning and mangement. If the impact area is

widespread, data which covers a large area will be extremely useful. This type of data may be provided via satellite-acquired data (such as Landsat and/or Metsat data) or it may be acquired by spreading in-situ sensors (such as Data Collection Platforms or ground measurements taken by humans) throughout the potential area of impact.

These data requirements also vary with the stage of disaster management. For instance, in the process of early warning of severe storms and hurricanes, satellite data can be used extensively to forecast storm occurence and to monitor storm development. However, in the case of flooding, satellite data might be useful in the initial generation of an early warning, however, during relief and rehabilitation more detailed and localized information is required.

2.2.3 Disaster Development Time

Disaster development time is the time for a disaster to occur once it has been detected. This time can range from nearly immediate to the very long term. For instance, once an earthquake is detected its impact is almost immediate. At the other extreme, drought and subsequent famine may well be detected long in advance of their most serious impact. This characteristic of disasters translates into frequency of data observations and data availability requirements depending on the stage of disaster mangement. It also defines, in part, the type of communication systems needed for warning and management. For example, a drought which takes a relatively long time in developing requires data that is less frequently collected and less immediately available then a Tsunami, for instance. A Tsunami which can develop in a matter of hours, requires continual observation in near-real time in order to predict its loction and magnitude. Figure 2.1 generalizes these requirements.

Figure 2.2 shows the applicability of various existing satellite capabilities to those particular data requirements shown in Figure 2.1. These figures suggest that frequency of observation and data availability requirements for disaster early warning information imply that Meteorological Satellites carrying DCP payloads and the geosynchronous Meteorological Satellites are most appropriate. However, the other characteristics of particular types of disasters and the subsequent data requirements of those disasters will have an enormous impact on the overall applicability of satellite-acquired data.

FIGURE 2.1
STEPS IN DISASTER MANAGEMENT
Frequency of Observations and Data Availability Requirements

Disaster Development Time	Early Warning	Country Preparedness	Emergency Relief	Rehabilitation
Short Term (Hours)	Frequent Obs.--Near Real Time Reports	Frequent Obs.--Near Real Time Reports	Frequent Obs.--Near Real Time Reports	Moderately Frequent Obs.--Weekly/ Monthly Reports
Intermediate Term (Days)	Moderately Frequent Obs.--Hourly or Daily Reports	Moderately Frequent Obs.--Hourly or Daily Reports	Frequent Obs.--Near Real Time Reports	Moderately Frequent Obs.--Weekly/ Monthly Reports
Long Term (Months or Years)	Infrequent Obs.--Monthly or Annual Reports	Infrequent Obs.--Monthly or Annual Reports	Frequent Obs.--Near Real Time Reports	Moderately Frequent Obs.--Weekly/ Monthly Reports

FIGURE 2.2
Satellite Capabilities

Frequency of Observations/ Data Availaibility	Metsat DCP's	Metsat Polar Orbiters	Metsat Geosynch.	Landsat
Frequent Obs./ Near Real Time	+	-	+	-
Moderately Frequent Obs./ Hourly or Daily Data Avail.	+	-	+	-
Infrequent Obs./ Monthly or Annual Data Avail.	+	+	+	+

+ indicates data source can provide for requirements
- indicates data source cannot provide for requirements

2.2.4 Frequency of Occurrence

Frequency of occurrence refers to how often a particular type of disaster occurs. This, like location and impact area has an effect on planning for disaster warning and management. For instance, large scale earthquakes occur infrequently while flooding in some areas is an annual event. This is an important characteristic in any effort to develop disaster warning and management plans as it will bear on how often data is required. Very rare disasters may require less frequent observations while frequent disasters are likely to require more frequent data observations. Of course, it must be considered at in conjunction with severity of impact and number of people affected by a particular disaster type. As such, this characteristic of disasters is particularly important in the area of country preparedness planning and decisions about whether to establish early warning systems in specific areas for specific disasters.

2.2.5 Number of People Affected

The number of people affected by a particular type of disaster is critical to planning early warning systems and disaster management. For example, an area subject to annual flooding or drought that has a low population will not likely rate a high priority for disaster planning and mangement efforts. However, tsunami's which typically strike coastal areas where there are fairly large concentrations of people will rate a high priority for disaster planning. In addition, number of people affected will also influence how important and how frequent observations are required. This again stongly affects decisions regarding country preparedness.

2.2.6 Severity

Disaster severity is another factor which influences

disaster planning and management. Along with numbers of people influenced, frequency of occurence, location and area of impact, the severity of a disaster type will have an effect on decisions to plan an early warning system and to develop preparedness plans. For instance, localized landslides might not merit a full up disaster management effort while hurricanes, which are much more severe, probably would. Severity, like the other characteristics, effects the need and frequency of data collection efforts.

2.2.7 Visible Indicators

Some disasters do not generate visible indicators of when they are going to occur. For instance, an earthquake does not produce any visible indicator as a prelude to its occurance. It may however, seismic activity,tilting, strain or other subtle indicators, which can be sensed by an in-situ sensors. Tsunami's produce a visible indicator which can be sensed by in-situ sensors, however the indicator (wave height) is such that current satellite-acquired data can not track tsunami development. Drought and desertification indicators may be quite extensive and easily observable. Satellite data may be much more useful in monitoring this type of disaster development.

This particular characteristic also influences planning, in that the type of disaster and the indicators of that disaster will dictate what type of data collection technique is appropriate. Here, one can look at the capabilities of remote sensing satellites to provide spatial data which matches with the indicators of particular disaster types. For the purposes of this study, the size of natural disaster indicators can be classified as large-scale to small-scale. Large-scale data, such as weather patterns concerned with weather-related disasters, are available from meteorological satellites. Medium-scale data, such as

that related to desertification and deforestation processes, are available in part from Landsat. Small-scale data, such as that related to localized flooding or wave patterns related to tsunami's, are available from in-situ data collection platforms monitored by satellite.

2.2.8 Disaster Characteristics and Data Requirements, Summary

The above discussion clearly illustrates several things which are extremely important in thinking about satellite remote sensing applications to data requirements for disaster warning and management.

1. There are a number of characteristics of disasters which have little to do with satellite data and information. In fact, many of these characteristics are more important to a priori planning of disaster early warning and management systems, than they are to the types of data required by those systems. For instance, location of disasters, area of impact, the frequency of occurrence, numbers of people effected and severity of the disaster have more to do with planning for disaster management (including early warning) systems, than they do with the types of data to be collected once a decision has been made to implement a system.

2. Once a decision has been made to develop an early warning and mangement system, then decisions are required as to how frequently data observations are required and what type of data is to be collected. Frequency of data observations varies primarily with the time it takes a disaster to develop. Shorter lead time requires more frequent, if not continual, observations while longer lead time allows less frequent data collection. The type of data collected (whether it be satellite data, aerial photography, in-situ data, human observations, etc.) depends in large part on the size and visibility of the indicators of a particular disaster.

3. Particular disasters have characteristics which are peculiar to that type of disaster. It is difficult to generalize the requirements of disasters for data and information. In fact, because of the differences in disasters and their characteristics it may be difficult to integrate disaster warning information systems.

2.3 Communications Requirements for Disaster Early Warning

The same characteristics of disasters outlined above affect the planning of the communications aspects of any disaster early warning and management system. Possible locations of particular types of disasters dictate where communications facilities will likely be required. The area of impact will have an affect on whether mobile or stationary communications is required. Disaster development time also affects the type of communciations facility required. If a disaster develops rapidly, then mobile or in-place communications is essential. If a disaster is slow to develop, then longer term communications may be required and established. If a disaster occurs frequently in a particular area, it may justify a permanent communications link, however, if a disaster is a rare occurrence then a permanent link is hardly justified. Obviously, the numbers of people affected and the severity of the disaster will also influence the priority attached to the need for communications facilities for a particular disaster type.

Another characteristic of disasters which affects communications requirements, but has little impact on information requirements, is whether or not the disaster destroys in place communications facilities. For instance, a drought or famine is not likely to affect already established

communications facilities while an earthquake may destroy not only communications but power facilities as well. This is extremely important when looking at satellite applications to disaster management.

These characteristics of disasters generate a need for various types of communications. The following sections describe the types of communications which are available (television, voice and data) and then discusses these various types of communications as they relate to various aspects of disaster warning and management.

2.3.1 Voice

The use of voice for most emergency purposes is the most straightforward, and the most prevalent. Via satellite, a voice channel can be transmitted singly either by use of an entire narrowband transponder (as used in early experiments with NASA's ATS-1 and -3 satellites), or it can be "trunked" together with dozens of others in a multi-channel system (as in a use of the CTS satellite). Each of these uses have occurred in past emergencies. To describe a situation reliably by voice, however, requires good understanding, as well as communication, between the speakers.

2.3.2 Low-speed Data

As a result of difficulties in accurately communicating data about disaster situations via voice links, data is often used as an effective communications type, particularly when logistics are involved. Here, errors of interpretation, because of noise or stress, generally are avoidable because of the use of the printed word and the capability of others to interpret the message. This is particularly true where international assistance is being provided through the use of languages that are foreign to one or the other correspondent.

Included in the data category is the use of machine and telegraphic symbol transmission such as teletype or telex. These require transmitting and receiving equipments that are not commonly available to the general public, but are common among news and weather reporting agencies for translation to the public via radio and television.

Analog facsimile is also considered as a specialized form of data transmission. It is uniquely useful for weather data distribution. But again, the need for a special receiver, and graphic recorder makes it almost unique to the sophisticated user. Interpretations of the charts so produced are often best left to the professional, and are then transmitted to the general public via either television or radio.

Another, even more specialized, data system is the use of data collection platforms (DCPs). The collection of information on environmental conditions via remote, unmanned, battery-powered DCP's can be vital to early warning of disaster conditions. They provide low-speed data streams to a central location for processing, analysis, interpretation, and integration with other sensor data. The generalized data collection platform can be host to a wide variety of local environmental sensors. They can transmit at timed intervals or on interrogation, either through telephone lines where available, or through satellite links.

With the growing use in developed countries of data terminals and personal computers in homes, it may, in the future, be possible to disseminate emergency data using a personal computer network. It is unlikely to be as universally useful as voice for the same purpose, however, for local authorities' use, two-way communications via slow-speed data systems for damage assessment, rescue, and rehabilitation purposes could be superior to voice under conditions of weak signal strength and acoustically noisy environments. These conditions could exist where

portable satellite terminals are used at low power. Data terminals also afford the use of stored and approved messages where skills for communication by voice may be unavailable.

2.3.3 Television

The use of television is particularly worthwhile in situations where critical judgments must be made with remote assistance. In specialized situations, such as severe personal injury or illness where immediate assistance is given with remote, verbal guidance while observing television, it can not only save lives but can ease suffering and concern, and help to accurately prepare for advanced care. In other cases where widespread damage has occurred, a local camera, communications, and a remote professional observer often can accomplish more together than if both were on site. For instance, Alaskan lives have been saved through the use of television from remote villages to the Juneau hospital, when there has been no chance of a doctor being available on site.

There are many parameters that apply when considering the quality of reception needed in any transmission system. One basic factor is the power level from the uplink system, which depends basically upon the transmitter's power and the size of the antenna used. The use of small terminals for television generally implies non-real-time imagery because of these power limitations. Again, development will no doubt continue to progress in smaller, lighter electronic packages to process the television camera's signal so that slow-scan and freeze-frame transmission techniques from low-power satellite terminals can be used. Present technology is advancing rapidly to permit high-quality, limited-motion digital television to use data rates as low as 500 kbps -- a data rate that is approaching true portable earth station utility.

2.3.4 Communication Needs in Disaster Management

These three types of communications, television, voice and data, are all parts of an effective disaster early warning and management system. However, their usefullness during various aspects of disaster management vary. The following sections outline the use of these various type of communication to particular stages of disaster management.

2.3.4.1 The Need for Television

The use of television during the earliest stages of an impending disaster is useful in instructional ways to inform people who might be involved what might happen, how best to avoid the worst of the consequences, and how to help others. The need for instruction of the simplest sort is sometimes not obvious. For instance, because tsunamis often occur in sequence, returning to a beach soon after one wave can lead to further losses. Simple instructions to involved people not to return to the beach might well save lives.

In developed countries, television and its accompanying audio are the most practical for instruction. In conjunction with battery-powered radios, television can provide for a relatively complete preparation and warning system. But in countries where the regular use of television is not possible, it is not practical to implement just for disaster training. Radio instructions must be all the more convincing, being made by a reliable and trusted source in order to prompt the action desired.

In the following stages of disaster management, television can be used, not for the general populace, but from the scene on a special link to aid and rescue forces. In this way, it can be used effectively in damage assessment, and then to decide when, where, and what kinds of aid should be given. Then, as later rehabilitation stages get

under way, television becomes less useful. Overall, then, television is at its most effective use for country preparedness and in damage assessment during disaster relief.

During damage assessment, the need for mobility of the communications terminal is essential, and the use of mobile television cameras is feasible. The regularly decreasing price, size, and weight of all electronic systems makes probable more widespread television applications in the near future. Although small, low-light television cameras have been operating for years inside well-drilling bits, little use of small cameras has been made for use in natural disasters. The well-known use by military forces in observing a wide range of critical situations has required development of many types of rugged, high-resolution television cameras, but these technologies have not yet been transferred into use in disaster observation.

2.3.4.2 The Need for Voice

As noted above, voice is also often used for the purposes of instruction and warning. In fact, although it clearly is not always the best type of communication, voice is so universal that it can be used effectively in all stages of an event. The frailties of voice transmission in a disaster situation generally are the subjective and interpretative characteristics attributable to the human communication process, not the transmission channel itself.

However, voice communication is so universal, flexible, speedy, and capable of subtleties of expression not found in other types of communications, that there are generally overriding considerations when deciding between voice and television. In addition, the transmission channels for voice are well established through switched

telephone networks, which have been made internationally compatible through the cooperative efforts and fora of the ITU over the last hundred-plus years.

In general, voice is the most likely communications medium to be used in country preparedness and disaster relief and rehabilitation efforts. With regard to early warning, voice channels are particularly important where disasters are developing rapidly. In addition, given that a voice-grade channel is established, several other transmissions are possible given that the proper equipment is at each end. These include the use of facsimile, slow-scan and freeze-frame television, and moderate-speed data and teletype, all of which can move well over a voice-grade channel.

2.3.4.3 The Need for Data

The use of data for pre-disaster instruction is limited because of its narrow availability to the general populace. However, for specialized users with teletype receivers, the use of messages for warning stages can be most worthwhile because of its apparent veracity, brevity and impact, and a lesser need to interpret. It is useful for authorities' traffic where radio or television is available for warning dissemination to the general populace.

During rehabilitation, the use of teletype messages can be excellently applied where logistics such as resource requests for money, medical, materials, shipping means and schedules, bills of lading, etc., are best made through written messages. Where specific, numeric and tabulated lists must be sent, the naturally-organized teletype and other data forms are best. Additionally, where personal approvals must be recognized remotely, -- a signature, for instance -- facsimile transmission has no equal.

In the area of disaster early warning, the

transmission of data is essential as input into forecasting models and in the transmission of those forecasts. While voice and television warnings are most useful when disasters are developing rapidly (such as tsunami's), data communications can and is being used for warning of slowly developing disasters (such as droughts).

2.3.4.4 Communications Requirements, Summary

The role of the human in use of these media is critical. In each case, none of the human sources using these transmission types is disengaged from the medium. That is, the use of each of these system types requires a knowledgable, rationally-thinking and skilled person with organized approaches to information use and transmission. While this provides the chance for misinterpretation and judgement error, universal and perfectly useful automatic sensing will never exist. Even if it did, we cannot presuppose disaster characteristics to prepare worthwhile automated processing of the wide range of potential conditions that we need to warn and be warned about worldwide.

In summary, voice is useful for all disaster stages, although not always best; data collection and reporting is useful to authorities for warning stages, and only if interpreted and rebroadcast by other general media is it worthwhile to the general public; data is also especially useful in latter, rehabilitation stages; and television has its place for the public in early warning and in country preparedness, and for authorities in post-event assessments.

2.3.5 Applicability of Satellite Telecommunications to Disaster Management

To understand the importance of satellite communications to disaster warning and management, it is necessary to observe the unique generic, characteristics of satellites. In addition to its obviously unique technologies, the geosynchronous satellite used for communications has the following special properties:

1. Networks using satellites are distance-insensitive to user who are within view of the satellite. In the vast majority of cases (except for rare instances of below-surface communications needs

and thick or wet foliage), satellite communications can be conducted without being hampered by the local environment. There may be special instances where high hills and low elevation angles from the terminal to the satellite prevent a line-of-sight path, but these are at least statistically infrequent.

2. The relatively small size of satellite voice terminals results in total physical control. This personal handling, particularly in difficult environments and without mechanical aids, can be important for emergency use and in control against damage of the terminal itself. Effects of earthquake, flood, and high winds will not affect satellite communications as long as the terminal itself (which, even for multi-channel sized antennas, occupies a relatively small amount of real estate) and a power source either can be reasonably protected from the environment, or restored after the threat diminishes. In some cases, such small satellite terminals have survived difficult environments where cables, wires, terrestrial microwave towers have not.

3. Overall power requirements for satellite terminals are small in comparison, for instance, to the operation of an entire long-distance wire and microwave network. They therefore are amenable to use under stored-power and efficient-generation conditions where otherwise communications would be precluded or traded off against other operations needing power for health and safety.

4. A communication satellite system, with an on-site operator using a hand-held, battery-powered camera and a small terminal, can bring relatively high resolution, real-time, color imagery to damage and rescue analysis personnel located remotely for

purposes of control and assessment. The implementation of voice feedback from remote observers to the cameraman can further enhance the observational value. Even storage on a portable cassette recorder for playback through a satellite system can be useful. By contrast, current remote sensing systems can not provide live motion, instantaneous two-way voice feedback to the camera operator, or the high resolution possible with an on-site camera and satellite communications system.

5. Instantaneous restoration of full capability to a central location for control at the moment the terminal becomes operational is much quicker than having to rewire a terminal or set up a relay chain via microwave or cable.

6. Because it is centrally controlled, a satellite communication system is flexibly convertible from regular commercial use to a disaster voice network, permitting (1) a spread of whole-system costs over a much larger and generally profitable base, (2) avoidance of the duplicative costs of a separate network's acquisition, maintenance, and training, and (3) availability of regular equipment maintenance, spares, fuel, and trained operations personnel to assure network utility when needed for an emergency.

7. Standardization, in general, of satellite frequencies, bandwidth, and transmitted power permit the interchangeability in some cases of one satellite for another. This provides not only reliability against failures and dispersion of facilities against physical loss, but the opportunity in some cases to apply competition to the costing of the emergency service.

In large part, disaster communication requirements have characteristics such as: "infrequent but urgent, anytime, anywhere, and affordable." The satellite system's characteristics meet these in large extent as proven by many experiments, but they have been minimally exploited to meet communication needs of disaster warning and management.

2.4 Institutional Requirements For The Use of Satellite Technology in Developing Countries

In discussing any type of system for the early warning and management of natural disasters, it is essential to remember that a system includes not only technology, but also institutions, procedures and trained personnel. In fact, it is in the routine use of data and information, rather than in the technology for the collection of data, that the operational use of most high (including satellite) technology meets its toughest test.

There is a need therefore, to understand and develop the users institutional environment in addition to the technologies which make up any satellite based-system. One might develop a very efficient satellite based early warning system but without the institutions and people who know how to use it, it would be useless.

A recent study on technology transfer to developing countries developed the following typology of user environments in developing countries.[5] This typology is summarized in Figure 2.3 and is a useful tool for understanding stages of institutional development in developing countries.

What this typology suggests is that prior to the development of a sophisticated technological system for disaster early warning to be used by developing countries, an institutional framework capable of working with the technological system must be developed. Transferring the technology to

end users does little to aid in the crucial infrastructure development stages 1 or 2 (as shown in Figure 2.3), which are in turn essential for the successful infrastrucutre development at stages 3 and 4. The key point here is that many international technology transfer projects (particularly those working with high technology) have overemphasized technology at the expense of infrastrucutre and institutional development. The above cited study suggests that efforts to build the technical capabilities associated with stages 3 and 4 (Technology Maintenance and Modification and R&D) will fail unless the objectives of stages 1 and 2 (Organization Development and Technology, Search and Acquisition) have been realized within the developing country. This suggests that, with regards to satellite applications to disaster warning and management, that along with efforts to introduce satellite technology into developing countries, one must also focus on the institutional development essential to the effective use of that technology.

2.5 Summary

This introduction provides a framework for understanding the applications of satellite remote sensing and communications technology to disaster management and early warning of natural disasters. It describes disaster characteristics and subsequent data and information requirements. It details the critical role of communication satellites and of the need for institution building in developing countries.

Section 3.0 provide a detailed look at current and future satellite systems which are potentially applicable to meeting the data needs for disaster management and early warning. Section 4.0 then discusses various applications of satellites to early warning programs currently underway.

FIGURE 2.3

Development and Infrastructure

Stage of Technological Development in Developing Countries	Objectives or Goals Within Each Stage That Must Be Achieved Before Procedding To The Next Stage
1. Organization Development	1. Building an initial institutional strucuture.
	2. Building an internal problem solving and diagnostic planning capability.
2. Search and Acquisition	3. Problem identification and search for appropriate technology.
	4. Technology acquisition.
	5. Technology application and use in decision making.
3. Maintenance and Modification	6. Maintaining and modifying technological and decision making structures as new technologies and problems arise.
4. Research, Development and Engineering	7. Development of internal technological capabilities.
	8. Spreading technology to other sectors of the country.

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3. Ibid., p.1.

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3.0 SATELLITE (AND ASSOCIATED) TECHNOLOGY APPLICABLE TO DISASTER EARLY WARNING

This section presents an overview of various satellite and related technologies which are applicable to early warning of natural disasters. These technologies include: (1) meteorological satellites, (2) earth resource sensing satellites, (3) communications satellites, and (4) computer technologies related to geographic information systems (GIS).

3.1 Geostationary Meteorological Satellites[1]

Meteorological satellite data has been collected and disseminated since the launch of the first United States TIROS polar-orbiting satellite in 1960. At the present time, the US operational weather satellite system consists of both polar orbiting satellites and geostationary meteorological satellites. These systems provide data to national and foreign stations, as well as contribute to international programs such as the Global Telecommunications System (GTS) of the World Meteorological Organization (WMO). In addition, there are three other geostationary meteorological satellite programs in existence today (European Space Agency, Japan and India) and one other polar-orbiting system (Soviet Union). The instruments on these satellites have developed in such a manner as to be almost completely complementary. These systems and projected future systems are described below.

3.1.1 The US Geostationary Operational Environmental Satellite (GOES) System

The GOES system is made up of two satellites orbiting at 135 and at 75 degrees west longitude. These satellites carry:

> ...the Visible Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS), and the Space Environment Monitor (SEM). Major communication capabilities include the GOES Data Collections System (DCS), direct transmission of VISSR data and the WEFAX (Weather Facsimile) service. 2

The VAS scans in an west-east direction which permits it to view the full earth disk within view. It observes in two bands, one in the visible spectrum and one in the infrared. The VAS sensor provides cloud viewing images with resolution of 1, 2, 4, and 8 KM in the visible range and 8 and 14 KM in the infrared range. It has a unique capability amongst geostationary meteorological satellites to provide moisture profiles and vertical temperature readings over selected areas via 12 infrared channels. It operates in three different modes and produces three types of products:

1. In the VISSR mode, the VAS operates as a normal cloud mapping sensor. It produces full images of cloud patterns in the visible and infrared every 30 minutes throughout the day, or partial images at intervals up to every five minutes--this capability is used to track quickly developing severe storms, for instance; in addition, full images in the water vapor portion of the spectrum are provided four times per day; and

2. In the Multi-spectral imaging mode, the VAS adds to the normal VISSR images, images in any two additional spectral bands at a resolution of 13.8 km.

3. Finally, atmospheric soundings can be taken, but not simultaneously with the collection of images.

Models have been developed to translate this data into a wide variety of products--these include low-level computer wind vectors and low and high level manually determined wind vectors in numeric form; digital sea-surface thermal composites for the coastal zone of the US; daily time-lapse film sequences for plotting the direction of storms and clouds; cloud top heights; quantitative estimates of percipitation; classification of hurricanes; sea fogs; the earth's energy budget; and patterns of sea ice critical to shipping.

The Space Environment Monitor (SEM) on-board the GOES satellites is an integration of three separate monitors which measure magnetic fields, solar x-rays and energetic particles. The SEM is used for detecting the emergence of solar flares which may be detrimental to space communications and the operations of spacecraft including data transmission.

GOES satellites are also equipped with a data collection system (DCS) which is used to collect and relay environmental data sensed by remote data collection platforms (DCP). These DCP's include such things as "river and rain gauges, seismometers, tide gauges, buoys, ships, and automatic weather stations."[3] The satellites utilize transponders on-board the spacecraft to relay DCP UHF transmissions via s-band to properly equipped ground stations which then relay them to the World Meteorological Center, Washington D.C.

The satellites can handle up to 12,000 DCP's reporting an average of 11 times per day, and these reports can be either scheduled or prompted. Data from the US GOES system can be obtained through direct communication with the World Meteorological Center in Washington D.C. or through the Global Telecommunications System (GTS). The data received is used for a wide variety of applications including:

1. Monitoring of river stages and flood forecasting;
2. Monitoring of moisture levels and "sun time" for crop yield modelling and forecasting of food shortages;
3. Hurricane reconnaissance;
4. Verification of wind fields over the pacific and tsunami forecasting.

The GOES system also has direct readout data transmission capability. One of these is the WEFAX (or Weather Facsimile) Service which provides broadcasts of processed satellite images. This service includes the broadcast of meteorological charts as well as satellite imagery. Generally, "unmapped GOES images and mapped images from polar-orbiting satellites make up the bulk of WEFAX transmissions."[4]

3.1.2 European Meteorological Satellite Program

The European Space Administrations (ESA) Eumetsat program currently consists of two satellites, the Meteosat-1 and Meteosat-2. The Meteosat-1 is currently used primarily to support data-collection systems, while the Meteosat-2, launched in 1981, is used for imaging purposes.

The Meteosat uses a visible and infrared scanning radiometer to provide near continual imaging in three spectral bands, the visible, infra-red and water vapour bands. Every thirty minutes, one complete set of Earth images is collected and this set consists of either a visible, infra-red and water-vapour image with resolution of 5 km, or visible and infra-red image with a resolution of 2.5 km in the visible and 5 km in the infra-red band. In addition, the Meteosat supports a data collection and WEFAX system very similar to that of the US GOES satellite system.

The Eumetsat program produces a variety of products including cloud motion vectors, sea surface temperatures, cloud analysis, upper tropospheric humidity, a climate data set consisting of radiation balance data (this program is still considered experimental), and cloud-top

height maps. Of these, the cloud-top height maps are disseminated via WEFAX and the rest are available via GTS link with European Space Operations Center.

3.1.3 Japanese Geostationary Meteorological Satellite (GMS)

The Japanese GMS is located at 140 degrees east on the Equator and carries a visible and infra-red spin scan radiometer, space environment monitor, data collections system and WEFAX.

The VISSR takes both visible and infra-red Earth pictures with 1.25 km resolution and 5 km resolution respectively. The SEM monitors solar activity in much the same way as the US GOES system by tabulating the flux in the number of solar protons, alpha particles and electrons in the space environment; and, the data collection and WEFAX capabilities of the GMS are similar in nature to the Meteosat and GOES systems.

3.1.4 Indian National Satellite System (INSAT)

The INSAT system will eventually consist of two geostationary satellites located at 74 degrees and at 94 degrees E. These satellites are unique to the weather satellite system in that they combine telecommunications capability with meteorological imaging. The primary instrument on-board INSAT is the Very High Resolution Radiometer (VHRR) which produces images from the visible channel at 2.75 km resolution and from the infra-red channel at 12 km resolution. Full frame images are collected every half hour. INSAT instruments also include a data collection system (DCS). INSAT-1a failed in September 1982, and INSAT-1b was launched in August of 1983.

3.1.5 Soviet Union's Geostationary Operational Meteorological Satelllites (GOMS)

The Soviet Union is planning on launching GOMS in the near future into a geostationary orbit at 70 degrees East longitude. It is intended to carry Television-type Scanning Equipment capable of producing visible band images with resolution of 1-2 km and infra-red images with resolution of 12 km. In addition, GOMS is expected to carry a data collection system and WEFAX capability.

3.2 Polar-Orbiting Satellites

In addition to the Geosationary Satellites, both the Soviet Union and the United States have polar orbiting satellites which are a vital part of the international weather satellite system.

3.2.1 US NOAA/Advanced TIROS-N Satellite System

The operational NOAA polar-orbiting satellite series consists of two satellites which carry four separate instruments: the Advanced Very High Resolution Radiometer (AVHRR), the TIROS Operational Vertical Sounder (TOV), the Space Environment Monitor (SEM), and the Data Collection System (DCS). Data from these systems is transmitted via "three S-band transmitters at three frequencies, two VHF transmitters at two frequencies and a search and rescue communication system."[5]

The AVHRR provides imagery in five channels in the visible, near infrared, and infrared portions of the spectrum. These images provide 1 km resolution which are in turn processed on-board the satellite to produce a global data set for central processing with resolution of 4 km. In addition, a separate processing unit produces 4 km resolution analog data for Automatic Picture Transmission (APT) purposes.

Real time APT data and High Resolution Picture Transmission (HRPT-digital) data is available for properly equipped ground stations, and is also collected at NOAA's central processing facilities in Alaska and Virginia.

There are three transmission systems by which data from the NOAA/TIROS-N satellites are transmitted to users other than NOAA. These are the APT, the HRPT and Direct Sounder Broadcast systems. The APT system includes two VHF transmitters which transmit to ground receivers while the satellite is in sight of the ground stations. There are over 900 of these APT ground stations, including over 600 in 120 countries outside of the United States. The APT broadcasts AVHRR data at 4 km resolution. High Resolution Picture Transmission (HRPT) data are transmitted to ground stations via S-band transmitters on-board the satellite. There are currently 46 HRPT ground stations located in 23 user countries. The following products and services are derived from AVHRR data.[6]

1. Full resolution data are broadcast in real time to HRPT stations around the world;

2. Low resolution data from the visible and thermal infra-red channels are continously available to APT users worldwide;

3. Detailed sea-surface temperature analysis can be prepared--these are useful as input to models which correlate sea surface temperature with fish concentrations, for forecasting sea fog and for locating major current boundaries;

4. Snow cover maps can be produced to help in forecasting snow melt in support of flood prediction and water management;

5. Weather data which provides information important to agricultural development including the development of a vegetation index which shows the general health of vegetation cover;

6. The provision of a climatological record for studying long-term weather trends and for spotting anomolies in weather trends which might portend the development of droughts, severe storms, floods, etc.

7. Quantitative data on the the structure of the atmosphere is input into numerical weather prediction models to develop weather forecasts for periods up to 12 days into the future;

8. Information on precipitation, surface temperatures and winds are useful as inputs into models to project global crop condition and crop-yield/production estimates.

As a complement to the data collected by the SEM on-board the GOES satellite, the NOAA polar orbiters carry an SEM which collects additional data on solar activity. This activity is important to ionospheric radio communications, over the horizon radar systems, high-altitude aircraft, and manned space activities such as the shuttle.

The ARGOS Data Collection and Platform Location System was provided by France to the United States to fly on the NOAA/Tiros-N satellites. This system provides a mechanism for collecting data from fixed or moving platforms worldwide. This data is broadcast to U.S. facilities then transmitted via satellite to CNES/France for processing and location determination prior to dissemination to users. It may also be directly received by commercially available down-link systems within moderate range of the DCP's. The ARGOS DCS supplies the following service and products:[7]

1. In-situ observations of ocean and land surface weather conditions;

2. The location of moving platforms to provide information on surface currents and wind patterns;

3. Tracking of research vessels on the open seas;

4. Data on the Arctic and Antarctic regions which are not observable by the GOES system;

3.2.2 USSR Meteor-2 Polar-Orbiting Satellite

The USSR has launched six polar-orbiting satellites to date. The general goal of the Meteor system is provide on an operational basis, twice a day, global data relating to the distribution of cloud snow

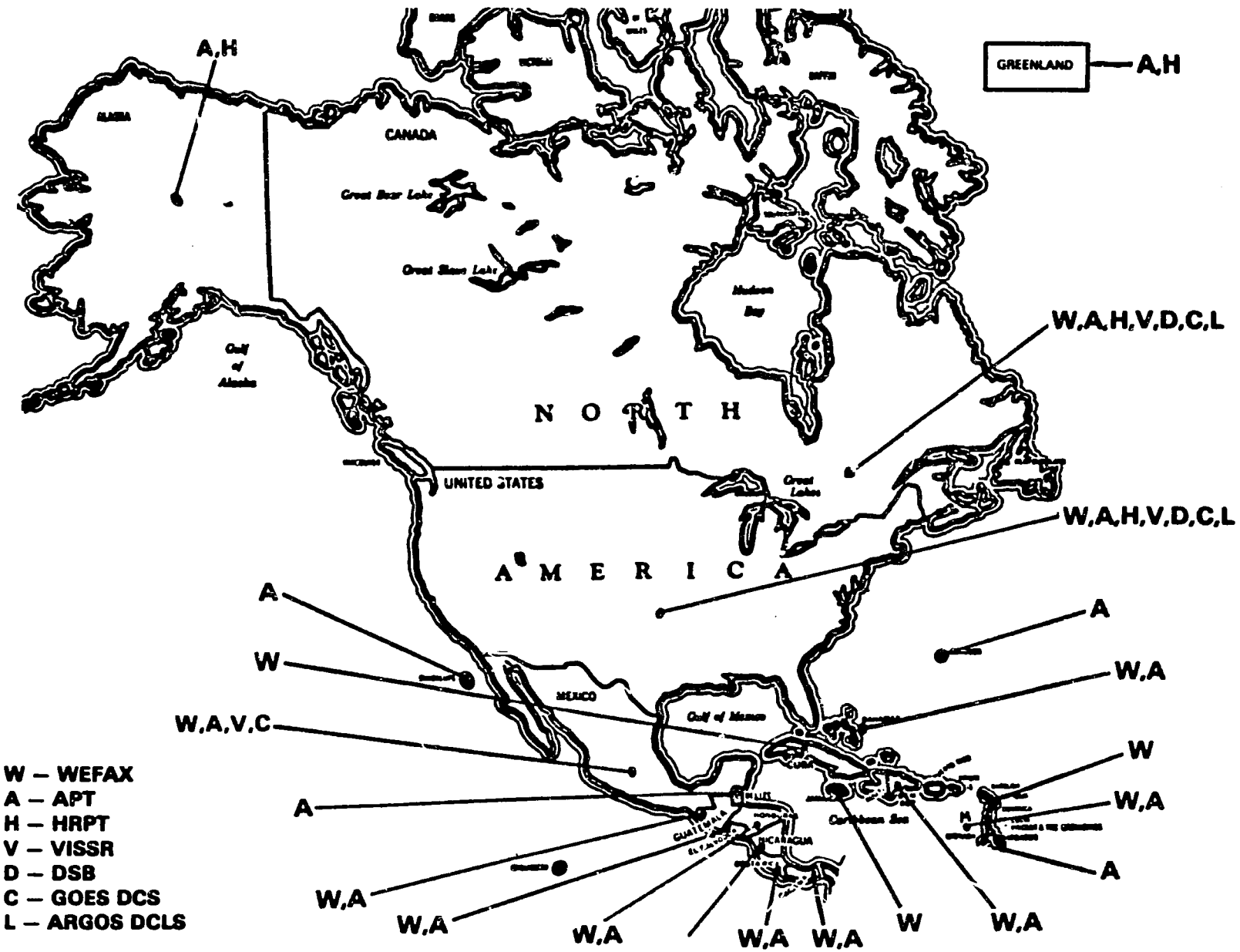
and ice cover, cloud top hieghts, radiation temperature of the underlying surface of the clouds, global data on vertical distribution of temperature, and data on fluxes of penetrating radiation in outer space near the earth.[8] The primary instruments on-board the satellite include a scanning telephotometer for automatic picture transmission in the visible band, producing images with resolution of 2 km, television-type scanning equipment providing data at 1 km resolution and an IR scanning radiometer providing data with 8 km resolution.

Figures 3.1 through 3.6[9] show the worldwide network of meteorological satellite ground stations. This includes WEFAX, APT, HRPT, VISSR, DSB,GOES DCS and ARGOS DCS stations.

FIGURE 3.1

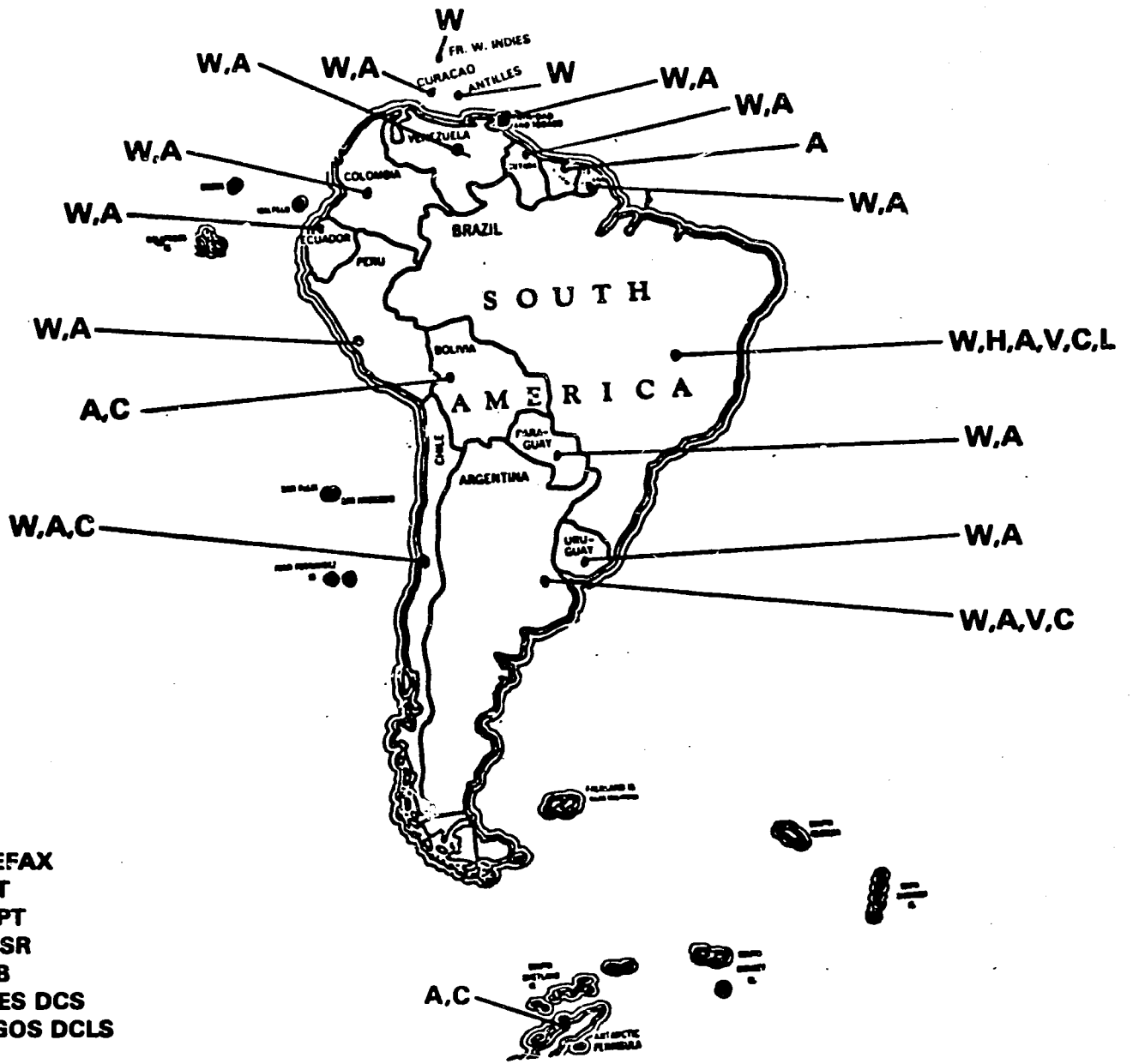
North America and Central America

June 1983



South America

June 1983

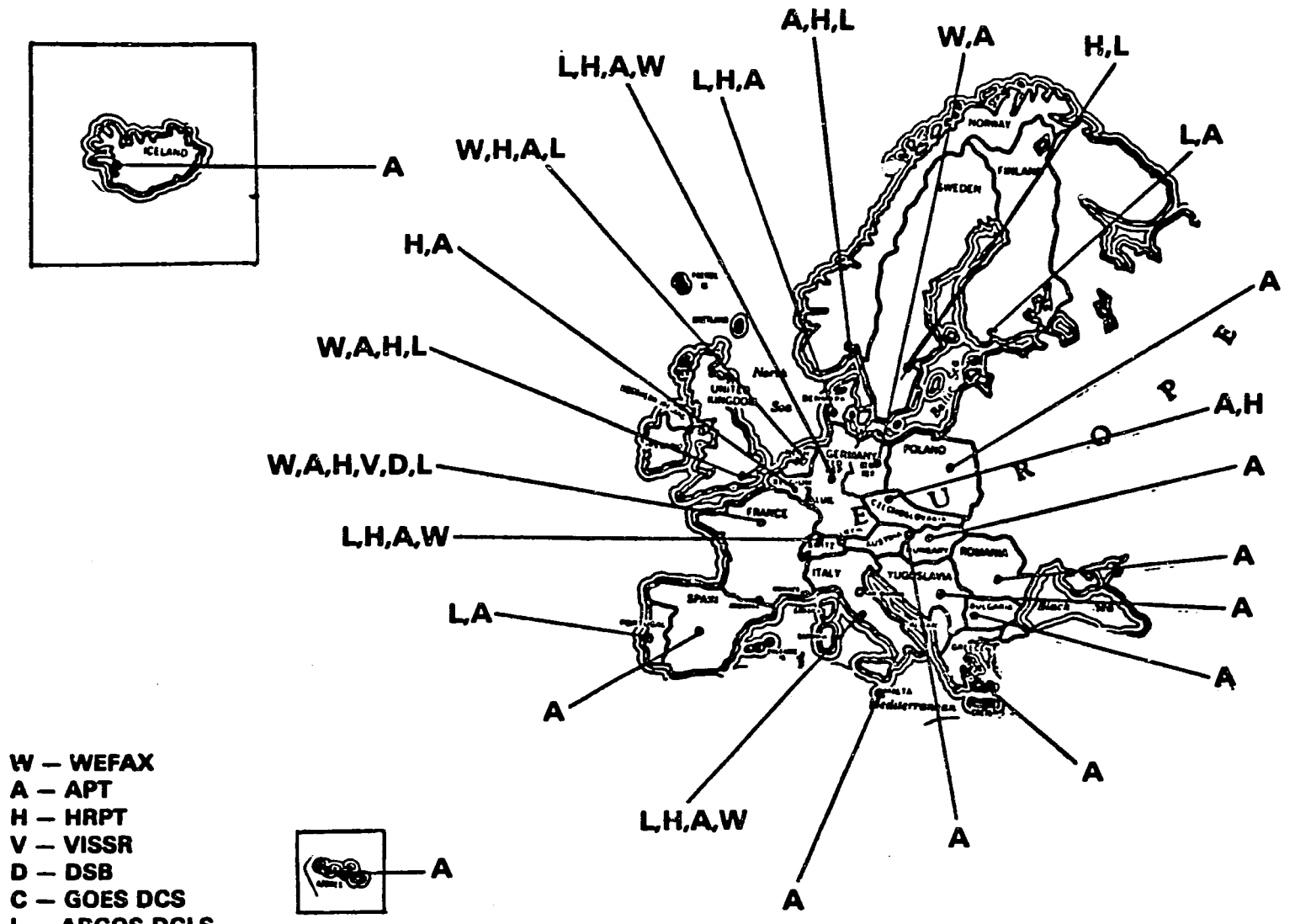


W — WEFAX
A — APT
H — HRPT
V — VISSR
D — DSB
C — GOES DCS
L — ARGOS DCLS

FIGURE 3.2

Europe

June 1983



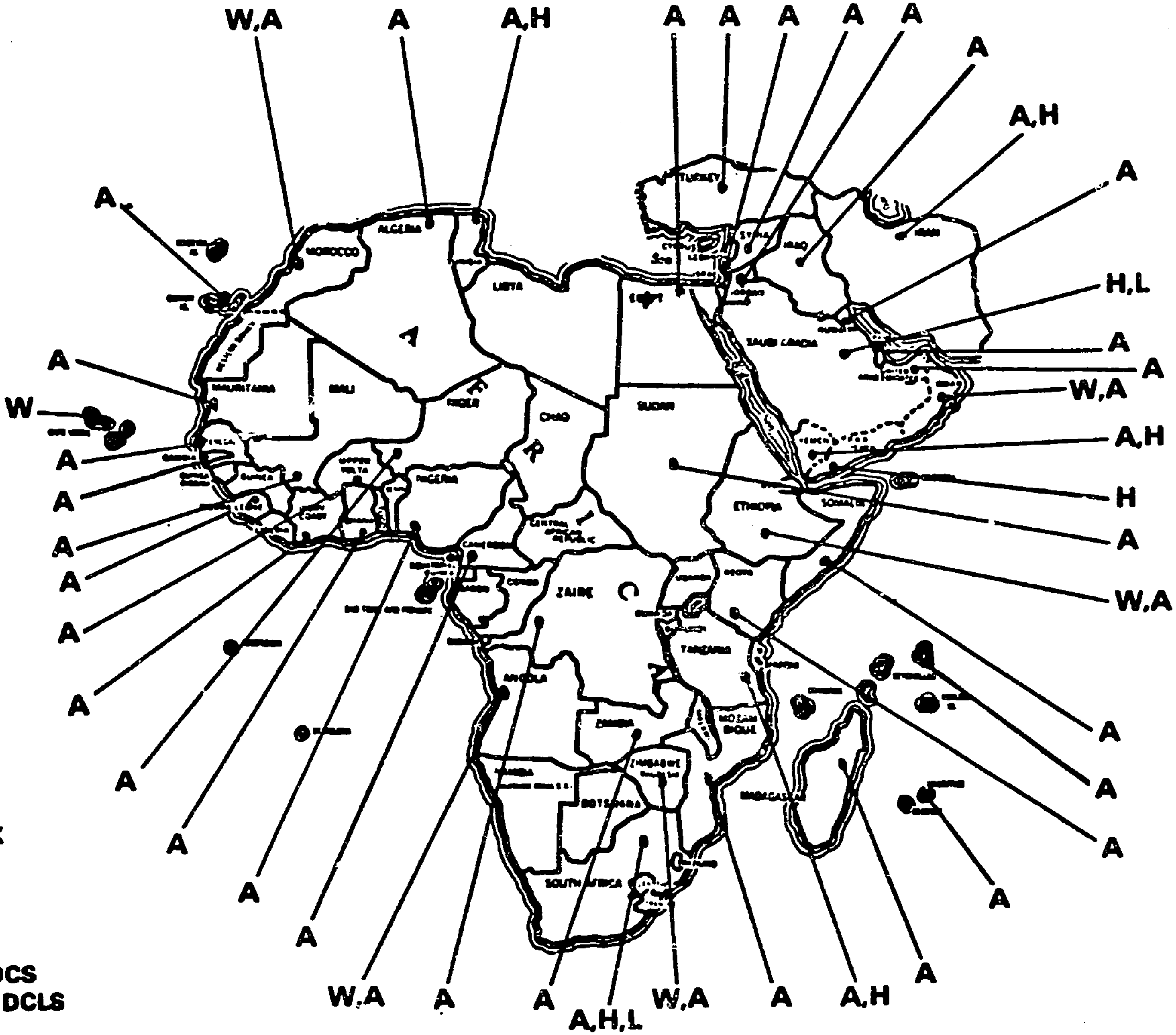
W — WEFAX
A — APT
H — HRPT
V — VISSR
D — DSB
C — GOES DCS
L — ARGOS DCLS

FIGURE 3.3

FIGURE 3.4

Africa and the Middle East

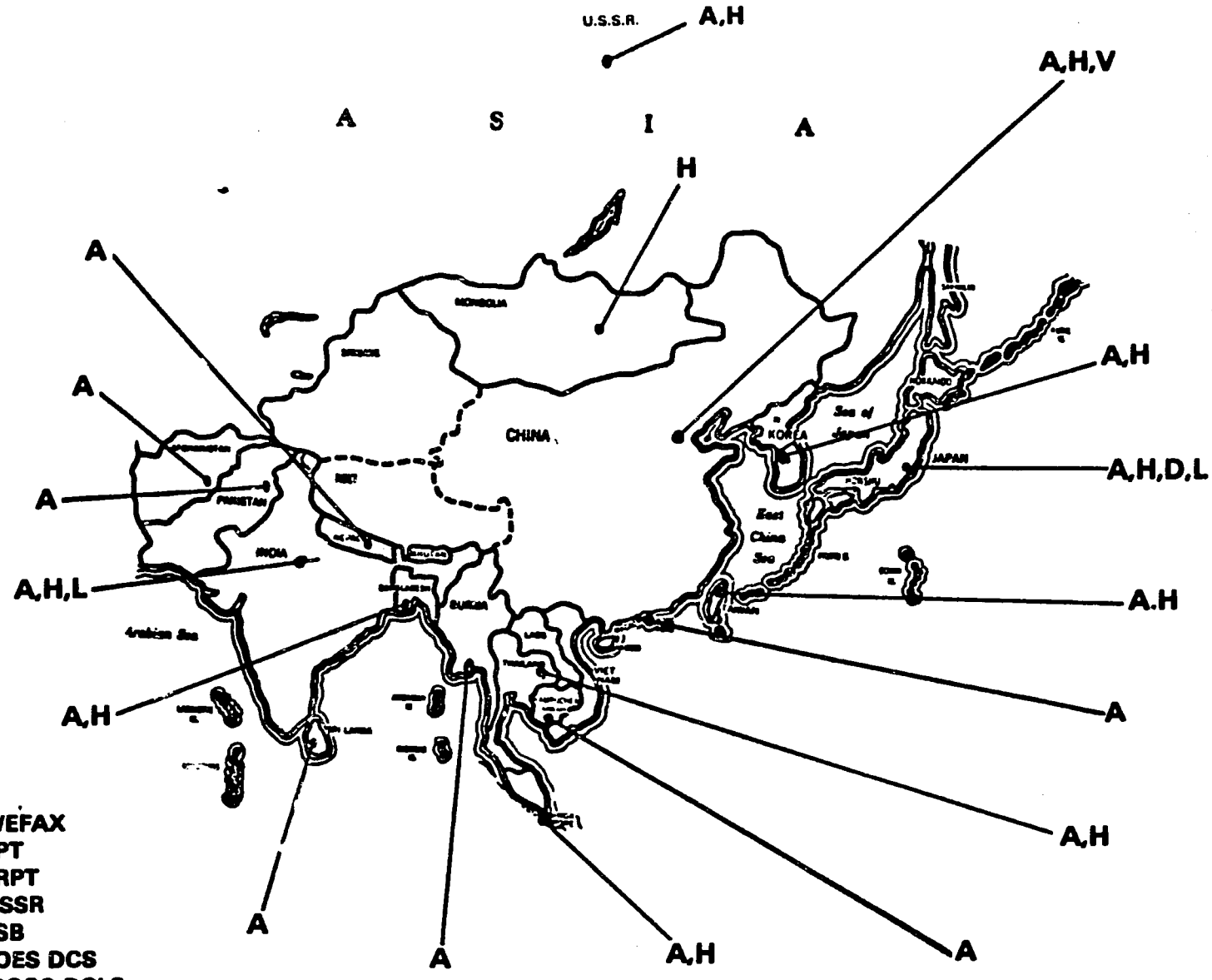
June 1983



W – WEFAX
A – APT
H – HRPT
V – VISSR
D – DSB
C – GOES DCS
L – ARGOS DCLS

Asia

June 1983

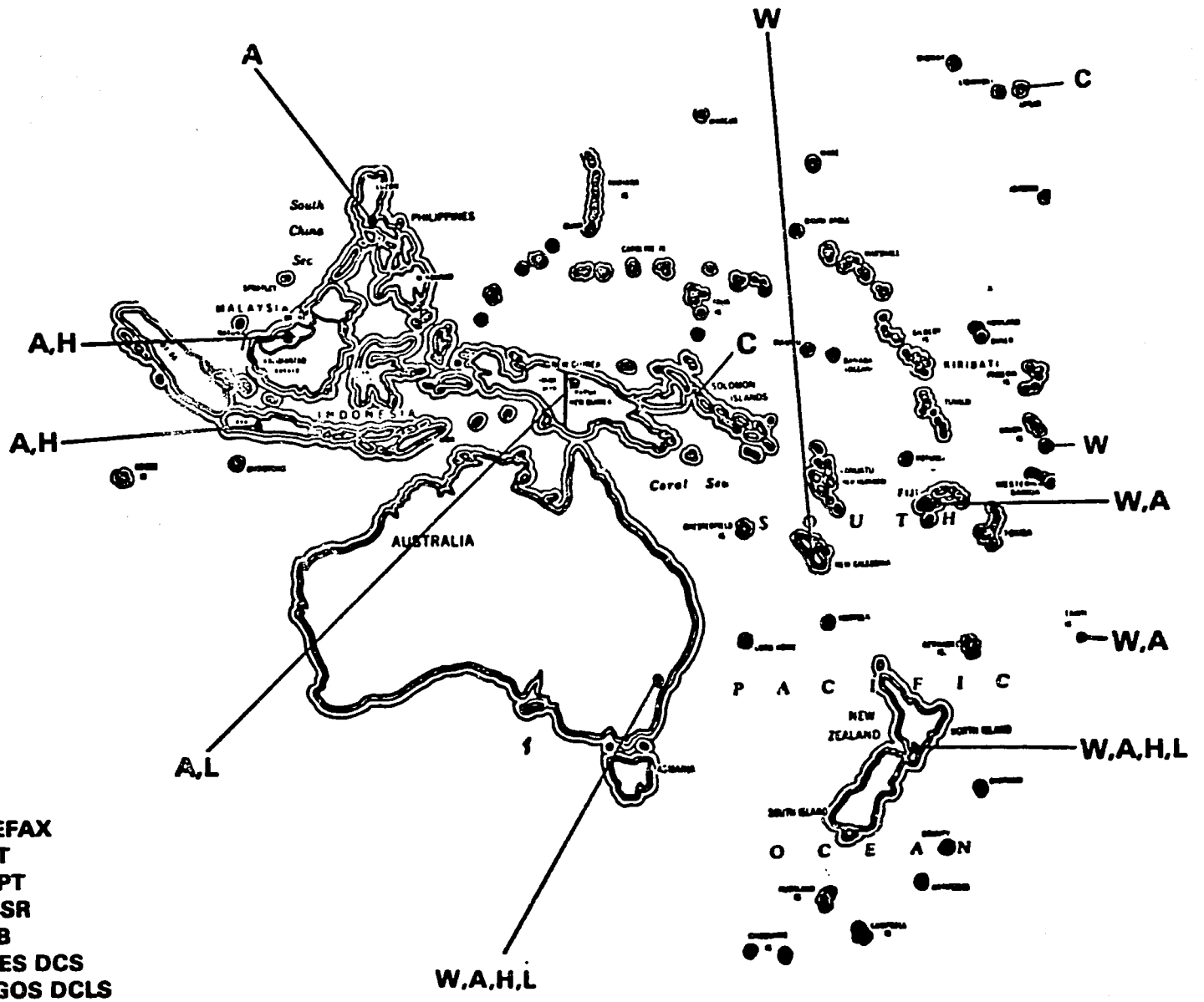


W — WEFAX
A — APT
H — HRPT
V — VISSR
D — DSB
C — GOES DCS
L — ARGOS DCLS

FIGURE 3.5

South Pacific

June 1983



W — WEFAX
A — APT
H — HRPT
V — VISSR
D — DSB
C — GOES DCS
L — ARGOS DCLS

FIGURE 3.6

Together, the Geostationary and Polar Orbiting Satellites, and the extensive ground systems form an international network for acquiring and analyzing international metorological data. There are several other key telecommunications aspects of the international meteorological satellite system. These include the Global Telecommunications System (GTS) and the International Exchange System (IES). The GTS is organized as shown in Figure 3.7.[10] It promotes rapid and reliable data collection, exchange and distribution of observational data and processed information. The IES is a system by which environmental data collected from around the world is brought to the United States. The system consists of low-speed teletypewriter channels, high-speed data channels, and high-speed data and facsimile channels. These channels include radio teletypewriter, long-line, cable, and satellite channels operating from 60 to 3000 wpm.[11]

3.3 Earth Resource Sensing Satellites

Current national programs for remote sensing of earth resources from outer space are in various stages of development. Figure 3.8 provides an overview of the countries involved with the space segment of satellite remote sensing, and the current status of their programs.[12] In general, it appears that there will be upwards of six national remote sensing programs operating by the end of the 1980's. While they will not be as complementary as the meteorological satellite system, and some of them will be commercially oriented, they do form an international earth observations capability. The following sections briefly outline the programs of the countries shown in Figure 3.8.

FIGURE 3.7

Global Telecommunications System

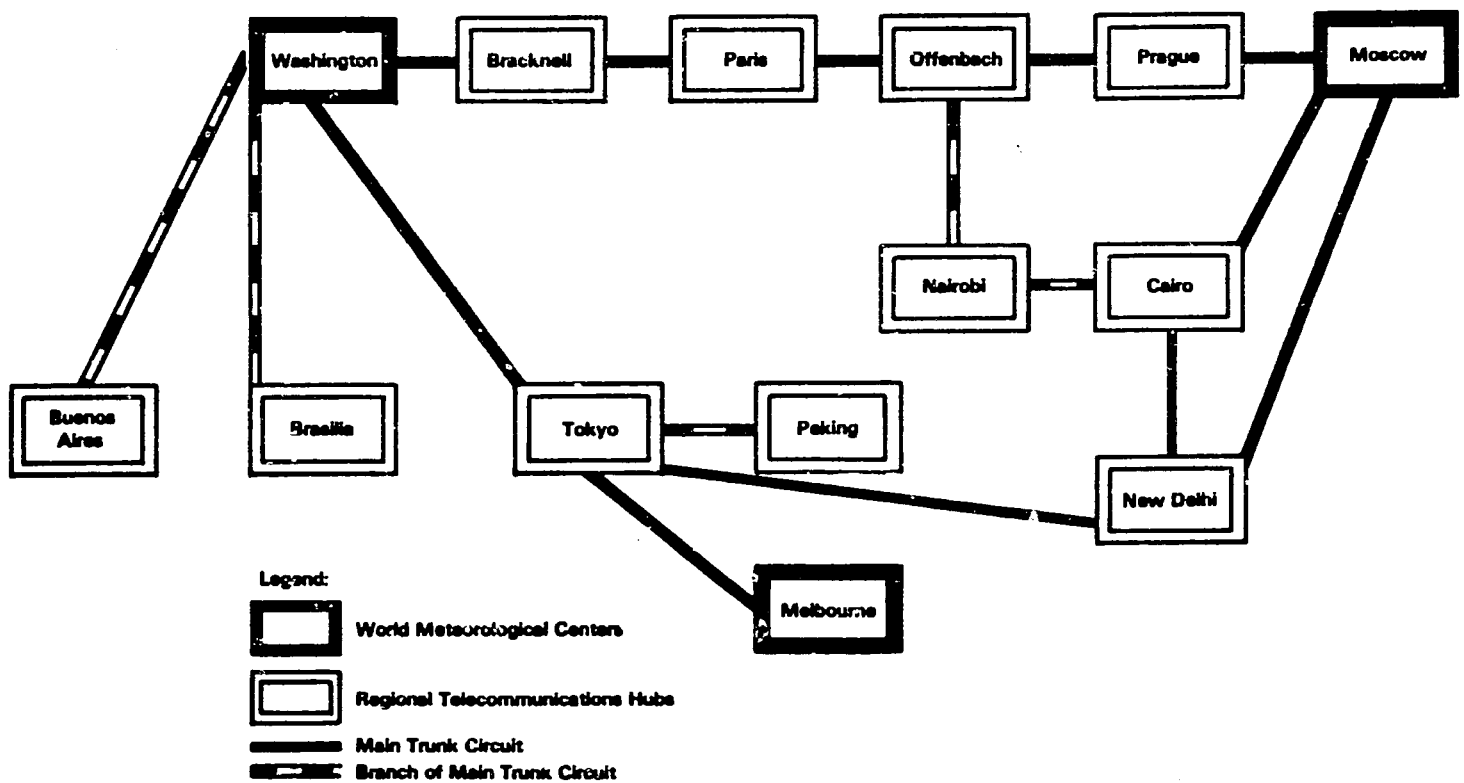


FIGURE 3.8

NATIONAL EARTH RESOURCE SENSING SATELLITE PROGRAMS

	Stage of Implementation			
Country	Operating	Under Construction	Designed	Concept
United States	Landsat-3 Landsay-4 Landsat-4'	OSTA-3 LFC/MAESS	MLA	MAPSAT Space Station
Union of Soviet Socialist Republics	Meteor Salyut-7 Cosmos Series	Space Station		
India	Bhaskara-2			IRS-1
China		Chinasat-10	Chinasat-11 Chinasat-12	
France		SPOT-1 SPOT-2	SPOT-3 SPOT-4	
European Space Agency		SPAS-01 Spacelab 1	ERS-1	AERS Spacelab D
Canada			RADARSAT	
Germany, Federal Republic of			MOMS	
Japan			MOS-1	ERS-1
Brazil				Equatorial
Netherlands/ Indonesia				TERS

3.3.1 United States

In July of 1982, the United States launched its second generation earth resources observation satellite--Landsat 4. This satellite was launched as a follow-on to Landsats 1-3 and carries the Multi-spectral scanner (MSS) which was the workhorse sensor of the first three Landsats. This is a four channel sensor and provides data with 80m resolution. In addition, Landsat 4 carries a new sensor, the Thematic Mapper (TM) which provides for several more spectral channels and 30 m resolution. This satellite has experienced difficulties with its solar arrays and with its x-band transmitter (for sending Thematic Mapper data to ground stations) and has become only partially operational. Due to these problems, NOAA launched Landsat 4', a copy of Landsat 4, on March 1, 1984. It is now operating, and plans have been made to "rescue" Landsat 4 using the Shuttle sometime in 1986. This rescue would follow the precedent set by the recent repair and return to orbit of the NASA Solar Max mission.

The Landsat ground segment is a critical part of the Landsat system, particularly during the years prior to the development of the TDRSS system for relaying data from Landsat satellites, through a satellite network (TDRSS) to a central receiving facility in White Sands, New Mexico. At the beginning of 1983, ground stations were located in Argentina, Australia, Brazil, Canada, India, Indonesia, Italy, Japan, South Africa, Sweden, Thailand, and of course the United States. Ground stations are also planned for China, Kenya, and Upper Volta. Figure 3.9 shows the global coverage of the Landsat ground segment. These stations are extremely important as they will be modified to accomodate data from other remote sensing programs, such as those of the Japanese and the French.

Distribution By Foreign Ground Stations

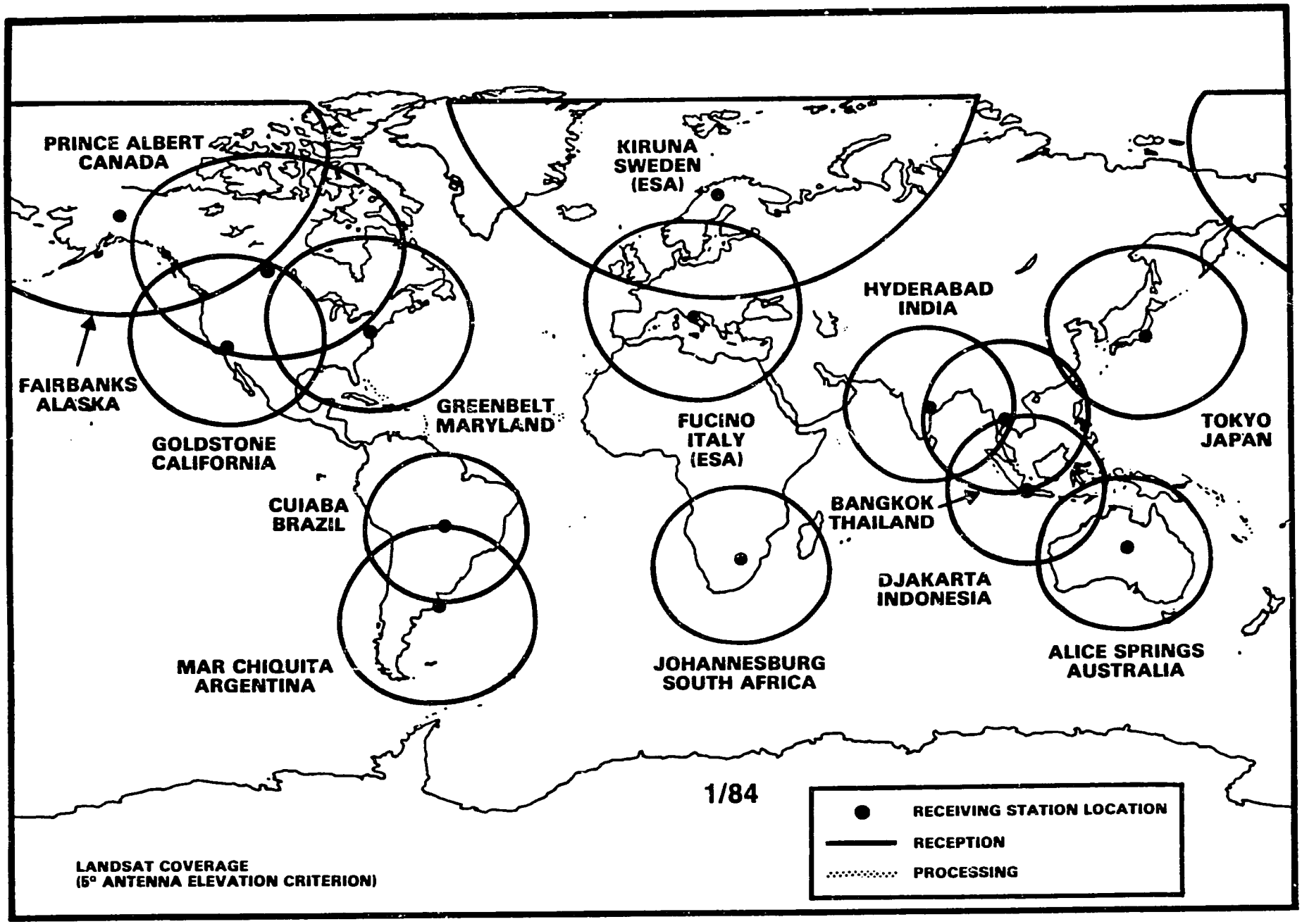


FIGURE 3.9

87a

The United States is currently in the process of "commercializing" the Landsat system. In January of 1984, a Request for Proposal was issued by the Department of Commerce in order to attract bids by US firms to take over the operation of the Landsat system, and to provide commercial earth resource sensing services on an international scale. The outcome of these bids should be known sometime in the summer of 1984. It is expected that this commercialization process will have a tremendous impact on the future of the United States earth resources remote sensing program.

3.3.2 France

Since 1978, the French space agency, Centre National d'Etudes Spatiale (CNES) has been engaged in a national program (with some support from Belgium and Sweden) to develop an operational land remote sensing system called SPOT (Systeme Probatoire d'Observation de la Terre). Through the prime contractor, Matra, CNES is designing a two part satellite consisting of multi-purpose bus with power-supply and station-keeping systems, and a sensor payload which can be altered as the system develops. The SPOT satellites will be placed in sun-synchronous 832 KM orbits designed to provide 26-day repetitive coverage of the entire earth. The initial design calls for two types of coverage: 1)multi-spectral observation with 20 m resolution; 2) black and white observation with 10 m resolution. (This compares to the Landsat 3 multi-spectral scanner resolution of 80 m, and Return-Beam-Vidicon resolution of approximately 30 m). Both of SPOT's instruments can be pointed by remote-control to cover any area of interest within a path 950 km wide; each individual swath is 60 km in width. This pointing capability makes it possible to provide stereoscopic images, i.e. successive views of the same area from different angles, which are particularly useful for map-making and geological interpretation. It also allows for viewing a particular region more often than once every 26 days; such frequent coverage is necessary for agricultural purposes.

The SPOT images are produced by a linear array "push-broom" scanner that produces a continuous picture 60 km wide on the ground. The images are transmitted digitally, direct to ground receivers or can be stored on tape recorders for delayed transmission. The central receiving and control station is located at Toulouse in southern France. Other

countries will be able to build their own station, subject to agreements directly with CNES; or, data and processed data products will be purchased through Spot Image, a joint Government-industry organization being set up to market SPOT services. CNES will hold 34% of the company's shares, with the remainder split between various French firms and government agencies. SPOT transmissions are designed to be compatible with the U.S. Landsat and Landsat-D receiving stations, so that countries which already possess receivers for Landsat will be able to receive SPOT, with some adaptation.

Though each SPOT satellite has a design life of only 2 years, the system is planned to operate for at least 10 years, so that users can count on continuity of data for long-term remote-sensing programs. After the initial launch, scheduled for early 1985, additional satellites will be orbited to ensure continuous service. These satellites will be financed partly by SPOT Image, and partly by CNES through its revenues from foreign receiving stations.

Some countries may be concerned that SPOT's high resolution will provide foreign users with too much information. Political agreements on restricting dissemination of SPOT data may be required to avoid opposition from a number of states, and SPOT Image has announced that it will abide by agreed upon international regulations regarding data dissemination.

SPOT, of course, remains unproven both technically and institutionally. However, the commitment to a long-term operational status through a private corporation, SPOT Image, will help greatly in giving SPOT the credibility it needs to attract customers. In particular, worries about the continuity of the system (which are evident among Landsat users due to Landsat's currently unresolved budgetary and institutional problems) should be much less than with Landsat. SPOT Image plans to provide an

across-the-board range of services, including the provision of baseline data for further processing; processed data products for specialized purposes; and aid, advice, and equipment for potential customers. As with Landsat, users can arrange directly with CNES to receive, archive, and distribute SPOT data through national or regional receiving stations.[4] A smoothly functioning corporate entity, especially one heavily backed by the French government, would provide strong competition to any future U.S. system.

3.3.3 Japan

Japan has the world's largest fishing fleet and depends on the oceans not only for food, but for the transportation of vital raw materials and exports, to a greater extent than any other developed country. In addition, Japan is a frequent victim of typhoons formed in the Central Pacific, where meteorological facilities are poor and thinly scattered. Hence, there is a special interest in the development of ocean-monitoring satellites, both for weather prediction and for exploitation of ocean-based resources.

The most ambitious current program is the Maritime Observation Satellite, MOS-1, which will be Japan's first satellite to provide continuous global earth observation. It is designed to observe ocean surface phenomena and will include visible, infrared, and microwave scanning radiometers. The primary sensor will be the Multi-spectral self-scanning radiometer, a charge-coupled device (CCD) providing 50-m resolution imagery. Hence, MOS will provide operational experience with land remote-sensing data collection and data-processing, comparable to Landsat and SPOT. It is currently scheduled for an N-II launch in early 1985.

A proposed follow-on to MOS is the Earth Resources Survey Satellite, ERS-1, a 2700 lb. remote-sensing spacecraft currently in preliminary design. ERS-1 would be launched in 1986 as the first satellite aboard the new large-capacity H-1A launcher. Possible instrumentation includes synthetic aperture radar, stereo camera, and visible infrared measurement systems. The ERS-1 would eliminate Japanese dependence on outside systems such as Landsat and SPOT, and could be used to further the search for foreign sources of energy and raw materials. In addition, it would allow Japan to compete with these systems for the sale of remote-sensing data and data products.

3.3.4 Soviet Union

The Soviets have no specifically designated civilian land remote-sensing system. Large numbers of short-term film-return Cosmos missions have been flown for military purposes, and some of these have undoubtedly provided civilian data. Ocean surveillance for the military has been carried out using nuclear-powered active radar satellites; two specialized non-nuclear oceanographic satellites are reported to be in operation. The latest such satellite, Cosmos 1151 was launched in January, 1980.

There are presently no known Soviet plans to distribute remote-sensing information outside the USSR; entry of the Soviets into the global market, even on a selective basis, could have a significant effect on future Western commercial systems. The Soviets would be likely to sell-distribute data for political purposes, which could mean undercutting global prices while criticizing Western systems (especially those run as private commerical enterprises) for being too expensive for and/or violating the sovereignty of developing countries.

The Salyut-7 has carried several film camera systems for earth observation since being launched in 1977. One of these systems, the MKF-6, comprises six separate cameras which produce multispectral photographs with resolution in the 15-20 m range. A second camera, the KATE-140, can produce images of about 30 m resolution. In addition, certain Cosmos missions are expected to carry earth observation equipment, most likely the MKF-6 system.

In the U.N., the Soviets have proposed since 1979 that distribution of "local", i.e., 50 m. or less, remote-sensing data be subject to the prior consent of the state being viewed; this does not affect Landsat 3 MSS imagery but would apply to TM data from Landsat D, as well as France's proposed SPOT system. The Soviet proposal is designed to restrict the usefulness of U.S. and other Western remote-sensing systems, as well as to limit the dissemination of potentially damaging information about the Soviet Union and its allies (e.g., agricultural data that might give foreign firms a better bargaining position with Soviet purchasers). The United States opposes such a restriction.

3.3.5 India

In remote-sensing, India is one of 11 foreign countries to have a Landsat receiving station. Located at Hyderabad, it is operated by the National Remote Sensing Agency. Current plans call for a remote-sensing satellite to be developed and launched sometime in the mid-1980's, building on experience with the Bhaskara series.

With the launching of Bhaskara 2 Earth observation satellite on 20 November 1981 at the head of the Soviet Intercosmos rocket, India took another major step towards mastering the space-based remote sensing technology for resources exploration and exploitation. The 436 KG

quasi-spherical satellite, designed for a life period of one year, was placed into a near-Earth orbit of 525 Km. Designed and developed at the ISRO satellite centre (ISAC) on the outskirts of Bangalore, Bhaskara 2, like its predecessor Bhaskara 1, carried two TV cameras and a three frequency microwave radiometer system as remote-sensing payload. Bhaskara 2 is equipped to provide a more sensitive atmospheric water content estimate than Bhaskara 1. While the TV cameras will provide imagery of terrestrial features, both in the visible and near-infrared wavelengths, the radiometer will collect data of relevance to the state of sea-surface and water vapor content in the atmosphere.

The Indian Space Research Organization (ISRO) considers both the Bhaskara satellites as forerunners of a more complex Indian Earth-resources survey craft. India is planning to launch the IRS 1 and 2 in 1985 and 1986, respectively. IRS 1 and 2 will include two cameras, one of which will have 35-40 m resolution and overlap some of the bands of the thematic mapper (the first four bands), while the second will cover the same bands but have a resolution of approximately 75-80 m.

3.3.6 Brazil

Brazil, after the U.S., is the largest user of Landsat data and has operated a Landsat ground station, along with processing facilities, since 1973. There are currently plans to design and build four remote-sensing and meteorological satellites.

3.3.7 Netherlands

The Netherlands Agency for Aerospace Programmes (NIRV) has initiated a study of the Tropical Earth Resources Satellites (TERS). The proposed satellite would be launched into a low inclination orbit, and carry a multi-spectral linear array sensor. A ground station for such a

program would be located in Indonesia, and the orbit and sensor characteristics would be tailored to equatorial vegetation sensing and atmospheric conditions.

3.3.8 Canada

Canadian efforts at the current time are focused on radar. Having studied the Seasat Synthetic Aperture Radar results, Canada is naturally interested in ice and coastal monitoring. In a recent cooperative effort with the United States, requirements for the timeliness and coverage for a Radar satellite were defined. Canada owns and operates two Landsat receiving stations and will be a major part of any international land remote sensing network. They are also extremely active in transferring Landsat ground receiving and processing technology to developing countries.

3.3.9 People's Republic of China

The People's Republic of China (PRC) has been launching Earth resources observation satellites of varying capabilities since 1975. Chinasats 1-7 carried some remote sensing capability, Chinasats 10 and 11 are meteorological satellites, and Chinasat 12 is scheduled to carry a 80m resolution earth resources data transmission sensor. They have recently announced that they are proceeding with development work on a multi-spectral scanner, linear array sensor having eleven channels, and with work on a synthetic aperture radar system. PRC has also agreed to and contracted for a Landsat-D ground station. The station, which may also be configured to receive French SPOT data, will be receiving data from Landsat-D by late 1983.

3.3.10 Germany

A multi-spectral scanner system for spaceborne remote sensing of land and coastal/ocean features is under development for the German Ministry for Research and Technology. Called the Modular Optoelectronic Multi-spectral Scanner (MOMS), the system is based on multi-linear detector arrays for visible, near, medium, and thermal infrared spectral channels. Basic performance would allow 20m resolution at a 200 km swath width, with narrower spectral bands than are currently available. This device is planned for Space Shuttle flights as a development instrument and could, in the future, lead to advanced capability satellites.

3.3.11 European Space Agency

Earthnet is a mandatory ESA program consisting of four receiving stations and two processing centers which receive remote sensing and meteorological data from U.S. satellites: Landsat, Nimbus-7, the Heat Capacity Mapping Mission, and (formerly) Seasat. The data are available to all ESA members as well as to outside requestors.

The European Remote Sensing Satellite (ERS-1) will be used to monitor icepacks and to sense coastal and ocean regions; its instruments include a Synthetic Aperture Radar, a radar altimeter, and wind and wave scatterometers. Tentative launch date is mid-1987. ERS, as proposed, will use the SPOT bus but contain different instruments. ERS-1 is considered to be one element in a continuing program of earth observation satellites. An advanced ERS satellite, scheduled to be launched in 1989, will be dedicated to earth/land observations. It will carry a multi-channel sensor with 30m and a panchromatic band with 15m resolution.

3.4 Overview of Communications Satellite Technology

This section first discusses currently-operational communication satellites worldwide, then provides a discussion of two types of satellite under development: land mobile and broadcast. While these are not yet available, they could greatly enhance emergency communications when operational in the next few years.

3.4.1 Currently-Operating Communications Satellites

From the variety of satellite communications capabilities now existing and expected to be operational in the next few years, there are certain of these that could be applicable to emergency and disaster communications. The regulatory environment classes satellite communications in two ways: government (mostly military uses) versus non-government (commercial use); and fixed, mobile, or broadcast according to the type of service provided. Of these, broadcast does not apply to the military category, but all others are identifiable as valid service-type combinations. An examination of these produces a thorough coverage of the types being used, and prompts further depth of inquiry in some areas where they might find utility in disaster mitigation communications.

The radio frequency spectrum has been divided quite sharply between government use and non-government use. This division applies also to satellite band allocations. All government radio uses, of course, are not military, but most satellite radio uses are. This means that, for instance, if a radio communications system is to be set up between civilian and military entities, therefore requiring "interoperability," it must have some conjunction of regulatory agreement.

This has been accomplished in several bands where the general public use is served by allowing public communications with government entities on the same frequencies. An example is the use of a channel for marine safety by both the public and the U.S. Coast Guard.

The following are brief outlines of the types of satellite communication services existing today, and some estimates of how this changing industry will expand in the near future.

3.4.2 Fixed Service Satellites

This category relates to point-to-point services from fixed earth stations, and includes domestic (national), regional, and true international services. Five U.S. domestic satellite carriers are now operational, and many more have applied to the FCC for permission to construct and operate fixed service satellites. (See Figure 3.10). The Intelsat organization handles the vast majority of international satellite traffic because of national treaty signatures that tend to assure its exclusivity. There are, however, regional satellite services that are performed exclusive to Intelsat by domestic satellite systems. Recently, even the U.S. has seen some bidders for permission to handle international traffic outside the Intelsat network.

During 1982, several new potential U.S. satellite carriers were granted construction permits for domestic service. Because the transponders are, in general, useful for almost any type of transmission, they plan a variety of offerings. These include all-TV distribution (Hughes Communications' Galaxy I); combinations of expanded small-system digital service (American Satellite Corp's Amersat); telephony (Galaxy II and III with 24 transponders leased to MCI Communications, and GTE's Spacenet and Gstar), and other new services such as narrowband,

limited-motion videoconferencing.

Based on an opportunity to obtain a vanishing and limited resource, in late 1983 another group of U.S. applications were sent

Figure 3.10

New US Domestic Satellite Applicants

Company	Frequency Band	Number of Satellites
Equatorial Communications	C-band	Three
Columbia Comms.	Ku and Ku/C Band	Two
Cygnus Satellite	Ku-Band	Two
Digital Telesat	Ku and C-Band	Three
Martin Marietta	Ku-Band	Three
Federal Express/ Spacetran	Ku-Band	Three

Figure 3.11

New Potential US Satellite Carriers--With Construction Permits

Company	Frequency Band	Number of Satellites
Advanced Business Communications	Ku-Band	Two
American Satllite	C and Ku-Band	Three
GTE (Spacenet)	C and Ku-Band	Four
GTE (GSTAR)	Ku-Band	Five
Hughes Comms	C-Band	Three
Rainbow Satellite	Ku-Band	Two
US Satellite Systems	Ku-Band	Two

to the FCC requesting construction permits in the Ku-band (fixed-service satellite) frequencies (See Figure 3.12). The FCC intent for orbital positions to be spaced two degrees apart in longitude -- half their present distance -- has become an industry issue because of its implications for increased received interference by modest-sized earth terminals. These increasingly compressed orbital spacings have been traded off by the FCC against the interference potential in order to provide enough orbital locations in view of all the U.S. for a maximum number of satellites with minimally interfering services.

Today, with the proliferation of not only these fast-growing U.S. domestic, regional, and Intelsat services, but other countries' developments of domestic programs and improved technology, there are over 90 communications satellites in operation around the World. Clearly, the satellite operators and users will continue to expand their investments in this efficient, distance-insensitive medium.

FIGURE 3.12

NEW U.S. DOMSAT APPLICATIONS

Company	Frequency Band	Number of Satellites
Alascom	C-Band	Three
American Satellite	Ku, C and Ka-Band	Two
Comsat General	Ku-band	Three
Hughes Comms	Ku-Band	Two
Hughes Comms	Ka-Band	Two
Satellite Business Systems	Ku-Band	Four
RCA American	C and/or Ku Band	Four
Western Union	C-Band	Three
Western Union	Ku-Band	Four

3.4.3 Foreign Fixed-Service Satellites

Initial satellite communication services for many countries were provided by the use of a whole or partial Intelsat transponder. Those services are continuing, but in some areas are diminishing because of the advent of other satellites which are set up specifically for international communications under control of a more local body. A first example was the Indonesian satellite system, Palapa, which now provides service to other nearby countries. A second example is the ECS, or European Communications Satellite, used among several participating countries. Another example is Arabsat, the product of a 22-country Arab consortium's efforts to communicate under their own operational rules and tariffs, and nearing launch readiness. While these systems show the fruits of much cooperative effort where political difficulties cannot be surmounted, concepts such as the Andean countries' regional satellite system have not progressed beyond a start-and-stop situation for many years.

3.4.4 U.S. Military Mobile Satellite Communications

As satellite communications technologies emerged and military experiments using NASA's early SYNCOM proved geosynchronous satellites to be valuable, military plans for improved mobile communications entered the satellite field in the early '70s. Although Tacsat, the first of such high-powered mobile satellites, operated well, the success of the overall system was clouded by difficulties of interference and propagation anomalies. However, the high-quality mobile service concept was so attractive that the U.S. Navy arranged lease of UHF transponders on commercial maritime Marisat satellites to accelerate these basic benefits. This program was followed by the building of large,

dedicated military Fltsatcom satellites, which are operating today. The U.S. use of military-mobile satellites will continue to expand with launches in 1984 of the LEASATs (built by Hughes).

The military satellite channels operate in the Government-allocated band, 225-400 MHz. This band, so far, is for exclusive military use in the United States systems, but other countries use this band for non-military Government traffic. The low frequency permits modest power and relatively small and lightweight antennas to be used for voice and low-speed data.

By contrast, the latest U.S. military mobile communications satellite plans have moved to the highest practical frequency band for satellites. At 44 GHz, the new Milstar program operating wavelength will be very small. The antenna required for the ground terminal is correspondingly small, but it must be pointed carefully to the satellite -- a factor that was much less important for the UHF band. Among the many reasons for the move in frequency, is the need for more bandwidth to accommodate more traffic and to make room for its encryption.

The Milstar system, at several billion dollars, is the largest procurement in the history of satellites. It will be many years in development and will be a mainstay for a variety of military mobile needs to the end of the century.

3.4.5 Broadcast Satellites

Nearly 40 years ago, futurist literature described satellites that would bring information directly to individual homes. As our space program grew in capability and space electronics advanced, NASA and U.S. industry experimented with high-power technology and transmission

methods. By 1977, they had already proven satellites' practicality and effectiveness in transmitting television to small antenna systems in remote areas.

While in a sense, all satellites "broadcast", the technical experiments planned specifically for using the smallest possible, receive only terminals for television started in 1968 with the design of NASA's ATS-6 program. Among many other applications and technological experiments, ATS-6 demonstrated that high-power transmitters and large antennas in orbit could enable the use of simple receiving equipment for televised education and health-care delivery to remote communities. This satellite, with the largest space antenna for communications ever built, was launched in 1974 and decommissioned in 1978.

Two relatively low radio-frequency bands were used for these first direct broadcast television satellite demonstrations. ATS-6 operated in the 2.5 GHz band with one-way video. It was augmented for teleconferencing with two-way audio employing another NASA satellite, ATS-3, at VHF bands (149 MHz). For experiments conducted in India, ATS-6 was operated on 860 MHz for television transmission of Indian instructional programs to 2500 locally-built receiving terminals in villages and towns. ATS-6 also was used for voice to hand-held portable terminals in a few experiments, but was not cost-effective for operational uses.

The Communications Technology Satellite (CTS) was built in a joint project in which Canada developed the body-stabilized spacecraft, the antennas, and most of the transponder system, while the U.S. developed the new, high-power, 12 GHz down-link transmitter system. This was a pioneering effort leading to worldwide use today of the Ku-band and the (Western Hemisphere's) DBS band. The CTS design took advantage of

the short wavelengths at this band with its two individually-pointable parabolic antennas. In addition, its transponder power could be divided among one, two, or three TV channels simultaneously. This combination permitted experiments in two-way, full-motion color videoconferencing and other new applications.

CTS, called "Hermes" in Canada, was used in a host of demonstrations and experiments with educational delivery methods, as well as simply showing -- for the first time for many -- how a powerful satellite can bring excellent television to small earth terminals. For broadcast use, the 200-watt transmitter's down-link power enabled use of the smallest ground station receive-only antennas; some were only 60 cm in diameter, but brought excellent television performance at all power levels and in most weather conditions. The presence of heavy rain in the path to and from the satellite is a threat to signal quality at frequencies above 10 GHz, but CTS demonstrated satisfactory television reception except in the worst of conditions. The Canadian Government concluded that what CTS really had proven was that 200 watts was more power than future television systems would need.

Figure 3.13 provides an overview of current U.S. broadcast satellite development.

FIGURE 3.13

STATUS OF U.S. BROADCAST SATELLITE DEVELOPMENT

I. Companies in Contract For Broadcast Satellites

Satellite Television Corporation
CBS, Inc.
Direct Broadcast Satellite Corporation
Dominion Video Systems, Inc.

II. Companies With Construction Permits for Broadcast Satellites

United States Satellite Broadcasting, Inc.
Graphic Scanning Corporation
RCA American Communications, Inc.
Western Union Telegraph Company

III. Companies Awaiting Construction Premits

Satellite Development Trust
Satellite Syndicated Systems, Inc.
National Christian Network
Advanced Communications Corporation
Sapce Communications Servioces, Inc.
National Exchange, Inc.
Hughes Communications Galaxy, Inc.

3.4.6 Foreign Broadcast Satellites

Regardless of these U.S. and Canadian experimental successes, operational broadcast satellite activity has seemed to flourish more quickly in other countries.

Under contract to Japan, the U.S. built and launched the "BSE" (Broadcast Satellite Experimental) which operated from 1978-80 carrying two television channels in the 12 GHz frequency band to receiving antennas as small as 60 cm, while producing an excellent picture for the Japanese areas. This satellite has failed and been decommissioned. The second phase of this program is under way following the January 1984 launch of BS-2a. Design is now under way for the advanced BS-3 system, which will have even more capability.

Since earth terminal cost generally rises with radio frequency because of the more expensive and less-available technology involved, the Indian and Russian satellite systems were designed to rely on the lowest frequencies and simple technology for widespread, low-cost broadcast reception to community antennas for redistribution. In the late '70s in Europe, the USSR's "Ekran" geosynchronous broadcast satellite series began operation using a 96-element helical array to carry a single television channel via a 6 GHz up-link and an FM down-link in the UHF band at 714 MHz.

Another U.S.-built broadcast spacecraft, Insat, is an outgrowth of India's experience with a year of ATS-6 service and a similar period with Europe's Symphonie satellite. In addition to its 2.5 GHz broadcast mode, Insat has other missions: it is a meteorological observation satellite, a fixed service 6/4 GHz satellite, and a data collection system for small, ground-based transmitters.

Today, the AUSSAT, another U.S.-built broadcast satellite system, is under construction for Australia. And as mentioned, the Canadian's use of Anik satellites as being sufficiently powered for broadcast needs is continuing.

3.5 Satellite Communications for Disaster Situations

Two new satellite communication technologies to be developed for commercial purposes could be useful for disaster communications: direct broadcast satellite (DBS) and land-mobile satellite systems.

3.5.1 Today's Direct Broadcast Satellites

Although users worldwide are operating communications satellites to relay a wide variety of information between relatively large systems, only a few of these are used for television broadcast directly to users' premises. They are mostly serving either telephone (two-way) systems with relatively large terminals at multiple-trunk centers, or are distributing television to a variety of cable head-ends using fifteen-foot receiving antennas. Other users in a variety of service areas use satellites for data transmission, teleconferencing, electronic mail, and other uses. But, as foreign countries begin building high-powered DBS satellite technology, several U.S. operators also are preparing the development of this new direct-to-home service using small and inexpensive terminals.

The expectation for DBS system growth is that within only a few years, there will come into being -- at least for developed countries -- high-powered satellites which will be used principally for television broadcasting directly to homes using antennas of diameters less

than one meter. The associated receivers will have descramblers which are individually addressable in real time from the satellite itself, and will be connected to ordinary television sets and monitors. The entire home system up to the television set is expected to retail for less than $300.

In a few years, millions of these personally-owned small earth stations will be pointed toward satellites. For the broadcast industry, this direct contact with hitherto unserved markets will bring increased opportunities in TV programming, entertainment, advertising, and sales.

But DBS also could open the way for the innovative delivery of specialized, on-demand information. Coupled with other evolving information systems, this distance independent broadcast medium could alter plans for information storage, delivery and access. Under subscription services, innovative information services are envisioned, such as the dissemination of high-fidelity audio, high-speed data for access to information bases, and perhaps even interaction by means of low-speed return links. Of interest to emergency communications via DBS, is a regulatory allowance for operations other than television in the broadcast band.

As is well known, the satellite radio spectrum and orbital positions are already at a premium. Because this technology and service area is overseen by international regulatory bodies (ITU), a major international conference was held in 1983 to negotiate and allocate these resources among North American countries expecting to operate DBS systems. Among the agreements for use of this 12.2-12.7 GHz frequency band was a footnote (846) that services other than broadcast may be operated as long

as they do not demand more protection from, or cause more interference to, the operational broadcast systems which conform to the limits and rules regarding power levels and interference.

This potential for operation of an information-on-demand system as a part of television broadcast operations has not been lost on some applicants and current permit-holders who would provide for data transmission, both together with, and in lieu of, television. The way is, therefore, being paved for emergency messages to be sent directly to millions of DBS homes and communities. However, at this time there is uncertainty what utility that might have, based on how successful sales will be of the user earth terminals.

Where there are existing terrestrial services of competitive nature, the application of DBS technology is not expected to be widespread; but where rural and remote areas can be served with television, some for the first time (at wide bandwidth and data rates), the market penetration should be great. Predictions of market penetration have varied from total failure to tens of millions. The actual acceptance of the public of this new medium is as yet unknown, but it has been shown that it is by far the most efficient delivery means for television ever devised in terms of transmission costs per viewer. As such, it seems to have a potential for great acceptance at least for entertainment television, and probably for other delivery services as well. This tends to prepare a ready-made, no-cost means for use by emergency services -- improved in utility, but not as pervasive as the common radio.

It could be very effective to operate a DBS disaster mitigation function such as preparation and warning using a reliable, wideband (satellite) source with visual (television) display to the

ordinary citizen on his own, familiar receiver. Power consumption from the DBS and television sets is relatively small, and could therefore be run from a modest generator or battery/inverter supply in remote areas or in the case of power loss. The size of the entire system is so small and lightweight that it could easily be made transportable for hand-carrying and rapid set-up. While transportable, it cannot be used while moving, as in a true mobile terminal, because of the need for careful and accurate, continuous antenna pointing to the satellite.

Although it is a one-way system with no feedback planned at present, the use of a DBS in a narrowband mode for return links has already been considered by some operators for advanced DBS systems. None has so far considered this for two-way disaster communications, but such a possibility could be made to drive the development and implementation of such a capability. The interference and low signal levels from such a small antenna could be counteracted by the use of spread-spectrum modulation. This is a non-military adaptation of a jam-resistant modulation largely immune to interference. It is currently in commercial operation by Equatorial Communications Corporation with two-foot dishes for such data users as United Press International.

The use of television for observation of a damaged area or building or injured people could be, as explained above, most valuable. This would be true even if the imagery were only via slow-scan or freeze-frame television, as long as it is an accurate depiction of the circumstances in near real time. There can be strong value in remote, non-stressful and expert observation of a disaster situation. For instance, a careful analysis of cracks in a hospital building's foundation following an

earthquake can lead to responsible decisions, potentially avoiding problems such as evacuating without cause or not evacuating and having a collapse follow.

3.5.2 Land Mobile Satellite Communications

Some of the original satellite two-way voice experiments were done via mobile, walkie-talkie type radios using NASA VHF transponders with portable wire-frame antennas about ten feet in size. While the U.S. military has pursued mobile communications by satellite, as discussed above, only limited progress has been made toward satisfying the much-discussed potential market for voice using small terminals through a large satellite.

Such a concept was looked upon as only having a potential for technical demonstrations, because it was not seen how the commercialization of this technology could be supported through a large enough user set at affordable subscriber prices to justify a several hundred-million dollar satellite. That is, while the mobile equipment capital costs would be moderate, in order to pay for the satellite itself, the operational lease of a channel would still have to be much higher than current mobile telephone usage prices.

The Department of Communications in Canada, however, has initiated just such a program, now called MSAT-X, with minor participation from NASA. The intended usage includes government participation for a variety of needs.

Successful experiments conducted by General Electric since the mid-60s with NASA sponsorship using two VHF satellites to permit both voice and position location (determining remotely where a mobile vehicle is at any time -- not in-vehicle navigation), have not so far been

implemented in a commercial system. But recently, as an outgrowth of the GE experimental successes a new company, Mobilsat, has been formed and expects to obtain funding to pursue this capability commercially.

In the same general direction, a similar effort is under way by another new company, Skylink, in which data and voice to and from mobile vehicles would be commercially exploited. A third company, Geostar, has been formed to provide voice and navigation information to mobile vehicles, but has chosen to use frequencies that appear to be a problem in obtaining regulatory approval.

Of these three U.S. efforts, it appears that not all will be successful. However, some financial assistance from NASA should be forthcoming if the potential operators will agree to terms to be stated in a NASA Announcement of Opportunity soon to be issued.

In addition, the advent of what now appears to be a very fast-growing, terrestrially-based mobile system, the "cellular" system, will generate interest and support for these satellite companies. They would support similar service to cellular for vehicles out of the range of cellular transmissions. A long-term and so far unsuccessful effort has been under way at NASA to obtain frequency allocations for satellites that would be in the cellular band and have similar signal parameters so that there could be interoperation without additional expense.

These areas of development are discussed here because of the potential for future, similar developments in foreign areas that would permit communications coverage for emergencies. Outside of military systems, only Swedish concepts seem close enough to reality that they may be pursued. This would be a land-mobile satellite system ("Trucksat") for

low-rate data to be sent to trucks in motion. It was planned and discussed for several years, then in 1982, was restricted to a piggy-back payload on a larger Swedish satellite ("Tele-X"), and recently was postponed indefinitely.

3.6 Computer Technology For Geographic Information Systems

The production of early warnings of natural disasters consists of three critical steps--data acquisition, data manipulation, and information dissemination. Both data acqusition and information dissemination are directly tied to satellite communications and remote sensing technology. Data manipulation, on the other hand, is tied more directly to computer technologies and models or algorithims for manipulating data. During the last decade or so, much has been made of the development of Geo-based (or Geographic) Information Systems (GIS).

A GIS is a collection of procedures, computer programs, human resources, and hardware devices that supports the acquisition, storage, manipulation and display of geographically referenced data. In other words, various types of information can be coded to geographic points or areas. This is critical to all resource development and planning activities as well as to disaster warning and management. Any disaster warning or effort to manage a disaster relief program has a strong spatial component. Without data and information being coded to a spatial location, that data and information becomes useless. The importance of a computerized GIS system is pointed up by the fact that the amount of data is likely to be quite large; one satellite image of the Earth can contain from tens of millions to hundreds of millions of bytes of data, and when one begins layering data from a variety of sources (several different satellites, aircraft, ground truth, socio-economic variables, etc.), the

amount of data grows enormously. Handling this much data manually is physically impossible. In addition, data (as indicated directly above) comes from a wide range of sources. Varied data sets must be converted into a common structure. Again, manually it is very difficult to work with or justify maps of varying scale and size. A computer, working digitally, can make these adjustments quickly and accurately. Finally, many of the data manipulation functions required by disaster warning planners and managers require complex computer analysis. In order to use data from a variety of sources in complex prediction models, computer applications are often necessary.

A GIS, to be used as an effective spatial analysis and modelling tool, must be interlinked with a Data Base Management System (DBMS), Image Processing System (IPS) and statistical system. The data base management system is used for manipulating data depending on the characteristics or definitions of the user; the image processing system takes images from a variety of input sources and processes them for input into the geo-coded reference system, and a statistical system allows for data to be statistically analyzed or modelled for a specific purpose.

There are four sets of technologies which are particularly pertinent to the development of effective and cost-efficient GIS systems. These include processors, information storage, data communications and software for data management. The following sections present brief discussions of these various technologies. A full study of GIS systems is being conducted by the Office of Federal Disaster Assistance concurrently with this study, and it is expected that that study will be used in conjunction with this one.

3.6.1 Processors

During the 1970's and 1980's, there has been a tremendous increase in the speed of computer processing. In 1960, the fastest computer could process about a million instructions per second; by 1990, it is expected that computers will execute over 5 billion instructions per second. In addition, this five-thousand fold increase in speed has been accompanied by a parallel decrease in the cost of processing. These parallel developments have resulted in a substantial decrease in the costs of computing over the last 20 years.

Many of these gains have come through the development of large and very large scale integration--the process by which electronic components are printed on silicon chips. Advancements in this area have enabled smaller and smaller computers to have increasing amounts of computing power. Computers that 20 years ago filled rooms, will soon be available in desk top models. This has been at the heart of the home and business computer revolution in the United States.

In addition to the development of less expensive and more powerful large computers, and small, yet powerful desk top computers--the ability to mass produce silicon chips has made possible the prolifertion of special-purpose computers tailored to specific applications. With relation to GIS systems, the use of array processing computers (which are specialized computers) is important as such machines enable the user to process large quantities of data with special characteristics.

In sum, the trends in computer processing technology--e powerful, less expensive and economical specialty systems--indicate strong support for the development of cost-effective and decentralized computerized geographic information systems.

3.6.2 Information Storage Technology

The two key parameters of information storage technology are retrieval time and capacity. Retrieval time is the time it takes to get a piece of information from memory. This time includes the time it takes to find and read the information. Capacity is the amount of information which can be efficiently and effectively stored.

There is a direct trade-off between speed (retrieval time) and the capacity of the memory--the greater the capacity, the greater the retrieval time. However, with advances in computer processing speed and memory technology, the trade-off should become less difficult to deal with in years to come. This is also a very important technological development for the future development of GIS systems which incorporate information on a global scale as these types of global information systems will require increasing amounts of capacity to store the increasing amounts of data which are being collected.

In fact, the most rapid advances in the computer hardware field are in the area of micro-computer and semi-conductor memory devices. The development of 16 and 32 bit microprocessors and 1-Mbit random access memory chips will have a tremendous impact on speed and capacity. In particular, with regards to remote sensing devices in space, technological developments in this area will enable:

1. Integration of microcomputers and memory chips with sensors in order to perform some processing functions on-board satellites. The more work done on-board a spacecraft, in general, the less work must be done on earth--with subsequently less expensive ground equipment.

2. Increasing amounts of computing memory and power can be incorporated into intelligent terminals to enhance data analysis, display and presentation capabilities of "small" users.
3. Special-purpose computers and special-function computation chips will become increasingly affordable and provide efficency to computing systems.

These advances suggest the need to focus on software development and the man-machine interface. It is generally conceded that hardware is currently running ahead of software development and that in the future, in general, systems costs will driven by software and software development costs.

3.6.3 Data Communications

Critical to the use of geographic information systems for disaster warning is the development of sophisticated data communications network technology. This technological area is essential for developing distributed information networks which users around the world can access. The ability to access information remotely and to move it around the globe brings the user closer to the computer and to analysis capability required to develop disaster warnings in a timely fashion.

It is important to note, however, that data communications as part of an information system, can dominate that system due to its high priority and frequent interrupts. If a central processing facility is to also perform data communications functions, it is often necessary to have those data communications functions run seperately from the main processor--in order to allow that processor to focus on processing, not communications.

During the next decade, however, distributed data communications networks will come into their own, and this will have a great impact on users. Particularly with regards to disaster early warning and management, an information system linked by a data communications network will have the following advantages:

1. Remote users can rely on the power of the central processing facility to perform "expensive" functions--and thereby build up their own system in a cost-effective manner and adding sophisticated technology locally only as it becomes affordable and as people are trained to use it.
2. Remote users can also tailor their data processing needs to specific local conditions while relying on the central facility for more general or infrequently needed capabilities.
3. Data collection efforts may also be upgraded as the originators of data are usually in the best position to ensure that the data is accurate.
4. A widely dispersed or global information network will appear to users as an integrated, single information system. It is useful for users to deal with a single information system, rather than having to work with a dispersed set of independent systems.

Along with the advantages of a global information system which utilizes a data communications network, are some difficulties. Among these are:

1. The need to standardized data entry and data interaction between dispersed users with potentially very different requirements.

2. The need to ensure that if one part of the system "goes down" that this does not effect the central facility or other remote facilities--and that no data is lost.

3. Communications-based information systems are inherently less secure than other types of information systems. If the data and information being dealt with is of a sensitive nature, then efforts must be made to ensure that access is only granted when it should be.

4. Prioritization of work load can be a difficult problem, and must be dealt with in a manner which is acceptable to users.

3.6.4 Software/Data Management

There is an increasing trend to the use of large integrated data base systems which support a wide range of applications. Systems are being designed to allow users to access data in a wide variety of ways--some of which may not be forseen at the beginnings of system development. Developments in this field are expected to bring improvements to data base management systems throughout the eighties. One of these developments is the trend in mainframe computers toward an orientation more on data-base management than simply numerical computing. This trend toward a focus on data-base management will likely lead to the development of computers which are designed specifically for numerical computation and computers which are specifically built to handle and manage large data bases. Such development will be important to the generation of disaster warnings (which may entail large amounts of data and modelling) as well as to the ability of users to rapidly access information from a central processing facility.

In relation to the development of sophisticated data base management systems is the use of "query languages" which will enable "un-knowledgable" users to query a system for the information they need. This type of language will greatly enhance the human-computer interface and will make it less and less necessary for the end-user to work through an intermediary to access computer information and processing.

An extension to this concept is the use of intelligent systems (or artifical intelligence) which enable users to use the computer to help learn and do things the user might otherwise not be able to do. These systems are programmed with the aid of "experts" which enable the computer to "think" about problems and to put information together in ways which the user might not have thought of. This provides a multitude of options and allows the unsophisticated user to take advantage of the experience of a trained, but not present, individual.

There already exists a first generation of systems that reason from rules of experience. At the same time, researchers have begun to develop "deep knowledge" systems which will reason from structural and behavioral laws of nature. With the decreasing costs of computer hardware, such systems are expected to move out of the laboratory and into the commmercial marketplace by the late 1980's. The ability to "store" and use the knowledge of experts without their presence will lead to applications in a wide range of fields.

The problem solving ability of these systems is based, not on step by step procedures, but on a set of general procedures which are programmed into the computer. The computer is then programmed to follow these procedures--consisting of rules of thumb, models, facts, and other genral knowledge to use "facts" supplied by a user about a particular

problem, its own knowledge of the domain and general problem solving procedures to discover a specific solution. While research into applications of such capability is currently going on all over the world, there are few operational expert systems now operating. However, the potential for these systems to aid in the management of global information systems is great. They would, for example, enable a non-sophisticated user to perform sophisticated data analysis and modeling with results simply displayed for input into policy analysis models and subsequent decision making.

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3. World Weather Watch, "Information on Meteorological Satellite Programmes Operated by Members and Organizations", WMO-No. 411, 1975, p. IV.9).

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13. Programs Briefing, p.183.

4.0 APPLICATIONS OF SATELLITE TECHNOLOGY TO DISASTER WARNING

A number of activities disaster warning and management have been initiated which make use of the special capabilities of satellite remote sensing and communications technology. What follows is a brief outline of some of these programs and their use of satellites.

4.1 Tropical Cyclone and Storm Surge Warning[1]

The Office of Foreign Disaster Assistance and the Naval Environmental Research Facility have combined to develop a worldwide tropical cyclone threat early warning sytem. Cyclones, also referred to as typhoons, hurricanes, tropical storms, form in tropical waters near the equator in both hemispheres. The life cycle of such a storm may be two weeks and presents a great threat to shipping. Because of this threat, the Navy and the Department of Commerce have developed a worldwide capability to forecast and track these storms. Satellite remote sensing data is used in the forecasting and tracking of these storms, while satellite communications is essential for relaying data and information from around the world to and from the Navy's Fleet Numerical Oceanography Center.

The Navy and OFDA have now developed computer models which translate these forecasts into threat indices which are then used by the State Department in in its efforts to monitor and issue early warnings about these storms to potentially impacted countries. The threat indices are color coded and are based on probabilties indicating threat level and decreasing lead time. The highet level of threat, the red level, indicates that the probability of the storm (65 kt winds or greater, 2 meter or greater storm surge) is at least 20% within the next 18 hours. The other levels of threat indicate decreasing probabilities of occurence and increasing lead times. This is a critical point in all disaster warning, that of their inherent probabilistic nature--when actions are taken on the

basis of probability, there is always a chance that those actions will not have been necessary. It is therefore important to continue to refine probabilistic models and to train people in making decisions in the area of probabilistic decision making.

The system is run out of the Fleet Numerical Ocanography Center (FNOC) in Monterrey, California. It receives warnings from Guam, Hawaii, and Norfolk, Virginia every 6 to 12 hours. The FNOC then takes these warnings and translates them into State Department messages. These messages are then used by U.S. Embassies to advise the potentially affected country of the threat and to advise potential donor agencies of the impending disaster.

Meteorological satellite imagery has been used effectively to track cyclone development and hence provides an early warning of the path of a developing cyclone, which is quite difficult with surface level observations alone. Prediction of storm intensity is more difficult however. There have been efforts to infer from cloud top temperatures, and the shape and visual characteristics of the cyclone system the intensity of the storm.

The intensity of a cyclone "is deterimined on the basis of the distribution and movement of clouds or through analysis of the temperature variation through the storm." In general, reasonable forecasts can be made up to 24 hours in advance. However, longer-term forecasts are increasingly less accurate and hence less likely to be the basis of any response to a warning. Storm forecasts are provided routinely by regional meteorological centers of the WMO's World Weather Watch program. Warnings are only issued as a potential disaster situation develops. Then the warnings are issued at intervals of 3 to 6 hours.

4.2 Hurricane Warning Program

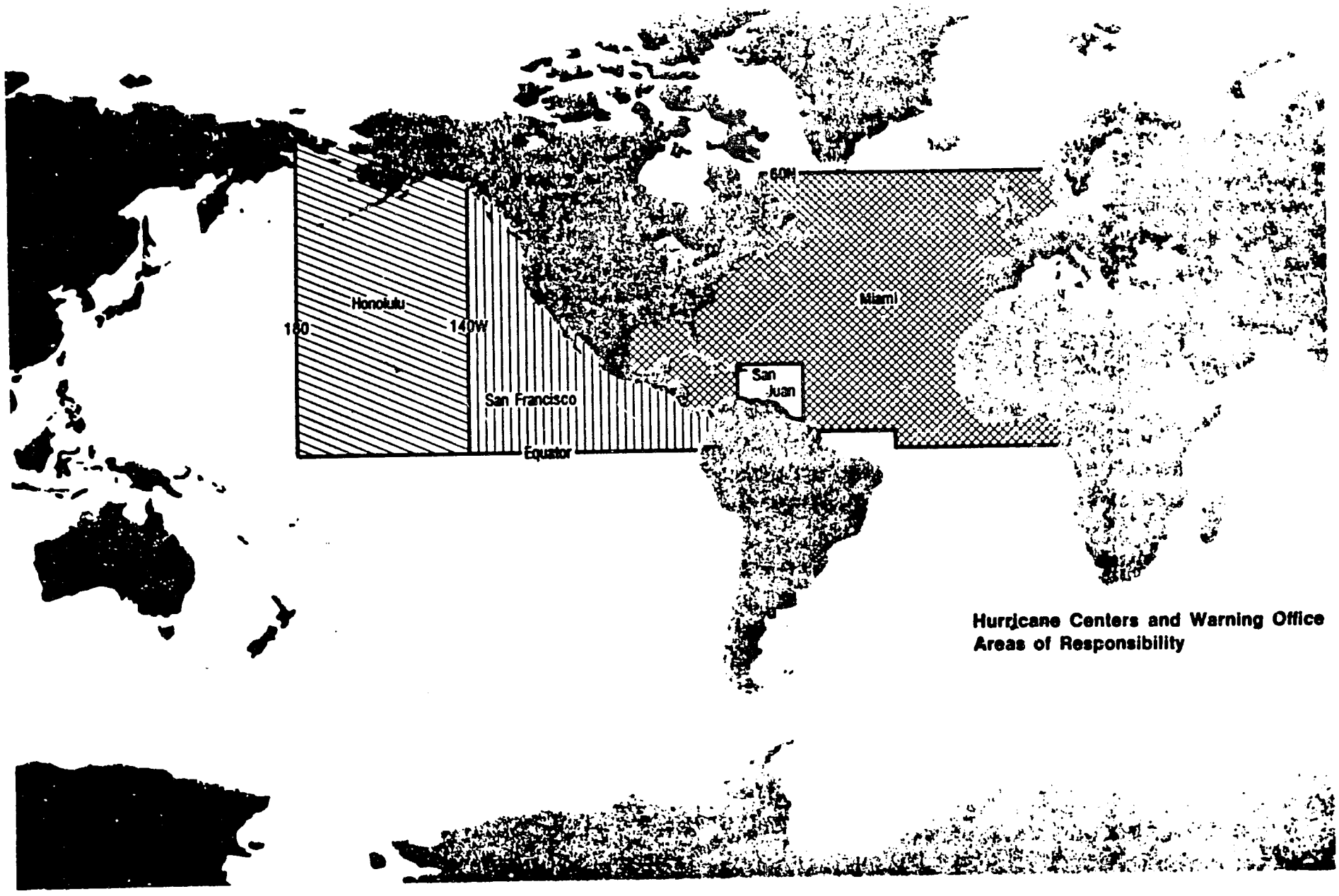
The National Weather Service (NWS) runs an operational hurricane forecast and warning program in line with US interests and internatioanl obligations. The National Hurricane Center in Miami has responsibility for the Atlantic, the Caribbean and the Gulf of Mexico. The Eastern Pacific Hurricane Center in San Francisco has responsibility for the Pacific Ocean north of the Equator and east of 140° W latitude. The Central Pacific Hurricane Center in Honolulu is responsible for the rest of the Pacific. These centers and areas of responsibility are shown in Figure 4.1. They issue tropical storm and hurricane advisories at least every six hours while there is a threat of a storm or hurricane. When there is no threat, these advisories are issued much less frequently. This program, based as it is in the NWS, makes extensive use of the weather satellite remote sensing and telecommunications systems for the data which is input into forecasting models and early warning reports.

4.3 Tsunamis

"Tsunamis are very long ocean surface ways generated by the rapid displacement of large volumes of sea water. The most common generators of tsunamis are sea floor motions caused by large submarine earthquakes occuring in shallow coastal areas."[3] Tsunamis are most prevalent in the Pacific.

Depending on the size of the submarine earthquake, the time for a Tsunami to develop and strike any particular land mass can be from 10 minutes to almost a full day. The only effective early warning that can be made for those land masses lying within a ten minute range is their own instincts. People will feel the earthquake and have to react on their own.

FIGURE 4.1



Hurricane Centers and Warning Office Areas of Responsibility

Those people who will be affected in over an hour can receive a warning from the Pacific Tsunami Warning Center in Hawaii. However, those people in the 10-60 minute range have no way of reacting instinctively (they won't feel the earthquake) and they will not receive the PTWC warning soon enough to react. So, data and analysis is required in near-real time. This can be provided by utilizing the US GOES satellite system capability for monitoring remotely located data collection platforms. These platforms can sense any activity above and beyond normal and relay that information directly to local organizations who can rapidly interpret the data and issue a warning, if appropriate.

Tsunamis, then, have the characteristic of developing over the span of one day, requiring near real time data collection on the ground and updates during the course of development. The GOES data collection platform capability fits this need perfectly.

4.3.1 Tsunami Warning System[4]

The Tsunami Warning System (pictured in Figure 4.2) became part of the National Weather Service of NOAA in 1973. The current system begins the warning process with detection of an earthquake at the Pacific Tsunami Warning Center (PTWC) in Hawaii, or the Alaska Tsunami Warning Center (ATWC) in Alaska. When sufficient data have been received to locate the earthquake and compute its actual magnitude, a decision is made concerning further action. If the earthquake is in an area where tsunami generation is possible and is strong enough to cause a tsunami, PTWC requests participating tide stations located near the epicenter to monitor the gages for evidence of tsunami. For earthquakes of magnitdue 7.5 or greater, watch bulletins are issued to the dissemination agencies

and data is provided that can be relayed to the public so that necessary preliminary precautions can be taken. A tsunami watch also may be disseminated by the PTWC upon issuance of warnings by regional warning centers.

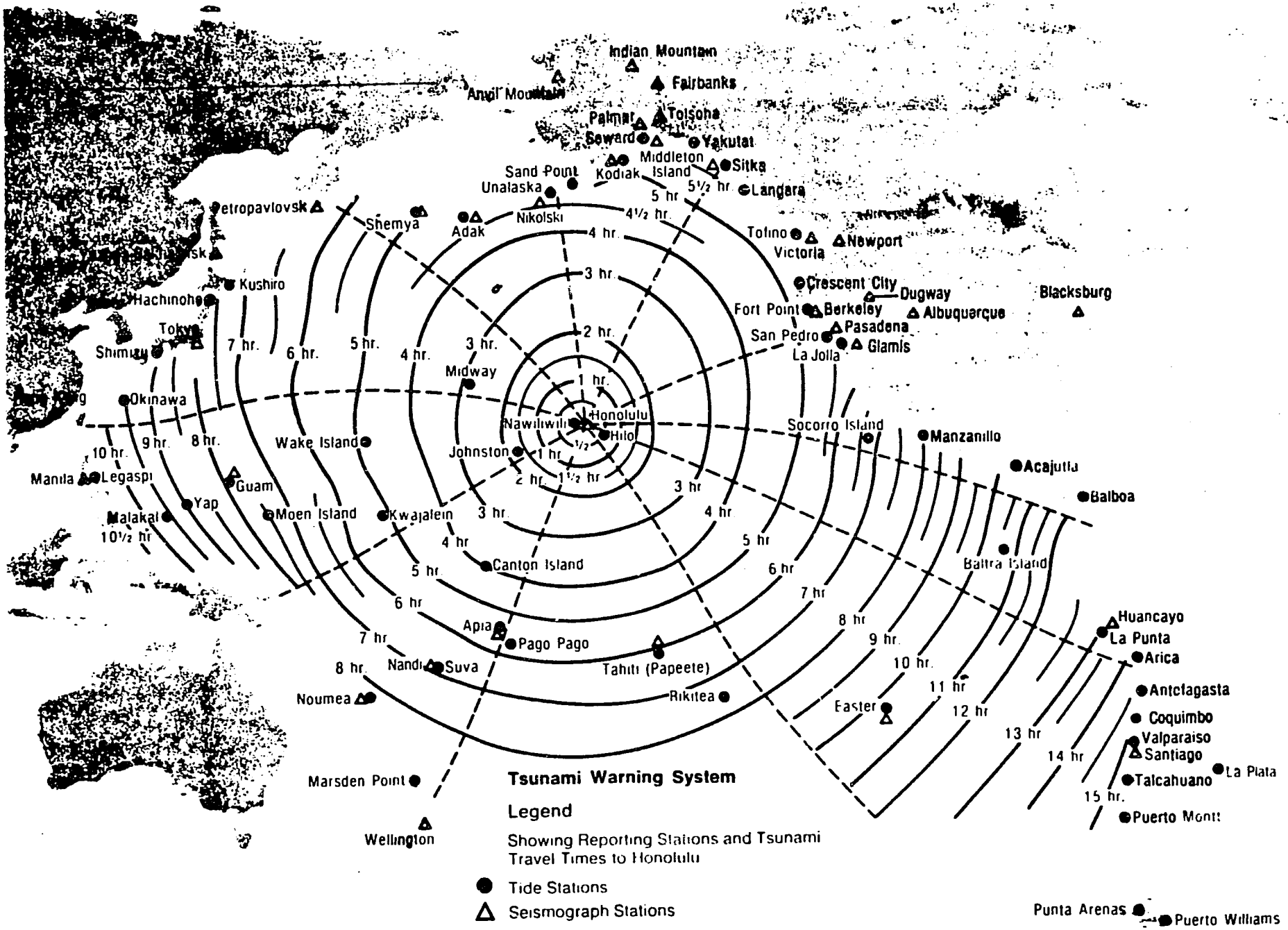

Indian Mountain
Anvil Mountain
Fairbanks
Palmer
Tolsona
Seward
Yakutat
Middleton Island
Sitka
Sand Point
Kodiak
Unalaska
Langara
Petropavlovsk
Shemya
Adak
Nikolski
Tofino
Victoria
Newport
Kushiro
Hachinohe
Crescent City
Dugway
Blacksburg
Fort Point
Berkeley
Albuquerque
Pasadena
San Pedro
Glamis
La Jolla
Tokyo
Shimizu
Midway
Okinawa
Honolulu
Nawiliwili
Hilo
Socorro Island
Manzanillo
Wake Island
Johnston
Acajutla
Manila
Legaspi
Guam
Balboa
Yap
Malakal
Moen Island
Kwajalein
Canton Island
Baltra Island
Huancayo
La Punta
Arica
Apia
Pago Pago
Nandi
Suva
Tahiti (Papeete)
Noumea
Rikitea
Easter
Antofagasta
Coquimbo
Valparaiso
Santiago
Talcahuano
La Plata
Puerto Montt
Marsden Point
Wellington
Punta Arenas
Puerto Williams
1 hr.
2 hr.
3 hr.
4 hr.
5 hr.
6 hr.
7 hr.
8 hr.
9 hr.
10 hr.
11 hr.
12 hr.
13 hr.
14 hr.
15 hr.
10½ hr.
Tsunami Warning System
Legend
Showing Reporting Stations and Tsunami Travel Times to Honolulu
Tide Stations
Seismograph Stations

FIGURE 4.2

If evaluation of reports received from tide stations indicate that a tsunami has been generated and that it poses a threat to the population in any part of the Pacific, a warning is transmitted to the dissemination agencies for relay to the public. The dissemination agencies then implement predetermined plans to evacuate people from endangered areas. If the tide station reports indicate that either a negligible tsunami or no tsunami has been generated, PTWC issues a cancellation of its previously disseminated watch.

To lessen the need for human intervention in data collection, NWS, in cooperation with the USGS and the National Ocean Service, developed tide gages to collect the data and to telemeter it via geostationary satellite and land-line to the PTWC or ATWC, which maintains joint operational control of the system.

4.4 Rainfall Estimation/Forecasting and Flood Monitoring

Over the last few years two basic methods for estimating rainfall location and amount have developed, one for routine, continuous applications and the other for application in special situations, such as the occurrence of a severe storm. In the first approach, rainfall on the ground is measured by ground based detectors and correlated with cloud conditions occurring during the storm. Once these correlations are made, similar cloud formations can be predicted to hold similar amounts of rain. In this way, rainfall estimates can be supplied to a variety of international agencies and/or countries in order to alert them to potential impacts on agricultural and hydrological development and to potential floods or impending drought.

The second method is to utilize the relationship between image brightness and rainfall. Cloud-top temperatures can be inferred from enhanced infra-red images and used in conjunction with the growth of clouds and their general appearance to produce relatively good estimates as to the rainfall expected from a particular storm. Because data is available at frequent intervals (every 30 minutes or less), immediate rainfall forecasts can be developed.

Flood predictions depend on data collected by data collection platforms which rely data on river heights and ground-based rainfall to analysts who determine potential flood danger, and by measuring snow cover. Satellite observations, in conjunction with snow thickness measurements (possibly using data collection platforms) and melt rate (determined by air temperature) can be used to help predict snow melt flooding.

In addition, satellite images are now also used extensively to help map ice flows. Accurate maps of ice flows and ice build-ups is essential to the shipping industry, and is very important to fisheries, off-shore oil drilling and to certain surveying activities, while snow cover is often directly related to the development of flood warnings.

4.5 Earthquake Detection and Monitoring

The collection of seismic data from remote locations has long been a difficult problem in the prediction and monitoring of earthquakes and earthquake development. This is particularly critical in that many major earthquakes are preceeded by foreshock activity which can be useful in issuing warnings. At the same time, after an earthquake occurs remote data is required to estimate the size and impact of the earthquake. With these estimates, an assessment of disaster response needs and supplies can

be made. Finally, the location of earthquakes may have important consequences for tsunami prediction in coastal areas adjacent to the earthquake area.

The Meteorological Satellites offer a way of continually monitoring earthquake prone areas by use of their data collection subsystem. This system has the capability of relaying data messages from remotely located data collection platforms to a central processing facility where an evaluation and assessment of the seismic data can be made. The USGS, in conjunction with USAID/OFDA has "developed a prototype earthquake event detector and GOES satellite-based telemetry system." This system consists of "a conventional short-period vertical seismometer as sensor, a microcomputer system to monitor the seismometer output, and a data collection platform to transmit the data to the satellite. The microprocessor monitors the seismic signal, selects the seismic events, and stores the associated waveform data in GOES satellite format for transmission to the satellite by DCP."[5] In this way, the satellite system is able to provide remote, ground-based data on seismic activity to analysis centers located anywhere within range of the GOES satellite. This type of data is extremely useful in both earthquake detection and management, and the prediction of tsunamis.[5]

4.6 Early Warning Crop Assessment

Assessment of crop yield is an important factor in the development of efforts to mitigate the human suffering from famine. Early warning of crop failure can provide the lead time necessary to respond to the impending shortage and minimize the human loss. Satellites have begun to be used to an ever-increasing extent in models to predict crop

shortages. However, their use in early warning of crop shortages is only in initial stages of development. What follows is a description of an FAO early warning system and of US programs in this area.

4.6.1 FAO Global Information and Early Warning System on Food and Agriculture

This system has two objective: First, "to monitor continuously the world supply/demand outlook for basic foods and fertilizers in order to assist governments to take action in quickly changing situations" and second to identify individual countries and regions where serious food shortages are imminent, and assess possible emergency food requirements."[7] The system estimates the production and consumption, imports and exports, and other aspects of various critical crops on a worldwide basis. In addition, it considers elements which are likely to affect food supply/demand, including weather crop/land conditions, diseases, etc.

The system is operated out of a central facility located in FAO/Rome. Situation reports on various parts of the world and information from a variety of FAO programs are sent to the central facility on a regular basis. In most developing countries, the FAO field representative plays a critical role by sending local information to the facility in Rome. During normal periods, these field agents report monthly, however during a crisis reports are telexed with whatever frequency is required. In addition, weather information from many developed countries is sent directly to the central unit at regular intervals. Data is continually analyzed and some forecasts are now computerized.

The system produces several different reports. The Food Outlook report is published monthly and provides up-to-date analysis of the current world food situation. The Food Outlook Statistical Supplement comes out annually and serves as a supplement to the Food Outlook by providing annual statistics of the world crop situation. The Foodcrops and Shortages Report is also issued monthly and provides information on various crops on a country-by-country basis. It pinpoints areas of concern as well as those already suffering from food shortages. Special Alert Reports are issued whenever a food shortage situation threatens to worsen or is exacerbated by local conditions. These reports are the primary vehicles for issuing early warning of impending crop shortages.

This global system has an excellent track record for forecasting food shortages on a global scale. However, satellite imagery has been used sparingly in this system which relies heavily on local field agents. As models for predicting crop production become more accurate and data from satellite become for useful to those models, it will be important for this FAO early warning system to incorporate such data and information into its system for forecasting food shortages.

4.6.2 USAID Agroclimatic Analysis and Development of Climate/Crop Yield Models7

This project was designed "to provide reliable, timely information on potential food shortages triggered by climatic events." The project assembled computerized data bases to determine the relationship between climate anomalies, severe weather, and crop failures. In this way,

one can monitor the weather and climate and forecast an early warning of crop failure and hence crop shortages. Bi-weekly reports which qualitatively evaluated unusual and severe weather were provided to USAID throughout the life of the project. Monthly assessments of crop condition were also provided.

The process for projecting abnormal food shortages was developed as follows:[8]

> Weather assessments begin with an analysis of precipitation amount, the most important meteorological element influencing crop productivity in the sub-tropics. Regional rainfall estimates are determined from ground station reports received thorugh an international communications network. Satellite cloud data are used to improve the accuracy of precipitation estimates, particularly in those regions where weather data are sparse and unreliable. Weather data are then interpreted by agroclimatic indices which indicate potential crop production in relative terms. Finally, the potential for abnormal food shortages is identified from these indices.

Agroclimatic indices, developed from historical data bases and episodic reports on known occurrences of drought and/or famine were used to identify critical thresholds for potential food shortages and to interpret the agroclimatic indices. Models were developed for much of South and Southeast Asia for a wide variety of crops.

This project has not yet been made opertional, and yet it has the potential to provide reliable information 30-60 days before harvest. This would provide a 3-6 month warning prior to drought-related food shortages.

4.6.3 Foreign Agricultural Service/USDA

The US Department of Agriculture is involved with the forecasting of agricultural production worldwide. Their programs are directly relevant to NOAA's AISC program and the FAO's international early

warning program. These programs include the Foreign Agricultural Service and the World Agricultural Outlook Board.

The Foreign Agricultural Service (FAS) is responsible for the export expansion programs of the Department. FAS maintains a worldwide agricultural intelligence and reporting system through its attache service. Attache reporting includes information and data on foreign government agricultural policies, analysis of supply and demand conditions, and market opportunities. Attaches report not only on more than 200 farm commodities, but also on weather, economic factors, and related subjects affecting agriculture. Part of the FY84 budget increase is for the purchase of satellite photographs of foreign crop production areas.

Landsat data is used on an operational basis to monitor and assess crop conditions. Landsat satellites, which constitute the land observation satellite system, provide valuable information for the assessment of global crop conditions, as well as insight into the status of renewable and non-renewable resources. The World Agricultural Outlook Board serves as the focal point for the Nation's economic intelligence related to domestic and international food and agriculture, and is responsible for coordination and clearance of all commodity and aggregate agriculture and food-related data used to develop outlook and situation material within USDA. The WAOB's primary objective is to improve the consistency, objectivity, and reliability of outlook and situation material developed in the Department. Its functions include market surveillance; coordination of assessments of international and domestic agricultural developments; weather, climate and remote sensing coordination; and forecasting techniques and information dissemination.

4.6.4 Climate Impact Assessment

The Assessment and Information Services Center (AISC) provides a weekly assessment of climate conditions around the world and their impact on selected geographic areas. Events are primarily noted when they will have impact on human population centers or on economic sectors. The publication "Climate Impact Assessment: Foreign Countries" includes assessments for Africa, Australia, Canada, China, South Asia, Caribbean Basin, Central and South America, the USSR and the USA.

There are three parts to the assessments, narrative, maps and tables. There are three sets of maps indicating weather induced problems, weather events during the last two weeks and weather events of longer duration.[10] These three maps contain the following information:

1. The Weather-Induced problems map indicates geographic areas where either recent weather events or ongoing long-term weather patterns are likely to have impacts on economic sectors;

2. The Weather Events During the Last Two Weeks map portrays unusual weather occurring during the period. Shaded areas indicate regions experiencing unusually heavy or light rainfall, strong winds, marked temperature anomalies, severe storms, or other weather-related events which may have impact on economic sectors;

3. The Weather Events of Longer Duration Map portrays persistent temperature or precipitation anomalies with potential economic impacts.

The narrative describes potential problems created by weather related anomalies. The summary tables include a list of weather events for areas identified on weather-induced problems map, and a summary of "current or potential impacts by sectors and by region for all assessed countries."

4.6.5 Landsat Data and Agriculture Early Warning[11]

Landsat data have been used in several programs to assist in the development of crop production and crop yield models. While, Landsat data are limited in their usefulness by cloud cover, resolution, frequency of data repetition and data turnaround time, they has been found useful in providing the following types of information for agricultural assessments (OTA):

1. spatial distribution of potential crop yield classes;
2. area of irrigation in crop area;
3. abandoned crop acreage;
4. areas of replanting;
5. soil moisture distributions
6. snow cover and some depth assessments;
7. floor area mapping and damage assessment; and
8. synoptic overview for design of area sample frame programs.

One commercial system uses both Landsat data and data from meteorological satellites to produce a crop forecast for various crops in various parts of the world. This system, CROPCAST™, inputs data from the various satellites into a geo-referenced system. After computer processing of the data, analyses of soil moisture, plant growth, stress, yield, etc. are made. These measurements are particularly useful in projecting crop stress and failure, and changes from the "normal" patterns of crop growth and production. The use of Landsat and Metsat data together is an extremely useful way to maximize the capabilities of the two types of satellites.

Finally, Metsat data have been used to the direct benefit of the agricultural industry in many ways. A good example of where this type of data has been most useful is in the agriculture industry, which is tremendously sensitive to weather conditions. As such, the ability to effectively monitor current and impending surface weather conditions is a tremendous benefit to farmers. For instance, infra-red is being successfully used in the US to track excessively low surface temperatures and to predict frost and freeze conditions which could adversely affect crops. This type of application has been and is being used effectively in relation to the Florida citrus industry. By monitoring frost conditions, Florida farmers can determine when to turn on artificial heaters to avert crop loss due to execssive cold, and when not to turn on those same heaters when conditions are not too bad.

4.7 Desertification

Desertification is a major problem in many parts of the world, including in the Western United States. In fact, nearly 1/3 of the earth's surface is arid or semi-arid and therefore subject to potential desertification pressures. Because desertification is such a wide-spread geographical phenomena, Landsat type data offers the potential for monitoring desertification processes on a global scale. Both AID and NASA have experimented with this potential application of Landsat data.

The United States has lent its assistance to several international organizations trying to monitor desertification on a global scale. These include the United Nations Global Environmental Monitoring System and the FAO's Global Information and Early Warning System (described earlier). As an example of its potential use, the Bureau of Land Management joined with the US Geological Survey in the "modelling and categorizing Landsat digital

data for purposes of mapping and describing wildland vegetation for a large section of the arid southwest."[12] The project was undertaken successfully and in a very cost-effective manner.

4.8 Satellite Telecommunications

The use of satellite communications in emergency situations to date is only a sample of the real potential, for the small and portable terminal for this purpose has not quite come to a state of low cost and wide availability needed for in-depth use, much less a breadth of experience sufficient for a statistical base. Additionally, almost all those examples which can be cited are with the use of American satellites, and those only in the recent past. Because of the somewhat more benign American environment compared to regularly threatening situations in other parts of the world, the direct uses of satellite communications in disasters are recognizable and well reviewed. The enormous potential for beneficial use elsewhere awaits exploitation. What follows are examples of applications of satellite communications, in addition to the use of telecommunications inherent in weather and land remote sensing systems, to disaster warning and management.

4.8.1 Communications Technology Satellite, CTS

A series of tests were run in conjunction with various assistance agencies in 1976 by Comsat Laboratories using the U.S.-Canadian satellite CTS. The U.S. Forest Service requested, and the National Red Cross assisted, in a simulated emergency to deploy a small satellite terminal using a 1.2-meter antenna at an unprepared site to furnish communications in the event of a forest fire. Both teletype and voice communications were successfully established within an hour after arrival at the site.

In a similar exercise, but using a commercial rental trailer and station wagon for deployment, a flood disaster communications link was tested. In this case, simulated emergency communications messages were sent via radio and telephones to the terminal site, then sent via satellite to the Red Cross Disaster Coordination Center in Alexandria, VA. This test emphasized the use of teletype because of the need for hard-copy records.

For an earthquake situation, a similar test was run in San Francisco, linking the terminal deployed there to the Comsat Lab in Clarksburg, MD. Another similar test was run for a hurricane watch in Corpus Christi, TX. All were successful and quickly set up.

During this Texas test, a real flood emergency occurred in Johnstown, PA, The terminal was shipped by commercial airline to Pittsburgh and by van to Johnstown. Messages routed through the two telephone channels established through CTS to the Comsat Lab site included casualty reports, requests for equipment and personnel, and facsimile transmissions of sketches made of the disaster area.

Several real-time, full-motion color television transmissions were also conducted using a slightly larger, 2-meter antenna with the terminal. The quality of the picture in this test was minimally acceptable for use in the public television network, but could have been useful in lieu of other forms of visual information. As noted above, the use of freeze-frame television with remote and transportable terminals is possible with further developments.

The transmission of multiple channels from a single small and portable earth terminal was demonstrated in a successful use of the CTS satellite from a 1978 Buenos Aires conference on technical

cooperation among developing countries. The terminal, using a 2.4-meter antenna augmented by available commercial multiplex equipment, transmitted a combined signal with real-time color television and high-fidelity audio, two channels of voice for coordination, five voice-grade channels with multiple languages, and a high-speed teletype channel. In a related test, documents in prepared on a Chinese-language typewriter were transmitted by facsimile to New York and rated of sufficient quality for translation.

In another test, two-way video and sixty voice grade channels were multiplexed onto a single satellite channel, but as an illustration of the size of the terminal required, this test used a 4.6-meter antenna.

At the suggestion of the Voice of America, a small horn antenna (about 20 cm square at the aperture) was connected to a commercial FM broadcast radio receiver. The reception was rated as very high quality.

4.8.2 Applications Technology Satellites, ATS

The use of NASA's ATS-1, -3, and -6 satellites in various types of public service experiments is well documented elsewhere. Without defining the characteristics of the satellites, little should be inferred about the future use of similar systems, but three examples of their use in emergencies will be illustrative.

The ATS-1 satellite was first operated in 1964 primarily as a weather observation satellite. After its batteries failed to operate the cameras, its single-channel voice communications system was operated in available sunlight, and has ever since provided the Pacific Ocean Basin countries with a party-line communications service that is unique for its availability, longevity, and international utility.

One example of its use was to provide the sole means of communications with a small, but inhabited island which, in the late '70s

was inundated by a tidal wave of huge height relative to the islands' topography. With all other communications having ceased, U.S. authorities were able to immediately contact this surviving small ATS terminal by voice, and ascertain damage and need for assistance.

Other examples of effective use of ATS-1 are legion and for the most part, are documented. These papers should be referred to in any consideration of disaster circumstances where communications are interrupted. While the satellite has deteriorated in voice quality over the years, often has the negative qualities of a party line, and is subject to unavoidable outages, it is nonetheless greatly admired for its unique and valuable services in the Pacific Basin.

The ATS-3 satellite was designed very similarly to the ATS-1, but has exhausted its orbital positioning fuel and has been located in a stable position over the U.S. for many years. This one-channel satellite also has been used far past its expected lifetime in experiments by NASA in conjunction with General Electric's corporate R&D personnel.

A principal ATS-3 use was unexpectedly effective, when telephone lines became totally jammed at the time of the Mt. St. Helen's explosion in May 1980. The disaster coordinator (Sheriff, Cowlett County, WA) was able to use a Jeep-mounted ATS terminal flown from the Air Force Rescue Service Coordinating Center at Scott AFB, IL to the local disaster management office near Mt. St. Helen's. It furnished two-way voice communications with the only other terminal able to participate, at GE Schenectady, NY, where personnel relayed messages by long-distance telephone connections to any location needed by the sheriff. Because it was, in effect, a private line to Schenectady, it was reported to have been the only method by which some essential communications could be made. Its

beneficial use was emphasized further when, as Federal assistance was sent to the area, it was found that the military communications radios could not operate together with the local civilian net because of different frequencies and other characteristics. This situation stills pertains, and is likely to occur in other countries.

Another use of the ATS-3 satellite was mentioned above -- voice and medical observations of a patient's condition telemetered from a moving ambulance. Oil-rig accidents have been treated remotely by a Coast Guard helicopter crew using an ATS-3 portable terminal. These and other successes of a single voice link via satellite and small terminal have shown the direct effectiveness of satellites in a variety of situations.

The ATS-6 satellite was capable of real-time, high-quality color television at several different frequencies, which enabled many different experiments to be conducted. The use of its capabilities has been important in remote observation and guidance of basic, life-saving surgical operations where patient mobility would have been life-threatening. The use of one-way voice to a hand-held terminal with a two-inch whip antenna was demonstrated, although this was not, and will not be, a commercially-viable system for many years. Voice and data communications at L-band to and from moving aircraft were also successfully demonstrated via ATS-6. The experiments were terminated in 1977.

Since the end of its useful life in 1979, many suggestions have been made about continuing the use of the S-band capabilities shown by ATS-6. This spacecraft was useful in the first demonstrations of high-power technology for television, and since has proven to be a forerunner of two new broadcast systems, one to be launched in 1984 for the Arab countries and the Insat, now operating for India. These new, multi-function satellites will be used for instructional

television at S-band to "community" -sized earth stations, e.g., those that can be made affordable when shared among many in a village, rather than having individual terminals at each home as in "direct broadcast satellites," or DBS. Also, it should be noted that Insat carries a data collection relay capability for in-situ remote sensing of weather warning conditions.

These examples are but a small sample of the use of satellites with small and sometimes portable terminals, and many of them for the purpose of disaster mitigation in some form. They were largely ended in the past few years, as NASA turned to newer technology and a lean experimental budget.

NOAA's Search-And-Rescue Satellite (SARSAT), however, has been a principal and successful thrust toward the direct saving of lives using small portable beacons carried aboard aircraft and ships. By Doppler positioning made possible by the motion of low-orbiting spacecraft, the beacon signal is used to calculate location which is relayed to rescue agencies. The improved response time and lowered uncertainties of position are providing strong improvements in rescues as well as direct savings in expense.

4.9 Other Applications

There are a range of other applications of satellite technology to disaster warning and management. A few of these are briefly touched on here.

4.9.1 Monitoring Volcanic Activity and High Winds[13]

The eruption of Mount St. Helens in May 1980 renewed public interest in monitoring volcanic activities. Within minutes after the eruption of Mount St. Helens, data from the GOES satellite system began

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providing information on the extent and the direction of the plume of ash and smoke which eventually carried thousands of miles. This allowed meteorologists to warn the populace in areas whre fallout was to occur and local governments were able to issue advisories. Aircraft were also able to reroute based on the data supplied by the satellites. Other volcanic eruptions have been monitored using satellites since the eruption of Mount St. Helens and because of the success of satellite monitoring of volcanic activity, aviation authorities are considering a plan whereby the World Weather Watch would issue aviation alerts based on satellite imagery.

4.9.2 Sea State Measurements

Data collection platforms are used off-shore to monitor sea state and to maintain a watch on wave height and sea temperature. Together with data from satellite, these measurements are used to forecast sea state which supports the fishing industry and marine transportation. More importantly, anomalies in sea state can indicate a global change in weather conditions such as those experienced during the El Nino. In fact, several NOAA-7 satellite images have enabled analysis of surface thermal temperatures off the South American coast. These measurements, in conjunction with buoy and ship measurements have provided scientists with an integrated overview of the El Nino phenomena. As such, this El Nino has been better documented and understood than any past El Nino.

4.10 Summary

This brief overview of satellite applications suggests that the potential use of satellites in global disaster warning and management has only begun to be tapped. It also suggests that there is already a wide range of operational and experimental programs which are rapidly becoming globally oriented and which are establishing global information and

communications systems. Satellite data will be used as input to these systems and satellite links will be used to trasnmit the data around the world. It is important to point out, however, that satellites make up only part of any such system--and as satellite capabilities grow, they will have to fit into on-going programs and early warning and management systems to be truly effective. Appendix 1 covers in some detail a wide range of on-going programs which are either directly or indirectly related to disaster early warning.

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5.0 CHALLENGES TO AN OPERATIONAL SATELLITE EARLY WARNING SYSTEM

Previous section of this study have discussed satellite applications to disaster warning and management. It is clear from those sections that there will be an ever increasing number of operational remote sensing and telecommunications satellites and that there already exist a number of globally oriented disaster warning systems. Any effort to develop a globalized early warning system based on satellite technology will, however, encounter a range of political issues, both domestic and international.

5.1 Development of Global Early Warning Systems

There are two primary aspects of an operational satellite-based early warning system for natural disaster which need to be addressed. These are the globalization of current and developing early warning programs for natural disasters and the development of a global network for response to early warnings. In other words, the early warning of natural disasters of course involves the generation of warnings, but the audience for those warnings nicludes not only those who will be effected by the impending disaster, but also those who might have to respond to it.

The development of both of these aspects of an early warning system for natural disaster have domestic and international policy overtones. In particular one must ask if the development of a global early warning system, by definition, requires international participation and cooperation rather than a solely national initiative; how national sovereignty and sovereignty over information about a particular country will effect the development not only of a global early warning system but also a global response system; how an international early warning system and national decision making regarding those warnings will interact?

In the following discussion of domestic and international policy issues regarding an operational early warning system, the following scenarios for development of such a system should be kept in mind.

1. Scenario 1: The United States initiates a program for the development of a global early warning system for natural disasters based on US technology and institutions. This system begins with a focus on developing a US government response network and the globalization of forecasting models and early warning programs within the US government. International participants would be invited to join this iniative, at first as users of the system and then later as contributors of technology and institutional support. This would be a US system with international participation after the initial structure of the system was established. The decision of whether to integrate existing disaster warning programs for different type of natural disaster would be made by an interagency group of the US government. This is the "US Initiative" scenario.

2. Scenario 2: The United States proposes that an international effort be made to establish a global early warning system for natural disasters. The system would be based on the interests of a variety of international participants and would take include many of the internatioanl disaster warning program already in existence. Decision making would be undertaken through an informal/international body convened on an annual basis. Efforts would be made to establish focal points for various types of disaster warning information in existing programs. This system would be based largely on technologies and programs already in

existence in a variety of countries and would be apolitical to the extent that international relationships would develop prior to the development of any formal international institution. This is the "International" scenario.

3. Scenario 3: The United States would propose that a new international agency/organization be established to develop/implement a global early warning system for natural disasters. The US would contribute to this system on a par with its current capabilities and would expect like participation from other developed and developing coutries around the world. Such a system could be used to upgrade the status of the United Nations Disaster Relief Organization (UNDRO) or by the creation of a new agency for disaster warning. Such an agency might follow the model of Intelsat or the World Meteorological Organization. System decisions would be made by this international organization. This is the "International Organization" scenario.

These scenarios are illustrative of the manner in which the US could approach the development of a global system for disaster warning. However, inherent in these scenarios are numerous challenges/issues which confront any US effort to utilize satellites on a global/operational basis. These challenges to US decision makers can be divided into two seperate but extremely interactive types--domestic and international.

5.2 Domestic Policy Issues

There are a wide range of interconnecting policy issues involved with the establishment of an operational satellite early warning system for natural disasters. These include (1) Inter-agency responsiblity and funding; (2) Private sector versus public sector concerns; (3) Military versus Civil government concerns; and (4) Domestic policy concerns versus

foreign policy concerns including commercial needs versus international scientific cooperation and humanitarian policies and commercial/private sector needs versus US reliance on international data sources.

5.2.1 Interagency Funding and Responsibility

The development of a satellite system for early warning of natural disasters will involve both budget and legislative implications. The establishment of such a system (including technology, people and institutions) will require time, money and manpower from those agencies which are required to participate in the system.

There are two levels at which an operational system must be developed--first the actual system for generating disaster warnings and second the mechanisms by which those warnings are disseminated to appropriate agencies who are expected to respond. Agencies involved in the generation of disaster warnings would likely include those involved in data collection (NASA, NOAA, Agriculture, Navy, Interior, etc.) while agencies involved in response would include further data collection but also those capable of providing disaster relief and technical assistance (USAID, Corps of Engineers, Coast Guard, Military, etc.) All of these agencies, in the development of an operational early warning systems, would have to make a budgetary and manpower contribution, and one would have to be given the authority and budget to organize and manage the system. Some of them--for instance, many of the data collection agencies--would claim that they are alrady providing hundreds of millions of dollars to finance satellites and extensive ground truth. Others will claim that they have no

government. Landsat and earth resource sensing satellites are in the process of being transferred from government to private sector ownership and operation.

This raises a set issues involved with the development of an operational satellite early warning system for natural disasters. First, will data be available from commerical remote sensing systems for use in an international disaster warning system and if so, how much will it cost, how hard will it be to obtain it, will private companies be able to stagger their pricing schemes in order to accomodate "humanitarian" uses of the data, and will those same private companies be willing to pre-empt on-going data collection to focus their sensors on a particular region where a natural disaster is developing or has struck? Second, if this type of data is "for sale" to international users, will the US be able to obtain timely and affordable data from other countries operating satellite systems? If not, will there be efforts to stem the flow of international resource data to the US include not only satellite data but also other types of data collected from in-situ platforms and ground agents? Will this have an impact on weather satellite cooperation and the international meteorological system which has developed so effectively?

In the area of communications and communications satellites, the buying or leasing of a transponder on-board a satellite is too expensive for disastertype communications. Can a system be developed with a private carrier by which disaster warning and management communications take precedent over regular communications uses? If so, should these provided at a low cost to developing countries for humanitarian reasons?

The key point here is that the requirements of private sector ownership of key satellite systems must be dealt with early on, as management of these privately owned systems will be extremely important to the development of any satellite early warning system.

5.2.3 Military vs. Civil Government

There are two key issues involved in the realm of civil/military interface with respsect to early wrning of natural disasters. First, is the issue of civilian access to military data and the use of military facilities, and second is the issue of the data and information itself, which might be of military value.

The military has access to data and information which is unavailable to the civilian side of the government for purposes such as the early warning of ntural disasters. It is important for those interested in developing such a global system to explore the possibility of utilizing military sources. The development of the Tsunami Warning System at the Naval Fleet Numerical Oceanography Center by the Navy and OFDA is a good example of how the civilian and military parts of the government can cooperate in the development of a successful early warning program. In addition, the military has facilities which could be of use to civilian agencies involved in disaster warning and management. Particularly in the area of satellite communications the military may be able to provide occasional links which could be useful to disaster warning and management.

5.2.4 Domestic Policy vs. Foreign Policy

As has been the case with the US space program since its inception, the dictates of domestic policy and the use of space technology in the area of foreign policy often come into conflict. This conflict takes the form of a strong desire of parts of the foreign policy

community to use space technology to support US foreign policy objectives and to live up to the initial goal of the civilian space program to be open to foreign cooperation and to be conducted for "benefit of all mankind," as opposed to domestic interests which are strongly in favor of protecting US high technology from enemies and competitors and commercializing that technology rather than using it in a cooperative mode. While these goals and objectives are not necessarily in conflict, they often seem at odds. In any effort to develop a space-based system for early warning of natural disasters this conflict is likely to arise.

This conflict manifests itself in a variety of ways which are particularly troublesome. This includes the trade-off between protecting US technology and international scientific cooperation and the need for data protection (for commercial reasons) and the flow of international data to the US. Space technology has always been international in character and much has been gained from international cooperative efforts both scientifically and in cost-sharing. Now, these cooperative efforts are being fought because of the desire of some people to protect US technological innovation. At the same time, commercial interests require that data and information be protected to some extent to make it commercially worthwhile. However, the US relies heavily on foreign sources of data for many of its global modelling efforts and there is a possibility that other countries might "retaliate" by witholding such data from the US if the US protects data collected by its earth resources satellites.

5.3 International Issues

At the international level, any such effort must confront a range of issues, some of which are directly tied to those domestic issues listed above. These include (1) transborder data flow and international free flow

of information; (2) dependence and accountability; (3) training and technology transfer; and (4) system sturcture/integration

5.3.1 Transborder Data Flow

The emergence of Landsat sparked a heated controversy in the United Nations regarding the distribution of satellite data and information. Over the last decade, the United States has disseminated data collected from the Landsat series openly and at minimal cost to all interested parties, domestic and foreign. This policy, in line with the US traditional policy regarding the free flow of information, mitigated many of the objections of developing countries regarding access to information about their countries. However, any program which will collect information about one country and distribute openly to the international community will raise serious political questions. In sum, many countries are simply uncomfortable with the open dissemination of any data and information about their country.

Directly related to the above point is the availability of data to the international community. Again, many countries do not wish to have any data of their country available internationally. The US Landsat program has operated very effectively with an open dissemination policy, however, data from Landsat's 1,2 and 3 were not very sensitive. While the plans for upcoming land and weather satellites call for open data dissemination, some concern will continue to be heard about this policy. For instance, it is possible that some countries might not wish others to know of a natural disaster which they are about to experience. The open availability and dissemination of climate and resources information will always be an international issue where satellite collected data and information are involved.

5.3.2 Training and Technology Transfer

In order for any early warning system to be effective on an international basis, training and technology transfer will have to play a big part in the development of the system. In-country personnel who will be handling the dta and information, and who will have to make decisions regarding whether to order a warning and how to respond to warnings, will hvae to be trained not only in the technical aspects of disaster prediction and warning but also in disaster management. Such training cold be incorporated into other aspects of training in-country such as remote sensing training efforts in the fields of hydrology, agriculture, civil engineering, geology, etc. This is obviously a key area for continued support by agencies such as USAID to provide technical assistance and training in disaster management and forecasting. This will also have an impact on the down-stream funding for any international disaster early warning system.

5.3.3 Dependence and Accountability

The issues of dependence and accountability are closely related to the international character of satellite information and global information systems. In this regard any international early warning system will, by definition, be international in scope and character. As such it will most likely be subject to the issues of dependence and accountability. These issues are summed up in the following quote:

> Should remote sensing technology fulfill its promise, it will become indispensible for many countries. User nations will have made significant investments in facilities of various kinds. They will have geared their data gathering and decision making processes, both in the public and private sectors, to the peculiar characteristics and assured availability of satellite imagery. Their interest in the stability and continuity of the service on which their domestic systems will have come to rely will consequently be considerable.

In other words, developing countries will come to rely heavily on US or other developed country technology. With that reliance will come a desire to have an input into the further development and continued availabiltiy of data. Because the system would be designed largely to alleviate suffering from natural disasters in developing countries, it seems that input from those countries might well be appropriate. This raises the central issue, then, of whether any international system for disaster early warning can or should be run solely by the United States or any other country? This issue takes on particular importance in that any international satellite based system will rely not only on satellite data from international sources but also on other international data sources and programs of other developed countries. Many developing countries are also developing sophisticated satellite programs which would be integral to any such international system. This suggests the obvious question of whether the planning of any such system should include international participants. To exclude foreign countries and international organizations currently working in related areas might well limit the effectiveness and use of a satellite-based international early warning system.

This issue takes on another form in that once a global system is initiated, participating countries must make decisions about how to treat data and information regarding non-participating countries. For instance, if a international disaster warning and management system were to forecast an impending disaster in a country or region which, for whatever reason, was not a participant in the system, would there be a humanitarian obligation to issue a warning? Under what conditions, in other words, would non-participating nations receive disaster warnings?

5.3.4 System Structure/Integration

The above discussion leads to a final issue which will confront the developers of any global early warning system for natural disasters. That is, there currently exist a number of global disaster monitoring systems in the US and abroad. They exist for a wide range of disasters, some of which are closely related (such as earthquakes and tsunami's) and others which are not closely related at all (earthquakes and drought). Any effort to develop a global system will have to determine whether or not it is useful and effective to integrate existing systems into a single network or whether it is better to maintain separate networks for distinct disaster phenomena.

One must also address the question of whether an initiative in satellite aided disaster early warning should incorporate (as discussed above) on-going programs of other countries and international organizations. One cannot ignore the realities, for instance, of the overlap of the FAO's agricultural early warning program with those of the US Department of Agriculture and NOAA's AISC. The difficulties of integrating these, both technically and bureaucratically, could be monumental, even though FAO and USDA already work together. In fact, one may want to maintain dual forecasting systems in order to provide two opinions. This is true, as well, of a number of programs which are described in Appendix 1 of this report.

5.4 Summary

There are a number of domestic and international issues which are raised by the possibility of developing a global early warning network for natural disasters. The potentials of such a system are great, but the domestic and international political realities of space technology and

applications require that the political problems likely to arise with the advent of such a system be dealt with at the outset.

One can look at the three system development scenarios described earlier in this section and weigh them against the various issues which are outlined above.

Scenario 1 (the US Initiative Scenario) would simplify decision making for the overall system because it would limit decision makers, at least at the outset, to domestic agencies. However, this scenario would not eliminate the difficult domestic problems associated with system development--particularly those revolving around budget, legislation and technology transfer. The decision to proceed with Scenario 1 would be the subject of extensive debate between those agencies in favor of a domestic approach and those with a more international outlook. Finally, such an approach would undoubtably raise the ire of international participants, both those with the capability of contributing to the system and those wishing to use it.

Scenario 2 (the International Scenario) would encourage international participation, but would do it in such a way as to develop informal contacts and agreements prior to any formal international structure being developed. It has the advantage of bringing international participants into the picture early on and developing a system based on user needs as well as current capabilities. However, it would not ameliorate the domestic issues facing US decision makers and might very well slow down overall progress on an international system due to the difficulties inherent in any international project. One can envision, however, that an approach similar to Scenario 2 could be used to bring international

participants together early on and informally begin building international programs and networks with the implied, if not actual, consent and participation of the international community.

Scenario 3 (the International Organization Scenario) would serve to exacerbate international issues as it would thrust any such initiative into the international political arena. While such an initiative might ameliorate any policy issues arising out of a lack of international participation it would focus attention on international political issues which are inherent in satellite technology and data acquisition. Domestically, issues facing US decision makers would not be resolved and increasing international political visability would generate increased domestic debate over foreign policy issues. Scenario 3, while having the attraction of mitigating international concerns over a US dominated system, would exacerbate other political issues such that little of no progress would likely be made on the system.

In sum then, Scenario 1 would likely make domestic decision making easier at the cost of irritating and perhaps alienating international particpants while Scenario 2 might complicate system decisions but would ameliorate international participants. Scenario 3 would likely cause the system to become overly politicized and bogged down.

It is also important to reflect back on basic assumptions regarding the use of satellites for disaster early warning and management. That is, it is always useful to ask "To what goal or purpose is this effort directed?" If it is to mitigate human suffering from natural disasters it is useful to consider any such satellite applications in the context of overall disaster management. In this context, the development of a global early warning system for natural disasters takes on a much

broader development context--including technology transfer, education and training and disaster management and an effort to educate leaders of all countries about the need to act on advance informatio rather than hiding the prospects of disaster for political purposes. This wider development context is essential to the successful implementation of any satellite related disaster warning and management programs in the developing world. It is hoped that the proposed conference and proposed interagency program committee (discussed in the following section) will provide the beginnings of a dialogue to deal with domestic and international political (as well as other) aspects of a global system, as well as the broader development context of disaster warning and management.

REFERENCES

1. Remote Sensing From Space, Prospects For Developing Countries, National Academy of Sciences, Washington D.C., 1977, pp. 149-150.

6.0 A CONFERENCE ON SATELLITE APPLICATIONS TO EARLY WARNING OF NATURAL DISASTERS

The proposed conference is a response to a US initiative at Unispace 82 which promised to make information available on existing satellite technology and its applications to disaster warning which are suitable for operationalization. John Bolton, then Assistant Administrator, Bureau for Program and Policy Coordination, U.S. Agency for International Development, in a paper entitled "Fulfilling the Promise Of Unispace", presented to the International Academy of Astronautics Conference, "UNISPACE 82: Did it Work?" described the US initiative as follows:

> State of the art disaster early warning technology currently available and suitable for operational implementation worldwide remains relatively unknown to many scientists and decision-makers in the LDCs." ...we can (make a contribution).. by providing orientation for LDC scientists in the proper use of data obtained from current and future satellite-based disaster early warning systems.
>
> ...the conference will be to expose LDC scientists and engineers to new advanced technologies available to them from U.S. sources."

The United States Office of Foreign Disaster Assistance is planning to hold such a conference in Spring of 1985. Current plans call for a three day conference focused on applications of satellite technology in four basic areas in which research and applications are already being supported by USAID/OFDA. These include:

1 global drought assessment, agroclimate, and famine early warning systems.

2. Tsunami early warning and monitoring systems

3. Severe storm forecasting and early warning systems

4. Regional seismic networks

5. Satellite-based data transfer and disaster telecommunications

6.1 Interagency Program Committee

In order to develop the interagency cooperation which will be necessry to implement this conference and to build toward the globalization of satellite-based disaster early warning, an intergency conference program coordinating committee has been identified and set up. The nature of the conference and its subject material dictates that USAID/OFDA, NOAA, the USGS, and USDA be involved in planning for the conference. The fact that space technology and technology transfer will play such an important role implies strongly that NASA should be a participant as well, particularly as longer term plans for a potential operational system develop, and as needs for computer and distributed data processing network capabilities become defined and understood. In addition, the the Department of Defense must be included due to its wide-ranging capabilities and requirements. It is suggested that, if it is appropriate at a later date, to expand the program committee be expanded into an interagency working group with an extended list of participating agencies and individuals. To form the program committee and the core of the interagency group representation from these agencies was sought, and the current status of the program committee is as follows:

NOAA - Dr. John McElroy appointed Ms. Joan Hoch of the AISC to the program committee. Dr. Willima Bishop is expected to be involved when his schedule permits.

NASA - Dr. Dudley McConnell, Asst. Associate Administrator for Space Science and Applications has agreed to serve.

USDA - Dr. Richard McCardle, Agency Remote Sensing Coordinator has agreed to serve.

USGS - Dr. David Russ, Deputy Director of Earthquake Research, has agreed to serve.

DOD - Mr. Charles Miller, Commander, United States Navy, Joint Chiefs of Staff, has agreed to serve.

DoState- Mr. Lisle Rose of the Office of Environment and Science has agreed to serve.

USAID - Mr. Paul Krumpe of OFDA has agreed to serve. Mr. George McClosky and General Julius Bechten will also be involved with the development of the conference.

An initial meeting of the program committee was held on April 26, 1984. A presentation was made to the committee, with an outline of the needs for a Global Early Disaster Warning System, with background information on the role and charter of OFDA, and a review of the UNISPACE initiatives. A second meeting of the program committee was held on June 4, 1984. Based on the discussions of that group and meeting held individually with the members of the program committee, this study recommends that the conference be structured around the ideas that natural disasters are costly to the nations involved, that aid from the U.S. and other donor nations will decline as population demands increase and resources are stretched, and that new technology which allows for forecasting of disasters can ameliorate the economic consequences, to the benefit of all. The agenda presented here is an example of how the meeting can be arranged, and is a recommended approach. Additionally, should there be a desire for more detailed presentation, the panel presentation format can be replaced by

individual papers. The current time for each panel is about one and one half hours, giving time for each panelist to give a ten minute statement (assuming four panelists) and leave ample time for a well guided discussion for the panel. Selection of panel moderators will be crucial to this end. Speakers have not been named in this agenda.

FIGURE 6.2

TENTATIVE CONFERENCE AGENDA

Opening Day:

8:00 - 9:30	Registration and Coffee
9:30 - 9:40	Welcome
9:40 - 10:10	Overview and Charge for the Conference
10:10 - 10:30	Coffee Break
10:30 - 12:00	World Economics of Natural Disasters Panel Discussion by IMF, Bankers, Economists and Insurance representatives
12:00 - 1:30	Lunch - Keynote Speaker
1:30 - 3:00	Tsunami Forecasting - New Techniques Panel Discussion including some foreign Participants
3:00 - 3:20	Coffee Break
3:20 - 4:50	Earthquake and Volcano Forecasting and Monitoring - Panel Discussion
4:50	Close

Day Two:

8:30 - 10:00	Flood and Hydrologic Applications Panel Discussion
10:00 - 10:20	Coffee Break
10:20 - 11:50	Tropical Wind and Severe Storm Strike Forecasting - Panel Discussion
11:50 - 1:30	Lunch - Independant Arrangements
1:30 - 3:00	Agroclimate and Crop Production Forecasting Technologies - Panel
3:00 - 3:20	Coffee Break
3:20 - 4:50	"Social and Economic Costs of Disaster Warnings - Can We Afford Them?"
4:50	Close

Day Three:

8:30 - 9:00	Overview of Communications System Technologies for Disaster Warning and Monitoring
9:00 - 9:30	Overview of Data Processing and Display Technologies for Disaster Warning and Monitoring
9:30 - 9:50	Coffee Break
9:50 - 10:20	Future Earthquake and Volcano System Capabilities
10:20 - 10:50	Future Crop Yield Forecasting System Capabilities
10:50 - 11:20	Future Flood and Hydrology Systems Capabilities
11:20 - 11:50	Future Severe Storm and Tropical Wind Wind Strike Capabilities
11:50 - 1:30	Lunch
1:30 - 2:00	Training Programs Available for New Earthquake and Volcano Technologies at USGS
2:00 - 2:30	Training and Assistance for Agroclimate and Crop Yield Forecasting Technologies at NOAA
2:30 - 3:00	Training and Assistance for Severe Storm Warning Technologies NOAA
3:00 - 3:20	Coffee Break
3:20 - 5:00	Panel Discussion - Information Needs of Developing Countries - Panelists to be Selected from Attendees

6.3 Illustrative Budget

The illustrative budget for the conference makes the following assumptions:

1. The US Government will pay for the air fare and per diem of all developing country international participants and speakers.
2. Members of US agencies and members of developed countries and/or international organizations will pay their own way.
3. The conference will be held in the Department of State at little or no cost. Coffee and refreshments will be catered by the Department of State.
4. Conference will be 2-3 days duration.
5. One conference banquet dinner will be held at a Washington area hotel or restaurant.
6. A private company will serve as technical manager of the conference, including coordination and review of papers, development of any needed position papers, provision of honoraria to speakers/session chairman, and publishing of the proceedings.
6. The private company organizing the conference will be under contract 8 full months before the conference is scheduled. The following is a tentative, illustrative budget.

FIGURE 6.3
ILLUSTRATIVE CONFERENCE BUDGET
SATELLITE APPLICATIONS TO DISASTER WARNING

I. TECHNICAL ASSISTANCE CONTRACT (Conference Management)

	DAYS	RATE	COST
DIRECT LABOR			
TECHNICAL COORDINATOR	80.00	160.00	12800.00
ADMINIS. ASSISTANT	160.00	112.00	17920.00
TECHNICAL EXPERTS	80.00	200.00	16000.00
SUBTOTAL SALARIES			46720.00
OVERHEAD (125% of salaries)		125.00	58400.00
OTHER DIRECT COSTS			
Air Travel			6000.00
Local Travel			1000.00
Per Diem			2100.00
Publishing Proceedings			10000.00
Printing Invitations/etc.			7500.00
Communications			1600.00
Shipping/Postage			1000.00
Miscellaneous			800.00
Banquet			5000.00
SUB-TOTAL ODC			35000.00
TOTAL COSTS			140120.00
FEE			14012.00
TOTAL COSTS, TECHNICAL ASSISTANCE			154132.00

II. TRAVEL AND PER DIEM, INTERNATIONAL PARTICIPANTS

TRAVEL	50 Round Trips @ $3000	150000.00
PER DIEM	6 days/person @ $75/day	22500.00

III. SPEAKER HONORARIUM, TRAVEL AND PER DIEM

SPEAKER HONORARIUM	10 persons @ 400.00/day	4000.00
SPEAKER TRAVEL	25 Round Trips @ 1000.00	25000.00
SPEAKER PER DIEM	5 days/person @ $75/day	3750.00
TOTAL COSTS. SPEAKERS AND INTERNATIONAL PARTICIPANTS		205250.00

TOTAL CONFERENCE COSTS	359382.00
10 % CONTINGENCY	35938.00
TOTAL CONFERENCE BUDGET	395320.00

6.4 Steps to Holding the Conference

During the course of this study, several key steps were taken in preparation for holding the subject conference. These included:

1. Identifying of key policy issues associated with the globalization of disaster early warning systems;
2. Identifying and convening an interagency program committee for the conference;
3. Through that committee, gaining general consensus over the type of conference to be held (largely informative) and securing the cooperation of several US agencies in conference planning;
4. Developing a tentative conference outline;
5. Developing an illustrative budget for the conference.

There are a number of additional steps which must be taken prior to of the conference. These involve the following, not necessarily to be undertaken in the order presented:

1. Formalize program committee meetings;
2. Develop and agree on conference agenda;
3. Determine budget and funding inputs from other agencies;
4. Once a conference date has been set, contract a technical assistance firm to manage the conference;
5. Solicit papers and secure speakers;
6. Review papers and disseminate, if appropriate;
7. Secure conference room and facilities for reception/banquet and hotel accomodations for visiting participants;
8. Line up publishing firm and secure camera ready copies of papers to be presented;

9. Send conference invitations to selected participants and solicit participation of desired persons.

10. Prepare State Department and other Agency international offices for participation in the conference, if necessary.

6.5 Summary

This study has developed a framework for understanding the data and information requirements for disaster management including disaster early warning systems (Section 2.0). It has described a wide range of satelltie technologies applicable to disaster management and early warning (Section 3.0) and has offered a range of examples of satellite applications to disaster management (Section 4.0). It then outlined various scenarios for a US initiative in the holding of an international conference on satellite applications to disaster early warning and identified policy issues associated with the conference and any efforts to globalize disaster warning systems (Section 5.0). Finally, this study outlined a conference agenda and illustrative budget, as well as steps required to achieve the conference in the Spring of 1985. With appropriate and timely action, a conference on satellite technology applications to disaster early warning could be held in the Spring of 1985 and continue the process of bringing satellite technology to bear on problems on Earth.

APPENDIX 1

1.0 PROGRAMS RELATED TO DISASTER EARLY WARNING

There is a wide range of programs throughout the US government which are either directly or indirectly related to disaster management and early warning. This appendix, utilizing the budget presentations of the major US agencies involved, summarizes those programs. Because of the quantity of data assembled and the focus on US technology, less attention has been paid to international programs.

1.1 National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) is involved in a wide range of programs relating to or potentially related to natural disaster management and warning. These include ocean and atmospheric research and the management of the weather and land remote sensing systems.

1.1.1 Ocean Climate Research

NOAA's ocean climate research is aimed at gaining a better understanding of ocean dynamics, variability of sea-surface temperatures, and air-sea interaction processes and their relationships to climate variability. The goal is to make better climate predictions. The Equatorial Pacific Ocean Climate Studies (EPOCS) program is a large-scale experiment to gather data and perform analyses and studies on the influence of the equatorial Pacific Ocean on inter-annual climate variations. Currently, EPOCS is concentrating on the eastern equatorial Pacific to study ocean processes that are responsible for changes in sea-surface temperatures and to analyze meteorological elements such as winds, barometric pressures, surface stress, and precipitation to obtain detailed morphology of the Southern Oscillation and related El Nino phenomenon.

The Ocean-Atmosphere Climate Interaction Studies

(OACIS) program, which is intended to test a theory for short-term climate variations over North America and other economically important regions of the globe, has been adopted internationally as part of the World Climate Research Program and renamed Tropical Oceans-Global Atmosphere (TOGA). A long-term monitoring program (10-years) has been started to provide a rapid response capability for observing the oceanic and atmospheric signatures of an El Nino event and to conduct a program of applied research to accelerate improvement of operational climatic forecasts of the National Weather Service. A new generation of drifting buoys will be used to monitor the air/sea heat and moisture fluxes, oceanic heat content, and ocean currents.

The Subtropical Atlantic Climate Studies (STACS) investigates the heat transport in the Northern Subtropical Atlantic Ocean. STACS emphasizes developing the techniques and strategies for monitoring the ocean transport of heat and is now concentrating on the Florida Current and Antilles Current regions.

Ocean climate modeling, analyses, and diagnostics are essential components of the NOAA climate research program. Ocean climate modeling and analysis concentrate on mathematical computer models of the global ocean-atmosphere coupled system to study such climatically important subjects as global heat, salinity and carbon dioxide balances, seasonal variations in oceanic transport, and the response of tropical oceans to fluctuating winds in relation to El Nino and Somali current phenomena.

In the Ocean and Great Lakes Service Research program, research is conducted on the physical processes that govern the exchanges of heat, moisture, energy, and momentum between the ocean and the atmosphere which contribute significantly to the generation of severe marine weather. The research seeks to improve understanding of these

processes and to apply this understanding to the development of improved forecasting techniques for use by operational elements. Specific topics of research include hazardous marine winds and waves, coastal currents and hydrography, sea-ice and lake-ice distribution and dynamics, storm surges, seiches, and tsunamis.

Research in marine winds is conducted to improve the observation and forecasting of hazardous coastal winds that affect marine activities either directly or through the generation of hazardous waves, storm surges, and seiches. Research topics include: wave generation processes; propagation and transformation phenomena; coastal currents. In addition, this program element also develops and applies new observational techniques such as ground-based radar, airborne imaging radar, airborne laser, profilometry, and satellite observations to observe the sea state or to determine sea state prediction parameters. Storm surge research emphasizes improved computational techniques for predicting destructive storm surges and associated wind waves and the resultant inland flooding in bays and estuaries. This information is used for both coastal planning and for real-time forecasts and warnings.

Sea-ice research consists of observational and theoretical studies to improve monitoring and prediction of growth, movement, and breakup of ice in the Bering Sea and along the Alaskan arctic coast. Algorithms for ice forecasts are being developed which incorporate ice, wind, and ocean current dynamics, ice thermodynamics, and coastal morphological features. Ice forecasts are designed for specific user needs and involve a variety of times scales, ranging from days to months, depending on the operational and logistical requirements. The modeling approaches depend upon the particular time scales in question and range from empirical models, drawing heavily on statistical parameters, to

localized dynamic models.

In the Great Lakes area, research is conducted to improve understanding and prediction of marine variables and phenomena primarily involved with warning and forecasting services. This research focuses on the development of: improved data, understanding, and prediction of surface waves, wind setup, storm surges, seiches, and over-water winds; improved techniques to stimulate and forecast the freezeup, breakup, areal extent, and thickness of the ice cover on the Great Lakes and their connecting channels; and applied environmental service tools such as engineering and forecasting models.

1.1.2 Ocean Services

The objectives of this subactivity seek to provide tide datums; to provide historical, real-time, and predictive data for tides, Great Lakes water levels, coastal currents, ocean circulation, other marine variables and statistical wave data; to conduct research on hazardous or special marine conditions as a means of improving forecast and warning services for the marine community; and to develop improved environmental data, information, analytic tools and advisory services to support users in Government and private industry.

The Oceans and Great Lakes Assessments and Services program provides oceanographic and related meteorological data and information in the form of observations, analyses, assessments, and predictions required for the safe, rational, effective, and economic use of oceans, coastal zone, and Great Lakes.

This program conducts oceans investigations, operates measurement systems, processes and analyzes data and provides physical oceanographic data annually in seven major categories:

(1) Tide Prediction Tables, published in four volumes annually providing high and low water predictions daily for 6,000 locations one year in advance;

(2) Historical Tide Data, including six-minute heights, hourly heights, monthly mean summaries, and daily high and low heights for 6,000 locations plus frequency and duration of tide innundations;

(3) Great Lakes Water Level Data, including hourly levels, daily mean levels, annual water levels, and seven-day means levels for fifty-four stations plus lake discharges, levels, flows, maximum levels, minimum levels, and precipitation summaries;

(4) Tidal Datums (long-term means levels) for 5,000 coastal locations, plus low water datums and tide zones for reducing hydrographic survey soundings;

(5) Tidal Current Predictions, published annually in two volumes which predict tidal currents at 56 major ports and 2,400 coastal locations, plus tidal current charts and diagrams for twelve coastal areas and special predictions for NWS and foreign countries;

(6) Ocean Current Data, for estuarine and coastal regions including current direction and velocity vs. depth, temperature and salinity profiles, tide levels and meteorological data; and

(7) Wave Statistics, including wave data in real-time; measured and hindcast time histories of wave heights and wave spectra; typical and atypical statistics, and descriptions of local hazards and severe storms.

The program operates the National Tide Observation Network at a level of 125 permanent coastal stations and the fifty-four station Great Lakes Water Level Observation Network. Fourteen tide stations telemeter real-time water level data in support of marine navigation and the NWS Tsunami Warning System. A total of 250 subordinate short-term tide states are operated. During FY84, five prototype stations were operated (New York four, Columbia River one) to telemeter real-time tide level data to improve the efficiency and safety of ship operations.

Of interest to disaster early warning systems is the coastal mapping services program which conducts aerial and ground surveys, performs photogrammatic analysis and compiles maps in three product categories, primarily in support of the preparation of nautical charts and bathymetric/topographic maps. Specifically, coastal mapping services prepare coastal maps showing shoreline changes, storm evacuation routes, and safety zones and boundary coordinates.

The geodetic reference system provides fundamental reference system for determining latitude, longitude, and evaluation. The program carries out field surveys, processes survey data, performs sophisticated mathematical computations, carries out research and conducts scientific investigations to provide four basic categories of products and services: horizontal geodetic information; vertical geodetic information; geodynamic data describing motion of the earth rotational axis, earth

rotation, earth gravity, variations in sea surface elevation, and providing limited crustal motion data for subsidence, uplift, and large scale lateral movement studies; and technology extension services.

The program operates survey and reconnaissance parties to establish new horizontal control points, perform readjustment work, develop the network and measure earth crustal motion. Four field parties resurvey about 6,000 kilometers of primary lines each year in the vertical network and determine new elevations in areas of subsidence and crustal motion. Eight additional Global Positioning System (GPS) geodetic receivers were procurred and deployed during FY 1984. Full operation of the 3-station Very Long Baseline Interferometric (VLBI) network in FY 1984 will allow NOAA to improve its polar motion, earth rotation and large scale crustal motion measurements. Stations in the Crustal Motion Network were occupied by portable or mobile VLBI observation systems transferred to NOAA from NASA. These data will be used for high accuracy determination of the variation in position and elevation of control points over time and for developing crustal motion models.

1.1.3 Atmospheric Programs

The objectives are to improve the timeliness and accuracy of meteorological, hydrologic, and oceanographic services by developing new techniques and procedures, applying new technology, and improving methods of dissemination of information to reach more people promptly in warning situations. Meteorological, hydrologic, and oceanographic warnings and forecasts are provided through NOAA's nationwide network of Weather Service Forecast Offices (WSFOs), Weather Service Offices (WSOs), and River Forecast Centers (RFCs). The warning and forecast program is supported by continuous monitoring of the status of the atmosphere, the rivers, and the oceans. The data are collected and

communicated throughout the network of offices for use in preparing warnings and forecasts which are disseminated to the public directly by the National Weather Service (NWS) and in cooperation with the mass media. Three major guidance centers, the National Meteorological Center (NMC), the National Severe Storms Forecast Center (NSSFC), and the National Hurricane Center (NHC), computer-process and analyze the data as the basis for development and distribution of warning and forecast guidance needed by the field forecasters.

1.1.3.1 Observations

Surface observation of temperature, atmospheric pressure, humidity, wind speed and direction, precipitation, visibility, cloud cover, and other weather elements are made with ground-based instrumentation at 288 NOAA-staffed stations, 215 contract stations, 345 Federal Aviation Administration (FAA) stations, and 320 industry-staffed airport stations. Additional surface observations of water temperature and ocean wave conditions are taken by 1,600 high-seas and 200 coastal and Great Lakes cooperative observing ships; by sixteen deep-ocean and eight Great Lakes moored data buoys, and through cooperative agreements at coastal and offshore staffed facilities. NOAA will operate advanced automatic weather observation platforms at thirty fixed coastal locations. In support of development and refinement of key sensors and techniques for automation of surface weather observations, NWS will conduct a system demonstration to evaluate operational factors prior to initiating nationwide deployment.

Atmospheric soundings are taken from the surface to about 100,000 feet (30km) at 94 NWS stations using balloon-borne instrumentation to provide vertical and horizontal distribution of

temperature, pressure, humidity, and wind. Observations of temperature and precipitation are provided on a daily basis at 12,000 cooperative stations, including hydrologic observations at 6,000 locations and including snowpack water equivalent assessment on major river basins in the north-central plains through the aerial gamma radiation program. In addition, 500 Automatic Hydrologic Observing Systems are interrogated by computers over the telephone or via the GOES satellite. A network of 56 long-range radars, supplemented by 72 local warning radars, provides round-the-clock surveillance of meteorological phenomena capable of causing natural disasters. These weather radars are the principal means of detecting and tracking severe thunderstorms and tornadoes and for measuring the heavy rains that cause flash floods. NOAA, DOD, and FAA are jointly developing a Next Generation Weather Radar (NEXRAD) system with Doppler capability to replace the existing network of aging weather radars with advanced radars, meeting the combined requirements of the three agencies and greatly improving data on tornadoes, thunderstorms, and hurricanes. The NEXRAD program will continue validation phase activities begun in FY 1983.

1.1.3.2 Communications

A complex network of leased and government-owned communications facilities and equipment provides for the collection and distribution of data used in NOAA weather and flood warning and forecast services. NOAA uses the facilities of other Federal agencies to collect and distribute a significant portion of meteorological information. For example, the FAA provides the two major teletypewriter networks used in the collection and dissemination of domestic weather data. DOD and the Coast Guard Circuits are also used for collection of meteorological data. NOAA operates a number of facsimile circuits which are the principal method of distribution, in graphic form, of the guidance products prepared at the

NMC, located at Suitland, MD. The National Facsimile System distributes NMC graphic materials to NOAA field offices, DOD, and other government and public users. Charts include observational data, analyses, and forecasts necessary for the general forecasting program and the preparation of hazardous weather warnings. The Digital Facsimile System distributes specialized guidance material prepared by NMC for WSFOs. Portions of the communications circuits will be phased down as Automation of Field Operations and Services (APOS) assumes these functions. The Tropical Regional Analysis Facsimile System distributes analyses and charts for hurricane forecast centers along the Atlantic and Gulf Coast states. The Geostationary Operational Environmental Satellite Facsimile (GOESFAX) system distributes high-resolution satellite pictures to the WSFOs and transmits hydrological Survey, which are used by the NWS River Forecast Centers. A Radar Facsimile System collects and distributes weather data obtained from Air Route Traffic Control Center radars to a number of WSO's in mountainous western regions.

Weather conditions in the US are influenced by conditions around the world. To establish a basis for warnings and forecasts beyond twenty-four hours, the World Weather Watch Global Telecommunications System (GTS) provides an international program of mutual cooperation for exchange of observational data through a system of communication circuits consisting of landline, satellite, and radio facilities. Circuits currently serving the World Meteorological Center in Washington, D.C., collect data from the Far East through Tokyo, Japan; from Europe through Bracknell, England; from Canada through Toronto; and from South and Central America and the Caribbean through terminals in Brazil, Argentina, Cuba, and other islands of the Caribbean, Mexico, and nations of

Central America.

1.1.3.3 Public Warning and Forecast Preparation

WSFO's are responsible for warnings and forecasts for states, or large portions of states, and extended weather outlooks for periods of up to ten days. WSFO's are responsible for locally adapted warnings and forecasts based on the WSFO zone forecasts. Each WSFO and WSO prepares severe weather and flash flood warnings and advisories for its designated area. Thirteen RFC's provide river stage, crest, and flood forecast for some 3,100 locations in all states except Hawaii. The Centers use computers to produce river and flood forecasts and other guidance to WSFO's for: flash floods; extended outlooks for river basins, including volume of flow, ice formation and breakup; and seasonal water supply estimates. Computerized river forecast models are being calibrated to improve hydrologic information in the support of existing services.

Four Ocean Service Units (OSU's), collected within the WSFO's at Seattle, Washington; Slidell, Louisiana; Washington, D.C.; and Anchorage, Alaska, provide warnings and forecasts for designated coastal and offshore areas. Warnings and forecasts for the remainder of the coastal and Great Lakes areas are provided by dispersed weather offices. The Pacific Tsunami Warning Center at Ewa Beach, Hawaii, and the Alaska Tsunami Warning Center at Palmer, Alaska, monitor seismic conditions that can produce sea waves which can inundate island and coastal communities, and issue warnings of potential danger to state, federal, and international officials.

To protect forests and rangeland from wildfires, NWS provides detailed forecasts of air temperature, wind speed and direction, humidity, timber moisture, and precipitation, and thunderstorm activity to wildlife control agencies and other forestry

personnel. Fire weather services primarily consist of daily forecasts for fire danger rating computations, sport forecasts, and on-site mobile unit support for prescribed burns and wildfires for the protection of life and property within the National parkland and forest system. Warnings of conditions leading to unusually high fire danger are issued as needed.

NWS provides agricultural weather services, including observations, forecasts, warnings, and advisories. As part of these services, NWS issues warnings of low temperatures injurious to winter and spring crops, particularly in citrus and other deciduous fruit-growing areas.

NOAA has implemented the AFOS system in day-to-day field operations nationwide, replacing outmoded communications, teletypewriters, and facsimile equipment with modern minicomputer-supported equipment at about 200 field offices to reduce NOAA's response time between the detection of hazardous phenomena and the issuance of warnings to the public. Those stations that do not have AFOS are being equipped with capabilities that permit them to interface directly with the AFOS system.

1.1.3.4 Dissemination

A wide range of dissemination systems are used, including NOAA Weather Radio (NWR), NOAA Weather Wire Service (NWWS), and telephone to distribute severe weather and flood warnings, forecasts, and other meteorological, hydrological, and oceanographic data to the public, disaster agencies, news media, industry, and other government agencies. In the case of NWR, 369 VHF broadcast stations, available to approximately 90 percent of the population, provide continuous broadcasts directly to the public. NWWS provides prompt delivery of warnings, forecasts, and other information to the mass media for relay to the public by way of commercial radio, television, and large-volume telephone recordings.

1.1.3.5 National Prediction Centers

The NMC in Suitland, MD; the NHC in Miami, Florida; and the NSSFC in Kansas City, MO, provide the basic forecast guidance used by field forecast offices in the issuance of warnings and forecasts of severe weather and floods.

The NMC collects, processes, and analyzes global weather data four times daily as the basis for prediction of weather conditions out to ten days, using numerical models of the atmosphere and large-scale computers. NMC also prepares monthly and seasonal forecasts for average weather conditions, performs climate analysis and projection, and provides climate information services which are used in assessing the effects of weather on flood and fiber production.

The NHC tracks and predicts the movement and intensity of hurricanes and coordinates the issuance of hurricane warnings with NMC and Hurricane Warning Offices at Boston, MA; Washington, D.C.; New Orleans, LA: and San Juan, PR. NMC and NHC continue to develop improved

techniques for prediction of formation, motion, and intensity of hurricanes.

The NSSFC issues severe thunderstorm and tornado watches which alert the local forecast offices to areas of high potential for severe weather development. The local offices, in turn, issue warnings based on actual sightings of tornadoes or radar signatures. The Techniques Development Unit at NSSFC develops procedures to improve the forecasting of severe thunderstorms and tornadoes.

1.1.3.6 Atmospheric and Hydrological Research

The objective of this subactivity is developing ground-based and satellite techniques for the remote sensing of critical meteorological and oceanographic parameters by optical, infrared, radio, and acoustic means; testing and evaluating systems designed for improving weather information and forecasts; and improving detection and prediction of severe storms. Another objective is to obtain better understanding of the physical nature of the atmosphere and the basis of atmospheric fluctuation by conducting regional and global experiments to acquire, process, and analyze data for use in developing physical and mathematical models for improving time, range, and accuracy of weather, air quality, and climate forecasts. Another objective is to provide forecasts and warnings of solar disturbances and their effects on the earth's atmosphere.

1.1.3.7 Meteorological Research

NOAA's meteorological research is composed of three main components: observation systems research, cloud processes research, and forecasting techniques research. Through observational systems research, NOAA seeks to develop ground-based and satellite

techniques for the remote measurement of critical meteorological, hydrological, and oceanographic parameters required by research and service programs. Satellite remote sensing techniques have advantages over instruments now in use which measure the atmosphere only at single points of instrument location. Typically, remote sensing from a single location provides simultaneous measurements of parameters important to weather at many points of instrument location, provides simultaneous measurements of parameters important to weather at many points throughout a wide area, provides data continuously rather than intermittently, functions without costly telemetry networks, and provides for highly automated operations, requiring fewer operational staff than conventional observation techniques. Considerable success has been achieved in establishing the feasibility of remote sensing of the atmosphere using acoustic, radio, and optical signals. The Wave Propogation Laboratory (WPL) is developing vertical profiling systems to remotely and continuously measure vertical profiles of wind velocity, temperature, humidity, and total water content. Satellite-based techniques are being developed to measure areal distribution of precipitation and to measure global winds using Doppler lidar. The Boulder Atmospheric Observatory (BAO) operates a tall (300 meters) meteorological research tower to provide demonstration, evaluation, and calibration of remote sensing instruments in support of research and service applications; and for conducting new research on atmospheric processes such as convection, clouds, precipitation, turbulence, low-level wind shear, and the transport and diffusion of pollutants.

Cloud processes research includes the study of hurricanes, tornadoes, and severe convective storms that pose a significant threat to life and property. Data collected through routine weather observations and by specially instrumented aircraft and satellites

are analyzed and compared to numerical models run with research computers in order to simulate the conditions under which storms occur. The Atlantic Oceanographic and Meteorological Laboratory, (AOML), in Miami, directs development of hurricane models and analyses based on data sets provided by NOAA aircraft. One example of this research is the Hurricane STRIKE program begun in FY 1980. The program employs two WP-3D aircraft to provide real-time monitoring of short-term changes in the path and intensity of hurricanes nearing landfall. The National Severe Storms Laboratory (NSSL), in Norman, Oklahoma, conducts research: to increase the understanding of tornadoes, squall lines, thunderstorms, and other severe local storms; to improve methods for prediction and early detection of these storms; to reduce the areas warned unnecessarily; and to increase public leadtime for protection of life and property. The structure and dynamics of severe storms are studied using a closely spaced network of automatic observing stations, an instrumented tower, serial releases of radiosondes, conventional and dual Doppler radars, and for processing, displaying, and transmitting the information obtained by radar. NOAA, in a coordinated effort with the Departments of Transportation and Defense, is engaged in the development of the Next Generation Radar (NEXRAD), which includes Doppler capability.

Forecasting techniques research includes, among other things, improved precipitation forecasting, the Prototype Regional Observing and Forecasting System (PROFS), and mathematical modeling. NOSS also conducts supporting research for computer forecasting of weather elements, hydrologic forecast models, and methods to quickly detect and predict small-scale, short-fused hazardous weather events. Increased emphasis is being placed on severe weather research to

substantially improve forecasts of extreme precipitation events, such as flash floods and accompanying phenomena including hail, high winds, gust fronts, tornadoes, lightning, and icing. NOAA works to: upgrade current NMC operational weather forecasting models to incorporate new understanding of the processes responsible for severe weather; evaluate and extend the use of new satellite and ground-based remote sensors for severe weather diagnositcs; and train field forecasters in up-to-date techniques of mesoanalysis and prediction.

Precipitation research is focused on: convective weather systems, including mesoscale convective complexes; and cloud precipitation processes, both directly support NWS need and PROFS program objectives in improving short-term forecasts, especially severe weather.

PROFS is: testing and evaluating technologies and research to determine which could have the greatest impact on weather and hydrological forecast improvements; and developing specifications for implementing these improved systems in the NWS field offices. Systems being tested include Doppler radar, Profiler vertical soundings, AFO's, satellite data sets, display techniques, and improved mesoscale models.

The Geophysical Fluid Dynamics Laboratory (GFDL), in Princeton, conducts a major research program aimed at understanding the physical laws governing the behavior of the atmosphere and oceans to continue improvements in weather forecasting and in prediction of weather events. This research makes use of regional, synoptic, and global data provided by weather satellites and by programs such as the Global Atmospheric Research Program (GARP), the Global Weather Experiment, and the Severe Environmental Storms and Mesoscale Experiment.

Constructing physically precise models of the earth's system, GFDL will be able to simulate the behavior of geophysical phenomena reaching from the surface of the earth up to the mesosphere and extending from short-term events affecting a single city to long-range weather forecast affecting large areas.

1.1.3.8 Atmospheric Climate Research

The purpose of NAAO's atmospheric climate research program is to achieve a better understanding of the physical processes which control climate and its variations, leading to the ability to forecast interannual climatic changes and long-term trends. The major elements of the program are radiatively important constituents, solar-terrestrial phenomena, climate modeling and diagnostics, and the Global Atmospheric Research Program (GARP).

GARP encompasses the World Climate Research Program (WCRP) and the First GARP Global Experiment (FGGE). Both programs are international in scope, jointly coordinated by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ISCU). NOAA is the lead agency for GARP activities in the U.S. While the GARP concentrates on the complete climate system, funds in this program budget only cover the international Tropical Oceans Global Atmosphere (TOGA) project which is concerned with the ocean's role in climate and minimal support for the cloud and radiation program element. That element is centered in the recently initiated International Satellite Cloud Climatology Program (ISCCP), which utilizes meteorological satellite imagery data to determine the effect of clouds on the earth's radiation balance. The first step of ISCCP is to reduce the vast quantity of satellite data to a compressed form amenable to systematic analysis to

determine the distribution and extent of clouds over the globe for a period of years. FGGE, also known as the Global Weather Experiment, is attempting to lead the way to the ultimate limit of deterministic weather and climate forecasting. FGGE has four objectives: to improve our understanding of atmospheric dynamics and the general circulation of the atmosphere to improve our ability to model those mechanisms responsible for that circulation; to determine the theoretical and practical limits of atmospheric predictability; to design an optimal, affordable observing system for the future; and to improve models of climate change by fully and accurately simulating the annual cycle as observed over FGGE's Operational Year. The formal international observing period covered twelve consecutive months, a complete seasonal cycle. This formal period was preceded by a build-up period during which the satellites of several nations and various specialized observing systems were launched and tested along with the data processing systems and models. Internationally, FGGE now has moved from the data collection phase to the research phase, accompanied by further work in organizing and archiving data so as to expedite the work of research scientists.

1.1.4 Satellite and Environmental Data and Information Services

The objectives of this program are: to operate, maintain, and acquire data from the NOAA operational environmental satellites; to process and analyze satellite data and prepare products for distribution, to supply data, interpretations, and consultation services to users, and determine requirements for future satellite systems; to conduct research to develop new and improved satellite systems to obtain environmental data, demonstrate new and improved methods using data obtained from NOAA and NASA satellites, aircraft, and laboratory

investigations, and apply these improvements to satellite data products for implementation by the operational elements; to provide evaluation and validation for experimental temperature and moisture sounding data obtained from the Visible Infrared Spin Scan Radiometer Atmospheric Sounder (VAS) carried on the GOES; and to continue to provide a data system that produces land resources information with accuracy, timeliness, and reliability required by users; to provide for international participation in the land remote sensing system; and to achieve commercialization of the LANDSAT system.

1.1.4.1 Environmental Satellite Services

NOAA operates and maintains satellite ground facilities, ingests and preprocesses incoming satellite data, provides satellite-derived products to users, and conducts research to improve the use of the satellite data. The program operates and maintains ground facilities to command and control the operational meteorological satellites, acquires satellite data, and transmits satellite data to the central processing and analysis center. These functions are carried out by the Satellite Operations Control Center (SOCC), Suitland, MD and the Command and Data Acquisition stations at Wallops, VA and Gilmore Creek, Alaska. The program is responsible for ingesting and preprocessing all data from the polar and geostationary spacecraft including vertical atmospheric measurements, soundings, winds, and sea surface temperatures for input to the National Weather Service analyses and forecast models. The program also provides products such as quantitative precipitation estimates for flash flood situations; hurricane classification; satellite monitoring and tracking of severe weather; and sea ice and ocean front analyses. It also provides research to develop new and improved methods of

obtaining satellite data and to develop techniques for applying these data to atmospheric, oceanic and land monitoring, warning, and prediction.

The principal products derived from polar-orbiting satellite data are: vertical temperature and moisture soundings; sea surface temperature measurements; global cloud cover images and mosaics; and total ozone measurements. The principal products derived from geostationary satellites are: full disc and sectorized cloud-cover images; derived wind speed and direction; assessments of hurricane motion and intensity; severe thunderstorm and tornado detection and monitoring; and warnings of potential flash flooding. Snow cover and sea and lake ice maps, and products to support agriculture are produced from data derived from both environmental satellite systems. The application products are delivered through a variety of formats: user accessable data bases; photo facsimile images; satellite facsimile transmission (WESFAX); interactive computer access; and archives. Stratospheric sounding data derived from instruments developed and funded by the United Kingdom and Data Collection System (DCS) data, derived from French-funded ARGOS systems on the TIROS-N spacecraft are relayed to the Project ARGOS in France as part of bilateral agreements. US users, in turn, receive processed data from the French.

Analyses and interpretations of geostationary and polar-orbiting satellite data are prepared by the National Weather Service at seven forecast offices staffed with satellite experts. These offices receive high resolution images on a twenty-four hour-per-day, seven day-per-week basis from the GOES Central Data Distribution System or direct from the Wallops Command and Data Acquisition station. These offices analyze and interpret the cloud and earth surface images and associated products for their customers. An automatic switching system enables the WSFO's and other users connected to the GOES data distribution system to

select desired images by pressing three digits on a touch-tone telephone. These images are used in preparing aviation forecasts, short-term forecasts and warnings of hazardous events, such as severe local storms and tornadoes, and hurricane advisories and gale warnings. The products are also used in preparing river and flood forecasts, snow melt and sea ice analyses. GOES imagery is distributed to television stations, universities, state governments, industry, other Federal agencies through the GOES-TAP which allows the user to receive any of the standard image sectors available to a particular forecast office. At present, this service has been extended to fifty-two WSFO's and about 600 other Federal and non-Federal organizations. NOAA provides a focal point for user services related to the Data Collection System, Weather Facsimile (WEFAX) service, and the satellite direct broadcast systems, which include Automatic Picture Transmission (APT), High Resolution Picture Transmission, (HRPT), and Direct Sounding Transmission (DST). NOAA will continue the expansion of weather forecasting and warning services through the use of data from the VISSR Atmospheric Sounder (VAS). This effort is a continuation of an initiative started in FY 1984. The satellite's vantage point in space provides data coverage in both time and areal extent not achievable by other practical observational techniques or systems. Universities and industrial groups participate in developmental activities through contracts and grants for satellite-related research. Also, close coordination is maintained with related NASA and DOD research and development programs.

1.1.4.2 LANDSAT Operations

In January 1983, NOAA assumed responsibility for the operation of the NASA-developed LANDSAT-D spacecraft and the

processing facility for LANDSAT, primarily, Multi-Spectral Scanner (MSS), data. LANDSAT-D has experienced a number of problems and will be replaced by LANDSAT-D Prime, to be launched in 1984. NOAA accepts requests for MSS data, schedules the spacecraft to obtain the data, acquires and preprocesses the data at the processing facility at the Goddard Space Flight Center and provides for final data processing and data delivery through the Department of Interior's EROS Data Center facility. In addition, at the request of participating foreign ground stations, NOAA will schedule the spacecraft to broadcast MSS data directly to those stations. In 1985, NOAA will assume responsiblitiy for the processing facility for data from the Thematic Mapper (TM) instrument on board the LANDSAT spacecraft. The TM instrument and processing facility have been an R&D project of NASA since the launch of LANDSAT 4 in July 1982 and by prior arrangement, will be turned over to NOAA in 1985 for operational use.

The LANDSAT-D ground processing activity receives MSS data through the NASA Tracking and Data Relay Satellite (TDRS). The NOAA ground processing system at GSFC, which does the initial processing of MSS data, is designed to move data through the processing system in less than forty-eight hours. High-priority data could be produced in a matter of hours. MSS data is then sent via a DOMSAT link to the EROS Data Center (EDC) where final product processing takes place. Computer compatible tape (CCT) will be available from EDC an average of two days later, and black and white film products for standing orders an average of twelve days later. Both the initial and final processing of TM data takes place at GSFC. The processed data is shipped to EDC where products are generated and distributed.

1.1.4.3 Satellite Systems

The objectives of this subactivity are: to continue procurement of spacecraft, instruments, launching capability, and ground equipment necessary to maintain uninterrupted operational polar-orbiting and geostationary satellite systems to: obtain quantitative environmental data such as temperature, moisture, winds, radiation flux, and solar engergetic partical flux used in numerical analysis and prediction programs; locate and collect data from remote offices and moving platforms, such as buoys, balloons, and ships; and provide imagery of the earth and its environment on a regular basis, day and night, including direct readout and environmental data broadcasts to ground stations. It also provides for the storage, testing and deferred launch services of the LANDSAT- D Prime spacecraft to extend the operational lifetime of the LANDSAT system. NOAA's geostationary and polar-orbiting environmental and land observing satellites are complimentary and provide unique sources of observations of the earth's atmosphere, oceans, surface, and near space. The geostationary satellites each provide an image every thirty minutes (more frequently for special observation) needed to detect, track, and monitor the growth and decay of severe weather systems in the temperate and tropical latitudes of the Western Hemisphere. The polar-orbiting NOAA satellite provides daily global observations of quantitative environmental data used to derive profiles of atmospheric temperature and moisture, sea surface temperatures, snow and ice coverage, and ozone observations. The satellite also provides for collection of data from remote fixed and moving observation platforms and has the capability to both locate data collection platforms and assist in search and rescue operations for aircraft and ships in distress. The LANDSAT polar-orbiting satellites provide observations of

the earth's land surfaces once every sixteen days on a scale which permits agricultural crop and population growth assessment, geological analyses, and related resource management information.

The following summarizes the three satellite systems:

System	Period	Resolution
Geostationary	5 to 30 minutes	1 to 8 kilometers
Polar Environmental	12 hours	1 to 4 kilometers
Polar LANDSAT	16 days	30 to 80 meters

Procurement of satellites is a cooperative venture with NOAA and NASA having key roles. NOAA, as the operating agency, represents the user and defines the basic requirements for the system. NASA develops detailed specifications and procedures and launches the spacecraft.

1.1.5 Data and Information Services

NOAA gathers worldwide environmental data about the oceans, earth, air space, and sun and their interactions to describe and predict the state of the physical environment. Other agencies, organizations and individuals, both domestic and foreign, also collect data for their missions. Once the original collection purposes have been served, selected data flow to NOAA's environmental data base. From the national data base, these service centers provide global data and information products to over 130,000 users per year. These include assessments of the impact of environmental fluctuations on industrial productivity, national defense, energy development, global food supplies, natural resources, natural hazards, and human health.

1.1.5.1 Climate Data Services

The National Climate Data Center (NCDC), NOAA's largest data center, is located in Asheville, NC, with a Satellite Data Services Division (SDSD) located in Camp Springs, MD. It is responsible for the National Archives of Weather Data for the U.S. The NCDC annually receives, processes, and archives over 30 million conventional meteorological observations comprising surface, marine, upper air, and solar radiation data. In addition, equivalent of 300,000 tapes and 250,000 images a year. The equivalent of 700,000 tapes are kept for SDSD by the University of Wisconsin. Data is gathered from the NWS, NOAA's satellite programs, military services, the Global Telecommunications System, and other national and international sources to provide a National Climate Data Base in digital, analog, microfilm, photo imagery, and manuscript forms. There are more than 92,000 subscriptions to regularly published NCDC data, and over 72,000 user requests were answered in 1984. NCDC also performs climate application studies for other government agencies, including the Air Force and Navy.

1.1.5.2 Ocean Data Services

The National Oceanographic Data Center (NDOC), located in Washington, D.C., is the world's largest repository of oceanographic data. A large volume of data is acquired through international exchange agreements. Holdings at the end of FY 1984 include over 1.4 million bathythermograph records; sea-surface to bottom or near-bottom records from 800,000 stations; 6.5 million surface and selected subsurface current measurements; and 375,000 surface temperature and salinity records. Data from automated ocean buoys include more than twelve million observations. Holdings include more than 7,000 other automated

data sets containing approximately fifteen million records from special projects or surveys.

1.1.5.3 Geophysical Data Services

The National Geophysical Data Center (NGDC), located in Boulder, Colorado, provides data and data products and services concerning the physical properties of the earth, its snow and ice environment, and ocean floor and submarine crust, and solar activity and its effects on the earth's environment. Disciplines covered include seismology, geomagnetism, gravity, geochemistry, geothermal energy, marine geology and geophysics, and ionosphere, magnetosphere, solar activity, glaciers, snow cover, ice sheets, sea ice, and paleoclimatology. Selected data are exchanged with World Data Centers in Moscow, Europe and Japan, under the auspices of the International Council of Scientific Unions. Data are collected through formal and informal arrangements with other government agencies, universities and many foreign sources. The Center prepares a number of standard summaries and listings, such as consolidated lists of solar flares compiled from worldwide observations and the annual history of earthquake occurences in the U.S. Special summaries and reports are prepared to meet specific user needs. Examples include maps of active volcanoes, geothermal data maps, and magnetic products for surveyors.

1.1.5.4 Assessment and Information Services

These activities, located in the Washington, D.C. area with a climate Impact Modeling Branch in Columbia, Missouri, provide quantitative environmental impact assessments, data interpretations and analyses, and library and information retrieval services to meet national and international needs. Current and historical environmental data are used to aid managers by assessing impacts of climate variations on

food, water availability, energy resources, etc. Impact assessment is accomplished by development and application of statistical and other numerical models, preparation of model inputs from multidiscipline data bases; and tracking and verifying climate anomalies on a global basis. The Center manages the NOAA Library and Information Service and also provides central publication services for the dissemination of NOAA's research and technical services program. Over 32,000 requests for assessments and technical information are answered per year.

1.1.6 Program Support

The objectives are to support NOAA's research and development programs in order to improve weather, marine, and climate services; and to provide weather reconnaissance support to NOAA program centers, Federal agencies, and international programs.

The NOAA Office of Aircraft Operations (OAO) in Miami, Florida, provides basic and special measurements from airborne platforms in a format tailored to the specifications required by individual research programs. The Research Facilities Center (RFC) possesses two fully-instrumented WP-3D research aircraft, which now comprise the most sophisticated meteorological research platforms in the world. The aircarft research systems, coupled with the navigation system, afford researchers detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. The aircraft can cover long distances in short periods (e.g., 3,250 miles in ten hours), providing synoptic coverage of a large area. They have a capability for measurements for ocean research that cannot be duplicated by ships. New sensors and high-speed recording techniques available on the aircraft enable collection of high-density, in-situ measurements of atmospheric parameters. In addition, on-board, real-time data analysis permits researchers to make inflight decisions to modify

data-gathering strategies. These uniquely instrumented aircraft, along with their scientific, engineering, and flight crews, have both the capability and the experience to fly into hazardous weather conditions. Thus, they are excellent platforms for research on the mesometeorological structure of atmospheric phenomena such as midlatitude convective complexes, hurricanes, and coastal winter storms.

1.2 Federal Emergency Management Agency

The Federal Emergency Management Agency (FEMA) is responsible for management of emergency situations which arise domestically. Of particular interest to OFDA are its national communications systems consisting of the National Warning System, the National Teletype System, and the National Voice and Radio Systems.

1.2.1 National Warning System

The National Warning System (NAWAS) is a nationwide leased dedicated voice warning network. Information can be furnished to state governments, cities, countries and various Federal and military agencies. These points will disseminate the warning information to the population by various local systems.

NAWAS is a dedicated, party-line type telephone warning system operated on a 24-hours basis. A National Warning Center (NWC) and an Alternate National Warning Center (ANWC) are manned continuously by Attack Warning Officers. Its special purpose telephone circuits connect the NWC and ANWC to FEMA Headquarters, the FEMA regional offices, selected Federal agencies and military installations, state, city, and country warning points which are manned 24-hours a day. Attack warning information is received from the North American Air Defense Command for dissemination by the NWC at Colorado Springs, Colorado or at the ANWC in Olney, Maryland.

The NAWAS consists of 63 circuits totaling approximately 170,000 nationwide circuit miles. The warning circuits are connected to approximately 2,400 terminals throughout the U.S. Approximately 1,600 of these are monitored at all times. NAWAS terminals are also located at certain Coast Guard facilities for alerting ships at sea, and NOAA for dissemination of warning via the weather network.

During FY 1985, the system will continue at the 198⅘ level including NAWAS expansion for counterforce areas. It is planned to initiate the phased upgrade of existing terrestrial systems into a more survivable infrastructure by using techniques of low frequency broadcasting and Meteor Burst communications. Existing warning systems are almost totally dependent on leased communications facilities. These are considered outdated and vulnerable in terms of current potential crises scenarios. The proposed consolidated and updated system will begin implementation in 1985. It will maintain an acceptable level of survivability over an extended period of time by exploiting the techniques of equipment design, media diversity, by using both low frequency and Meteor Burst technology, resource distribution, redundancy, mobility, dispersion, deception, response system control reconstruction, and electromagnetic pulse protection. The system for the low frequency primary warning is to initiate procurement covering the Northeast sector that include FEMA National, Regions, and sixteen remote relays. Low frequency stations will operate continuously. The advantage of this system resides primarily in the fact that low frequency transmissions can be broadcast over a wide area directly to dispersed receiving equipment. The system for the Meteor Burst backup warning system is to initiate procurement comprising master stations at FEMA National, Regions, and a remote relay; transceivers at each state; and receivers at warning points. All warning operation within the subsystem will be automated to the greatest extent possible. Teletypewriter warning messages sent from the NWC or the ANWC, respectively, by Line of Sight radio to Region or FEMA National will be automatically retransmitted to all master stations. After each master station receives the warning and automatically acknowledges its receipt,

the teletypewriter warning message will be automatically broadcast to warning points in its area of responsibility. The advantage of Meteor Burst communications is that it will function under virtually all conditions except the destruction of the terminal equipment.

1.2.2. National Teletype System (FNATS)

The FEMA NATS is the primary teletype telecommunications network used for direction and control of emergency conditions. FNATS includes a dedicated network for transmitting record communications between national headquarters, a relocation headquarters, regional offices, states, and territories, and selected Canadian civil defense locations. This teletype network simultaneously accepts and processes messages from teletype terminals and provides automatic message switching between users. The automatic switching feature allows users to send messages to a single address or to a multiple number of addresses within the system.

FNATS is a 100 word per minute non-secure system utilizing two IBM computers. One computer is in the Region III Olney, MD Communications Center and serves Regions, I, II, III, IV, and V and their associated states. The other computer is in the Region VII, Denver, CO Communications Center and serves Regions VI, VII, VIII, IX, and X and their associated states. The two message switching computers are connected with a high-speed data link. All interconnecting circuitry, circuit multiplexing and message preparation and receiving equipment is leased through the US Army Commercial Communications Office and Defense Commercial Communications Office.

In FY 1985, system expansion is planned to accommodate the FEMA National Emergency Management System mission, by initiating the

installation of mini-computer regional switches which will provide the critically needed secure backbone capability.

1.2.3 National Voice System (FNAVS)

The FEMA NAVS system provides voice telecommunications via dedicated leased circuitry to State Civil Defense offices and their Emergency Operating Centers. Inter-regional and regional FEMA Headquarters voice service is provided by the Automatic Voice Network (AUTOVON).

1.2.4 National Radio System (FNARS)

The FEMA NARS system provides for the exchange of information between Federal, state, commonwealth and territorial governments' civil defense activities. The control facilities for stations in this system are collected with the FNATS terminals in each communications center to enable immediate routing of traffic over either system.

FNARS utilizes single sideband voice and radio teletypewriter techniques. The purpose of FNARS is to provide a survivable backup to FNATS and FNAVS throughout the FEMA area of responsibility. Equipment consists of commercial high frequency transmitters and receivers of various power rating from 500 watts at the state sites to 10kw at the regional communications facilities. Electromagnetic pulse protection has been installed at the six protected FRC's as well as at approximately 35 state locations.

1.3 Department of the Interior: United States Geological Survey

The Department of Interior is involved in a range of activities potentially related to an integrated global early warning disaster system. These programs are outlined below.

1.3.1 National Mapping, Geography and Surveys

The objectives of the program are to produce and make

available cartographic and geographic information, multipurpose maps such as topographic, land use/land cover, and various base and special purpose maps, and cartographic and geographic data in printed and in digital format. The maps produced by USGS are a collection of data and information concerning natural and cultural features. The information is collected from aerial photographs, remote sensing images, historical records, legal documents, and from direct field observation and surveying.

The objectives of the Primary Quadrangle Mapping program are to prepare, print, and make available new 7.5 minute topographic maps of areas in the coterminous U.S. and Hawaii not previously mapped and new 15-minute topographic quadrangle maps of areas in Alaska not previously mapped; to produce these multipurpose maps based on priorities to meet specific requirements. These new maps are necessary to support such activities as the identification and development of energy resources, coastal area management; flood plain studies; evaluation of the impact of natural disasters such as earthquakes, floods, and volcanoes; and military and civil defense. USGS continues to replace most of the outdated analog graphic output mapping equipment with hardware and software systems capable of producing digital and graphic cartographic data.

The objectives of the Digital Mapping Program are to produce base categories of digital cartographic data in standard formats with accuracies and structures suitable for computer-based analysis to meet user requirements; to coordinate digital mapping programs and activities of Interior Bureaus and other Federal agencies; and to manage the data through a National Digital Cartographic Data Base and to conduct the program with the objective of eventual full cost recovery. In addition to the applications of digital cartographic data in various resource management

and analysis systems, there are also important applications in the mapping process. With digital cartographic data, it will be possible to generate small-scale and derivative maps in the future much more simply and efficiently than by current manual techniques. Digital cartographic data will also expedite the process of revising and updating maps. A Digital Cartographic Unit (DCU) is a yardstick for measuring data production. DCU's can either be Digital Elevation Models (DEM's) containing digitized elevation data or Digital Line Graphs (DLG's) containing digitized map information of public land net, boundaries, hydrography, transportation, or other cultural map features collected for a single 7.5-minute quadrangle. Production, to date, has been primarily DEM, land net, and boundaries at 7.5-minute format and scale.

The objective of the Small, Intermediate, and Special Mapping; Intermediate-Scale Mapping Program is to provide multi-purpose base maps at 1:50,000 and 1:100,000 scales in quadrangle and county formats to meet a variety of Federal and State requirements. Priority requirements include: The Bureau of Land Management; The Soil Conservation Service (Important Farmlands data); The Defense Mapping Agency; Forest Service (intermediate-scale maps of all National Forests); Geological Survey; Fish and Wildlife Service; National Ocean Survey; Minerals Management Service; Tennessee Valley Authority. Coverage is projected for 1990 to provide a national series of topographic quadrangle base maps at the 1:100,000 scale as a comprehensive source of base cartographic information.

The objective of the Small, Intermediate, and Special Mapping; Airborne Profiling of Terrain System Program is to build, test, and operate an airborne instrument system which will permit the rapid collection of geographic position information. The system will provide data with accuracies of 2 feet horizontally and 0.5 feet vertically. It

will be a major breakthrough in rapid, cost-effective methods of acquiring data for such activities as flood plain mapping, topographic mapping, and geologic studies.

The objectives of the Small, Intermediate, and Special Mapping; Small-Scale and Other Special Mapping Program are to prepare a variety of multipurpose base maps at various scales to meet the needs of natural resource agencies, Congress, and national endeavors requiring maps that show large geographic areas on a single map; and to prepare special map products to jointly meet unique and often unforeseen requirements of Federal and State agencies. Some of the projects include: 1:250,000-Scale Maps for the Defnese Mapping Agency, NOAA, and the National Park Service and Fish and Wildlife Service; National Parks Maps; U.S. and State Base Maps; and Special Maps.

1.3.2 Earth Resources Observation System

The objectives of this program are to develop, demonstrate and encourage new earth science applications of remotely sensed data (aircraft and satellites) and to develop techniques to merge these data with more traditional earth science data sets to assist in the resource inventory and management reponsibility by:

- providing leadership and coordination of Department of Interior activities in developing and using remote sensing technology;
- conducting cooperative demonstration projects and internal research leading to new and improved cost-effective remote sensing and spatial data applications;
- training and assisting users of remotely sensed data in using new techniques for analysis and merging of disparate data sets in the application of spatial data information systems;

- archiving, producing, and distributing high quality remotely sensed data in a timely manner for analysis of resource management and environmental assessment.

The program was established in 1966 to apply remote sensing techniques to the inventory, monitoring and management of natural resources. To meet its primary objective, the EROS program conducts research and training and supports other Bureaus of the Department of the Interior and other federal agencies in the interpretation, application, and merging of remotely sensed data with other traditional earth science data sets to develop spatial data information systems. The EROS program also provides certain types of remotely sensed data for purchase by scientists, resource managers and the public.

1.3.3 Cartographic and Geographic Information

The objectives of the program are to collect, analyze, and disseminate information generated by the national Mapping Program and other activities within the geological Survey as well as to serve as a clearing house for all domestic cartographic and geographic information. Through this program, the Geological Survey gathers, reviews, indexes and catalogs information about the Nation's cartographic and geographic products thus minimizing duplication while assisting Federal, State and private agencies in planning and developing the specialized products needed for their programs.

1.3.3.1 Side-looking Airborne Radar (SLAR)

The objectives of this program are to acquire, distribute, and use Side-looking Airborne Radar data for resource assessment. The objectives are accomplished by acquiring and archiving SLAR data; producing and distributing high quality SLAR data; and using SLAR data for geologic, hydrologic, and cartographic applications. The

SLAR program was initiated during FY 1980. Since then, the Geological Survey has acquired and entered into the public domain SLAR data within both the contiguous U.S. and Alaska. The areas chosen have either high potential for energy and mineral resources or lack quality maps due to persistent inclement weather. The survey recognizes the value of SLAR technology for certain applications and believes that sufficient SLAR data have been acquired and made available to the public to demonstrate their utility.

1.3.3.2 Geologic Hazards Survey

Surveys are conducted to acquire data useful in predicting and delineating hazards from earthquakes and volcanoes and to identify engineering problems related to nuclear reactor siting, ground failure and construction hazards. There are five elements in the program: Earthquake Hazards Reduction; Volcano Hazards; Ground Failure and Construction Hazards; and Reactor Hazards Research. The National Earthquake Information Service (NEIS) is part of this program. Activities in the program include maps and risk assessments for earthquakes and volcanoes, along with hydrologic hazards studies of areas of volcanic activity, research into geologic processes that may result in land-slides (including mud flows and debris flows), and Arctic engineering geology and permafrost studies in the northern Alaska coastal plain.

1.3.3.3 Land Resource Surveys; Geologic Framework Program

The program is one of three within the Land Resources Surveys activity which emphasize acquisition of baseline information needed to support ongoing and future mission activities. Information is developed across a broad spectrum of topics in geology,

geophysics, and geochemistry. The three major areas of research are: geological, geochemical, and geophysical surveys to determine the distribution and properties of both rocks and unconsolidated materials; studies to determine the absolute and relative ages of these materials in order to determine rates and frequencies of geologic processes; and studies of geologic processes responsible for the formation, modification, and distribution of those materials within and at the surface of the Earth. Geochemical surveys indicate the distribution of trace elements in near-surface rocks, soils, and vegetation. In FY 1982, 54 maps and 149 reports were completed; for FY 1983, 60 maps and 200 reports; in FY 1984, it is estimated there will be 62 maps and 200 reports.

1.3.3.4 Land Resource Surveys; Geomagnetism

The objectives are to measure changes in the strength and direction of the Earth's magnetic field. The data are used in the preparation and publication of navigational charts, topographic maps, and specialized magnetic surveys used by industry and Federal and State governments. Along with the 11 geomagnetic observatories maintained by the Geological Survey, data from NOAA observatories and 125 field sites throughout the US are used to produce 5-year revisions of the US Magnetic Charts and the mathematical model of the world magnetic field. The continuous data obtained by the observatories are studied to characterize and record the slow changes and evolution of the magnetic field and to understand the interaction between the Earth's magnetic field and the sun. Within the Geological Survey, the basic geomagnetic data provide the basis for interpretation of aeromagnetic anomaly maps used in exploration for fossil fuels, geothermal energy and minerals, and in studies of geologic structures associated with earthquake and volcanic hazards.

1.3.3.5 Land Resource Surveys; Climate Change

The program objectives are to: establish the long-term history of the rates, frequencies, and magnitudes of climate change through studies of the geologic record; determine the effects of climate change on natural resources; and develop and improve techniques for delineating climate history. Studies of long and continuous records receive priority, as these studies are important for delineating the reasons and mechanisms for climate change. The climate program provides prehistoric geologic information bearing on the natural variability of past climate. This information is necessary to assess if or how much man's activities are influencing natural patterns of climate change. The program provides a geologic data base that can test the results of numerical models seeking to predict changes in climate due to future man-induced or natural changes within the climate system. Principal activities in FY 1984 include: coring (including the study of pollen, ostracodes, and diatom fossils and geochemical and isotopic changes in sediments; study of the relationship between past variations of the Earth's magnetic field and climate change and the impact of volcanism on climate; investigation of the effects of climate change on contental margins; and study of times and magnitudes of past atmospheric Co2 variation using stable mineral phases, isotopes, compilations of carbon reservoir magnitudes, and other criteria; and to establish and test carbon cycle models.

1.3.3.6 Water Resources Investigations

The activities include: collecting, on a systematic basis, through a national network of hydrologic stations and sites, data needed for the continuing determination and evaluation of the quantity, quality, and use of the Nation's water resources; conducting

analytical and interpretive water-resource appraisals describing the occurrance, availability, and physical, chemical, and biological characteristics of surface and ground-water; conducting supportive basic and problem-oriented research in hydraulics, hydrology, and the related fields to improve the scientific basis for investigations and measurement techniques and understand hydrologic systems sufficiently well to quantitatively predict their response to stress, either natural or man made; disseminating the water data and the results of these investigations; and coordinating the activities of Federal Agencies in the acquisition of water data for streams, lakes, reservoirs, estuaries, and ground waters.

1.3.3.7 National Water Data System; Data Collection and Analysis

The objectives of this program are to collect, analyze, interpret and make available data and information on the quantity, quality, and location of the Nation's ground and surface waters. Some of the activities include hydrologic data collection where streamflow will be gaged continuously at 860 stations and lake and reservoir contents and changes recorded at 50 stations; streamflow measured intermittently at 90 sites; ground water levels or pumpage measured at 5,000 sites; and runoff data collected in 25 urban areas. National Water Quality Networks provides data, from 503 stations, on stream quality along with water-quality and water quantity records collected at 80 stations. Also included in this activity is the hydrologic benchmark network with water quantity data from 58 sites and water quality data from 52 sites. Water quality will be determined on a periodic basis at 760 surface-water sites. Research will continue to develop more precise and rapid analytical methods for analysis of trace metals, pesticides, and other organic substances in

water and more reliable techniques for collecting sediment data. In FY 1984, emphasis will be on improving the capability for measuring substances in aquatic ecosystems.

1.3.3.8 National Water Data System; National Water Data Exchange

NAWDEX is a nationwide interagency program consisting of a cooperative membership of more than 250 Federal, State, and local governmental, academic, and private water-oriented organizations. Over 430,000 data sites for which data are available from more than 400 organizations will have been indexed by 1984, over 800 data sources will have been identified, a system for indexing of areal water data has been implemented, and a membership-wide program for the manual indexing of water data maintained. The computerized data files of NAWDEX are used to produce a variety of listings, numerical summaries, and site-location plots to aid in identifying available water data. In addition, the Water Data Sources Directory is made available in both printed and microfiche form and various catalogs and indexes of water-data activities are produced.

1.3.3.9 National Water Data System; Regional Aquifer Systems Analyses

The objectives of this program are to determine the availability and chemical quality of ground water stored in regional aquifers, the recharge-discharge characteristics of the aquifers, and the hydrogeologic and geochemical controls that govern the response of the aquifer systems to stress. Although each investigation is designed to fit the particular problems of the study area, the general approach is to develop a computer simulation for the overall aquifer system, supported by more detailed simulations of local or subregional problem areas.

1.3.3.10 National Water Data System; Improved Instrumentation

The objectives of this program are to improve the technology, methodology, and instrumentation to collect hydrologic data in the most time and cost-effective manner. The program is designed to apply recently developed computer, electronic, and satellite communication technologies to hydrologic data collection at stream-gaging and other hydrologic stations to more fully automate and modernize the activity. Two key elements are the development of a new hydrologic field data aquisition system, and the enhancement and operational testing of real-time hydrologic data collection.

1.3.3.11 National Water Data System; Water Resources Assessment

This program provides information about the availability, quality, and use of water resources in formats to facilitate the analysis and development of water policies by: improving the understanding of the magnitude and trends of water problems; developing and maintaining an information base to support the quantification of water problems, the characterization of water conditions, and the analysis of options to mitigate the problems; improving existing methods to evaluate the impacts of development and water uses on water resources; and preparing thematic maps, reports, and summaries that portray the water situation. Among program activities for FY 1984 are: completion of the nationwide inventory of water withdrawals, consumptive use, return flows, and pollution loading for States not previously done; continued development of data bases (e.g., compilation of published and unpublished low-flow estimates at ungaged sites and extension of the river-basin characteristics

file to include water-quality and sediment-transport statistics) supportive of water-resources assessment; and complete initial water resources assessment.

1.3.3.12 National Water Data System; Flood Hazard Analysis

The objectives of this program are to prepare flood hazard maps in areas subject to significant flood damage and to continue development of improved techniques for flood-hazard analysis. Flood-prone areas have been delineated on more than 13,500 quadrangle maps and shown in descriptive pamphlets for 1,000 communities. The program is being discontinued at the end of FY 1983.

1.3.3.13 National Water Data System; Water Resources Scientific Information Center (WRSIC)

WRSIC maintains a national center for the dissemination of computerized and printed scientific and technical information on water resources, water resources research and technology development. Its data base reached 167,000 abstracts by the end of 1982, averaging 8,000 per year the past 2 years. The program is being discontinued at the end of FY '83; the existing data base will be retained but not updated beyond FY '83.

The atmospheric sciences, in the proposed FY '85 budget, are slated for increases. The four areas that were designated for significant growth in FY '84 continue to be emphasized in FY '85. The areas are: instrument and research equipment acquisition; mid-altitude storm research; global tropospheric chemistry; and climate studies. According to analysis reported in AAAS Report IX: Research and Development FY 1985, specific areas that will be emphasized include: climate dynamics,

research on the impact of radiation/cloud interactions on climate will be expanded; in experimental meteorology, the field program on east coast winter storm will be conducted in FY 1985; as part of the continuing phase-down in GARP, more of the support for climate-related modeling will be carried out in the Climate Dynamics Program; and at NCAR, the increase will provide for the initial acquisition cost of an Advanced Vector Computer (AVC) and additional mass storage capability.

1.4 National Science Foundation

The National Science Foundation is involved in some fundamental research with potential applications to disaster warning and management. A sample of these programs are outlined here.

1.4.1 Astronomical, Atmospheric, Earth, and Ocean Sciences (AAEOS)

The goals of the AAEOS activity are to: increase understanding of the physical nature of the universe; advance the knowledge of the behavior of the earth's atmosphere; improve knowledge of the composition of the world's oceans, their dynamic properties, the seafloor underlying them; and advance knowledge of natural phenomena and processes in the Arctic. Within the AAEOS Directorate is the Earth Sciences Division.

In the area of basic earth sciences, the NSF provides at least 90 percent of the funding to the academic community. Other agency funding in the earth sciences, primarily by USGS, NASA, and DOD, is largely applied research related to their missions. Budget reductions in this field in other agencies, however, may increase proposal pressure on the programs in this Division. The Consortium on Continental Reflection Profiling is funded to permit year-round field operations. Other research on the continental crust will also be funded. Overall funding for AAEOS

continues to increase. Some programs of interest in the Earth Sciences Division include the Environmental Geosciences Program which funds research that deals with the physical and chemical processes that occur near the earth's surface, the Crustal Structure and Tectonics Program which supports projects to reconstruct part of crustal plate configurations by use of geologic and structural mapping, age dating, and paleomagnetic techniques, the Experimental and Theoretical Geophysics Program which supports research concerned with physical properties of the solid earth including the earth's dimensions, magnetic, electrical, and gravitational fields, its dynamic processes, and the physical properties of the solid earth including the earth's dimensions, magnetic, electrical, and gravitational fields, its dynamic processes, and the physical behavior of materials under the condition of temperature and pressure encountered in its interior, and the Seismology and Deep Earth Structure Program which supports observational, laboratory, and theoretical studies directed at an understanding of the earthquake process, how seismic waves propogate in the earth, and the determination of earth structure from seismic observations.

1.4.2 Ocean Sciences

NSF currently supports about 50 percent of all Federally supported ocean research efforts in the U.S., and about 75 percent of all academic basic ocean research. In addition, almost 70 percent of the funding for the Federally-funded 25-vessel academic research fleet is provided by the Ocean Sciences Division. Anticipated reductions in research support by the Office of Naval Research, NOAA, DOE, Bureau of Land Management (BLM), and the USGS will increase the pressures on NSF's ocean sciences programs. Efforts are being made to reduce the size of the academic fleet and increase its efficiency to support grants better and

more economically.

The Ocean Sciences include studies of the physical, chemical, geological and biological processes in the ocean and at its boundaries with the atmosphere, the seafloor, and the shoreline to increase knowledge of these processes. Support is provided for research grants to universities for oceanographic ships and facilities essential in the research efforts.

The Physical Oceanography Program supports research to understand the physical properties and boundaries of the water masses and driving forces such as wind, solar radiation, precipitation, the earth's rotation and the tides.

The Submarine Geology & Geophysics Program supports research to define the characteristics and distribution of marine sediments and rocks, and work to decipher the processes such as plate tectonics, sediment transport, earthquakes, and submarine volcanism which control the nature of the seafloor.

1.4.3 Atmospheric Sciences

Research in Atmospheric Sciences is aimed at improved understanding of the atmosphere from the earth's surface to outer space. Processes ranging from those in the interior of a single cloud to those on an ocean/continental scale, such as monsoons, are examined. Scientific activities are carried out through research grant programs and the National Center for Atmospheric Research (NCAR).

In 1983, the budget for Atmospheric Sciences was supported by the NSF to be increased to allow initiation of field experiment data analysis and augmentation of research on local weather and chemical processes in the atmosphere. Also, NCAR research on large storms, cloud physics instrumentation, and use of the radar network will be

augmented. Support for the National Scientific Balloon facility (NSBF) was anticipated to be discontinued and the facility turned over to NASA.

This Aeronomy program supports theoretical, observational and experimental programs directed at understanding the upper atmosphere--its behavior and the physical processes determining that behavior and the interactions of its constituents with solar electrons, protons and electromagnetic radiations. Observational data are provided by various remote sensing instruments including optical and radar sensors. These include a chain of 4 incoherent-scatter radars located at approximately the same geomagnetic longitude. Program provides support for the atmospheric programs at the National Astronomy Ionosphere Center.

The Climate Dynamics Program seeks to improve understanding of global climate processes as a basis for predicting climate variations and for assessing their impact on humans. To achieve such an understanding requires improved and expanded global observations of present climate variables and increased efforts to describe important physical processes that control climate. Improved climate prediction is a national effort that involves the activities of many government agencies.

The Experimental Meteorology Program supports field-oriented research on the physics and dynamics of the troposphere including research on both deliberate and inadvertent weather modification. The Meteorology Program supports a broad spectrum of research on the physical and dynamical behavior of the lower atmosphere. These programs represent the major single source of support in the nation for research in this field.

1.4.4 National Center for Atmospheric Research (NCAR)

NCAR is managed and operated under an NSF contract with

the University Corporation for Atmospheric Research (UCAR), a nonprofit consortium of 50 academic institutions offering doctoral programs in atmospheric sciences. NCAR emphasizes increased understanding of atmospheric processes and events. The fundamental knowledge obtained is potentially useful for improved weather predictions, storm forecasting, and improved understanding of climate changes, of chemical constituents and reactions within the atmosphere, and of how solar energy drives the atmospheric heat engine and modifies terrestrial weather and climate. NCAR facilities include computing and data archival systems, a fleet of 4 NSF-owned and one leased research aircraft, radars and other instruments for observational and experimental programs.

The Atmospheric Analysis and Prediction Program is directed toward understanding the processes that determine the physical structure and behavior of the atmosphere and oceans and toward developing the means for predicting their behavior. This is accomplished through studies of climate patterns, severe storms, global ocean circulation, and large-scale dynamics of the atmosphere. Most of the increase in budget will be used to expand climate and mesoscale modeling research.

The Atmospheric Chemistry and Aeronomy focuses on understanding the chemical composition of the atmosphere and on determining the chemical, physical, and biological mechanisms that influence chemical balances within the earth's atmosphere. Mathematical models are being developed to analyze global atmospheric data and predict future trends in the chemical composition of the atmosphere. Increased funding will be used primarily for development of atmospheric chemical instrumentation to measure oxides of nitrogen and sulfur, and preparation for a global tropospheric measurement field program.

The Convective Storms program aims at improving basic

understanding of severe local storms and their production of precipitation, hail, lightning, and damaging winds. Research is centered on the microphysical processes and air motion interactions that occur in the formation and evolution of severe storms. Budget increase will allow development of advanced airborne cloud physics instrumentation in collaboration with NCAR Atmospheric Technology Division.

The High Altitude Observatory center conducts research on solar-terrestrial physics. Efforts range from studies involving interplanetary processes and the geomagnetic response to solar variations and studies of stellar analogues of the sun. These studies aim at improving understanding of solar processes and their influences on the interplanetary medium, including climate trends and their causes. Most of the increased budget will support development and construction of a new instrument to measure solar magnetic fields.

The Ocean Drilling Programs (ODP) is an interdisciplinary science program that supports a unique worldwide effort to explore the earth's crust beneath the oceans. The main thrusts are: 1) refinement of the plate tectonics theory; 2) detailed studies of the history of the earth's evolving climates and life forms in relation to changes in oceans and atmosphere; 3) establishment of a geological basis for understanding the formation and distribution of natural resources in the world's ocean floor; and 4) development of scientific and technical means for deep ocean scientific drilling and coring. The scientific ocean drilling programs have no counterparts at this time in academia, the private sector, other government agencies or elsewhere in the world.

At present, the Deep Sea Drilling Project is the only operational project in the Ocean Drilling Division. It has been supported

by NSF since its inception in 1966. The current International Phase of Ocean Drilling (IPOD) will be completed in early 1983. Major contributions include the first reconnaissance of the makeup of the earth's crust beneath the oceans, the most convincing research results to date in support of the plate tectonics theory, and technological innovation in deep ocean drilling. An ad hoc committee will be convened by NSF to make specific recommendations on scientific priorities and technical and support requirements in crustal studies supported by Earth and Ocean Sciences Division as well as the Office of Scientific Ocean Drilling. Since 1974, IPOD has been fully international. France, Germany, Japan, and the United Kingdom are full participants in all aspects of scienfitic planning and operation, and provide about one-third of the operating funds. The Soviet Union was an IPOD member from 1975-1979.

The U.S. Antarctic Program supports national goals to: maintain the Antarctic Treaty, ensure that the continent will continue to be used for peaceful purposes only, foster cooperative research to contribute to the solution of regional and worldwide problems, protect the environment, and insure equitable and wise use of living and nonliving resources. Thus, the U.S. scientific research program continues to be the principal expresion of national interest and policy in Antarctica.

The antarctic area is of further interest to the U.S. because it: has a major influence on world weather and climate; has the world's richest marine protein resource potential; has other resources of unique scientific and practical interest; and provides an excellent environment for international cooperation.

The U.S. Antarctic Research Program is intended to increase knowledge of the Antarctic continent and the surrounding oceans by developing an understanding of the antarctic ice sheets and the antarctic

physical, biological, geological, meteorological, atmospheric, chemical, and oceanographic processes. The research is conducted at four antarctic stations, from remote temporary field sites, and aboard ships. Remote sensing techniques, using satellites, aircraft, rockets, balloons, and unmanned stations are used in the conduct of the research. Cooperative research programs with scientists of other nations are commonplace.

The major objectives of the program are to advance understanding of the relationship of Antarctica to global weather and climate; to develop a better basic understanding of upper atmosphere physics, tectonics, terrestrial biology, and paleontology of Antarctica and their relationships to the rest of the world; to evaluate the renewable and nonrenewable resources; and to gain additional knowledge of the physical and biological characteristics of the continent and adjacent seas.

1.5 Smithsonian Institution

The Smithsonian Institution is involved in several research projects of direct relevance to disaster warning and management. This includes work in mineral sciences and ocenaography.

1.5.1 Mineral Sciences

"Volcanoes of the World," the most comprehensive summary of global volcanism ever assembled, was published in August 1981 after ten years of research. The detailed reference book covers 5,564 eruptions, arranged chronologically with data on duration, explosive magnitude, and volume of products; and 1,343 volcanoes active in the last 10,000 years, arranged by region with data on locations, heights, types, known eruptive history, and behavioral characteristics. The book's data is concentrated in a computer data bank, therefore, feedback can be quickly incorporated to build an increasingly complete record of global volcanism. The data bank is already being used for studies ranging from plate tectonic maps to tidal influences on volcanism.

1.5.2 Smithsonian Oceanographic Center

Collections arriving at the Center included trawl fishes from the Hawaiian Islands and African freshwater fishes from Lake Malawi. Collections of benthic invertebrates came from the Azores, the Philippines, Colombia, Okinawa, Hawaii, and the Solomon Islands. Notable geophysical events reported by the Scientific Event Alert Network in monthly publication included; the continuation of episodic lava extrusion at Mount St. Helens; major explosive eruptions in the USSR and the Mariana Islands that injected ash into the stratosphere; repeated extrusion of lava flows on Reunion Island; two destructive earthquakes in Iran; and meterorite falls in Yemen and Oregon.

1.6 Tennessee Valley Authority (TVA)

The Tennessee Valley Authority is currently engaged in several programs of potential interest to OFDA. These are discussed below.

1.6.1 Flood Hazard Analysis

A computerized flood information management system is about 90% completed. Although TVA's system of dams has removed much of the threat of flooding on the Tennessee, evolving changes in land uses and shoreline structures required continued attention to recognize changes in flood patterns and risks. The process of defining the potential for future flooding in the region will continue, and modifications will be made to computer programs needed for efficient flood hazard analyses. The effectiveness of the TVA reservoir system and flood control operations in reducing floods will be evaluated following major floods. Responses to requests for flood information and documentation of floods for use in future ev 'u[illegible] ..s will continue.

6.2 Valley Mapping and Remote Sensing

This program provides maps and other geographically referenced data fundamental to the development and management of the resources of the region. As critical as the geological representation of maps is, the inclusion of current documentation of manmade structures and alterations to land uses. The program produces topographic maps of various scales. Remote sensing provides innovative methods of resource and other data collection which reduce operating costs. A prototype land-use/land-cover thematic overlay will be produced to demonstrate the feasibility of such a resource as a supplement to the topographic map series. The program will continue installation of an Automated Mapping System. Using this system it will initiate revision of 12 Valley Topographic Map quadrangles. Revisions using manual methods will still be necessary until all

quadrangles are digitized under a phased schedule. Four surface and groundwater resource maps will be produced using remote sensing techniques. A prototype Valley-wide land-use-land-cover inventory will cover 23 7-1/2 minute quadrangle maps, will be referenced to the Valley's standard geographic base using the Automated Mapping System, and will be incorporated in TVA's Geographic Information System for use in resource management.

1.6.3 Water Resources Support Center

The Water Resources Support Center is located in Fort Belvoir, Virginia. Its divisions are the Institute for Water Resources, Dredging Division, Data Collection and Management Division, Publications and Training Division, and the Office of Administrative Services. The Center also manages the Hydrologic Engineering Center in California, the Marine Design Branch of the Dredging Division in Pennsylvania, and the Waterborne Commerce Statistics Center in Louisiana.

1.6.4 Data Collection and Management Division

The Division is responsible for: The National Dam Inspection Act which uses field investigations and satellite imagery to inventory and inspect non-Federal dams; the Water Resources Data Center; the Remote Sensing Research Program; the Waterborne Commerce Statistics Center which collects and processes waterborne commerce data; and the Port Facilities Branch.

1.6.5 The Water Resources Data Center

This multi-purpose facility was designed to support the office of the Chief of Engineers, the Director of Civil Works, and the field divisions of the Corps with centralized access to projects and program performance information. It was created because of the need for

engineers in one division to have immediate access to weather, flooding and similar data from other divisions. The WRDC enables the Corps to respond to inquiries through queries to any or all of its data bases.

1.6.6 The Remote Sensing Research Program

Remote sensing technology initiated integration with the Spatial Analysis Methodology Demonstration Program and a Memorandum of Understanding between the Corps and NASA to conduct a cooperative program of technology assessment and transfer. The Corps increased its use of Data Collection Platforms (DCPs) in 1981. Two hundred forty nine radio frequency authorizations were issued for operation of DCP's in 1981; the Corps has tripled the number of DCP's in the last two years.

1.6.7 The Hydrologic Engineering Center

In FY81, emphasis was placed on consolidation of recent R&D projects into field usable products. Areas of particular technical emphasis included real-time water control, automated flood-damage analysis, and hydrologic and hydrodynamic system analysis. New computer programs were released for modeling storm runoff, operating of reservoir systems, and inventorying and managing flood damage potintial. User documentation and technical guidance were issued for flood-flow frequency analysis, sediment transport modeling, hydrodynamics of two-dimensional flows, routing floods in densely populated floodplains, preparing flood emergency plans, and preparation of water balances for water supply investigation. Specific workshops in river hydraulics and flood hydrology were held. The HEC also provided assistance to the Federal Emergency Management Agency in density floodway analysis and was a major contributor to the Corps' National Hydropower Study.

1.6.8 U.S. Army Engineer Topographic Laboratories

ETL applies the latest advances in optics, electronics, computer data processing, space sciences, and related technologies to military and civil problems in mapping, surveying, navigation, and geodesy. ETL is organized into 5 operational elements, 3 of which are developmental laboratories. The Geographic Sciences Laboratory performs R&D associated with the extraction and presentation of geographic data for the Army in the field. The Topographic Development Laboratory supports technological development in surveying and mapmaking. The Computer Sciences Laboratory develops advanced computer techniques and systems for processing, analyzing, and displaying topographic data derived from digital photography. The Research Institute performs most of the Laboratories' basic and applied research, and the Terrain Analysis Center prepares terrain studies needed by the field Army elements. ETL is the principal laboratory for remote sensing. Research Institute personnel are investigating the types of data derived from sensors and means for exploiting those data. The Computer Sciences Laboratory staff is investigating the digital processing of remote sensing data. Geographic Sciences Laboratory members have defined remote sensing inputs required for Army terrain graphics and terrain data bases. ETL also assists the Civil Works Directorate with remote sensing information relating to inland waterways, water resources, and flood control.

1.7 Corps of Engineers

The Corps of Engineers is also involved in a wide range of programs related to disaster warning and management.

1.7.1 Hydraulics Laboratory

The Hydraulics Laboratory is the largest of its kind in

the world. It uses a wide range of working models and computer-based numerical models for research and analysis of dams, levees, rivers, and harbor projects, as well as soil and streambank erosion, and thermal pollution.

1.7.2 Coastal Engineering Research Center

CERC is the principal research and development facility of the Corps in the coastal engineering field. Its mission is to conceive, plan, and conduct research and data collection in coastal engineering and nearshore oceanography to provide a better understanding of the littoral forces (e.g., waves, winds, tides) and the interaction of these forces with shores and beaches, coastal and offshore structures, and the materials forming them. It conducts research on shore and beach erosion control; flood and storm protection; the location, layout, design, construction, operation and maintenance of harbor and coastal and offshore structures; navigation improvement and recreation. CERC provides consulting services to the Corps and other public agencies on the planning and design of coastal and offshore works; coastal and nearshore phenomena; and related engineering and environmental problems. It operates a Coastal Engineering Information and Analysis Center to collect, evaluate, analyze, and disseminate coastal engineering information. The Coastal Engineering Research Board (CERB) provides broad policy guidance and reviews plans and fund requirements for conducting coastal engineering and development. It also recommends research project priorities and performs other duties as assigned by the Chief of Engineers.

1.7.3 CERC Field Research Facility

CERC has established a basic environmental measurements program at the recently completed facility in Duck, NC. It routinely

measures, records, and publishes data on the meteorological and oceanographic conditions at the site. CERC has installed wave height and period gages, current meters, temperature and salinity gages. Tide gages and a weather station were installed by other agencies. Work to date has included wave data analysis techniques; analysis of wave spectra; relation of longshore transport to incident waves; techniques for measuring longshore transport rates; wave direction measurements (including use of radar); use of vegetation for shoreline stabilization; coastal siltation problems peculiar to the Alaskan environment; use of remote sensing in coastal studies; geomorphology of the Atlantic, Great Lakes and Gulf coastal zone; ecological effects of rubble structures; correlation of wave climate and beach deformation; effects of long-term water level changes in the Great Lakes; wave refraction and effects on design waves; development of standardized coastal revetment designs; and evaluation of completed work.

1.7.4 General Investigations

Surveys and collection and study of basic data are part of the annual report material submitted by geographical division. In Fy 84, a total of $63.5 million is the combined budget for all states or surveys and continuation of planning and engineering studies. Surveys may be done on projects ranging from navigation to flood control to beach erosion control to multi-purpose to comprohensive or special study projects.

1.8 Deaprtment of Energy

Objectives of the Department of Energy's climate effects aspects of the program are to continue the strategy for the first detection of Co2-induced climate change and subsequent climate data analysis. The natural interannual, seasonal, and monthly variability will be established. Data collection support will continue for the international satellite cloud climatology program which is a joint program with NASA and NOAA. The complete data set will be available in 1988, but data will be available to the climate modelers throughout the program.

The Department is also involved in the study of Indirect Effects of Carbon Dioxide. Objectives of the program are to continue to analyze the effects of climate change and increased atmospheric Co2 on agriculture, water resources, and human health; and to initiate a program to map the West Antarctic ice sheet by remote sensing methods to help answer the question of what the response of the West Antarctic ice sheet to Co2-included climate warming will be.

The Department of Geosciences activity supports long range research in geology, geophysics, geochemistry, rock mechanics and tectonophysics to develop a quantitative and predictive understanding of processes in the earth and solar terrestrial interface. Seismic activity, tectonic uplift and increased fumarolic activity at Long Valley-Mono Craters has opened a second area for detailed site study in the continental Scientific Drilling Program (CSDP). The need for in-site geophysical and geochemical information has increased the need for research in advanced geophysical techniques.

1.9 National Aeronautics and Space Administration

The National Aeronautics and Space Administration is an important player in any satellite based system relating to disaster mangement and monitoring because it will develop future spacecraft and be involved in their launch and operation. At the same time, NASA is currently developing plans for a manned space station which will impact on the future of all space activities. Here, we will review only three areas--those of earth remote sensing, communications, and geodynamics.

1.9.1 Remote Sensing

A major initiative currently under consideration in the Office of Space Science and Applications is the Earth Observing System, or EOS. This initiative is born out of the concept that many earth science disciplines have similar observational requirements, and that the traditional science disciplines are involved in studying similar phenomena. In addition, many of the problems involved in understanding the earth are cross-disciplinary. The EOS concept includes a permanent, highly adaptable and evolving civil space facility in low earth orbit and a ground data base and management system, interactive with the broad science community and science information data base systems.

At least part of the EOS will include orbiting platforms which comprise part of the overall space station program as detailed in NASA's five year plan. Data and information from EOS will complement and provide continuity with the data and information from currently planned earth science missions such as the Upper Atmospheric Research Satellite and the Topography Experiment for Ocean Circulation (TOPEX). It will also continue the use of data from current satellite systems including the US meteorological satellites and Landsat. As such,

this program represents a potentially very important step in moving towards a global information system based on remotely sensed data and information.

In the area of earth resource sensing, NASA intends to fly two instruments on the Space Shuttle--the Large Format Camera (LFC) and the Shuttle Imaging Radar (SIR-B). The LFC is a high resolution photogrammatic camera which will provide 15m resolution for high-contrast objects. The SIR-B is an upgraded version of the SIR-A flown on the second shuttle mission. It will have a resolution of 40m. In the future, NASA hopes to develop a Multispectral Linear Array which involves the development of an advance, high-performance, solid state sensor. The program to do the development is also focusing on development of on-board signal processing and advanced ground data-processing concepts.

In the area of Meteorological satellites, NASA continues to operate the Nimbus series of satellites. These satellites are instrumental in the measurement of the earth's radiation budget and in research and development on cloud formation and the effects of aerosols on the atmosphere and stratosphere. In addition, the International Satellite Cloud Climatology Project is expected to develop a global cloud-climatology data set.

There are a range of potential new initiatives being discussed by NASA at the current time. They include the Upper Atmospheric Research Satellite (UARS) several different types of instruments to be flown on the shuttle, TOPEX, and the Geopotential Research Mission.

The goal of the UARS program is to enhance our understanding of the chemical and physical processes occurring in the earth's stratosphere. Its primary objective is to develop an understanding of the upper atmosphere and the response of the upper atmosphere to natural

and man-made disturbances.

NASA is also discussing the possibility of flying an Ocean Color Imager as a follow-on to the Coastal Zone Color Scanner flown in the late 1970's. Such an imager would provide data on the ocean which is essential to the determination of global fishery productivity.

The TOPEX program is proposed as a means of improving dramatically our capability to observe the oceans on a global scale. Its key objectives will be to measure ocean topography and to integrate that data with other data to develop an understanding of the general circulation of the ocean and measurements of its variability. Climate changes, fish production, commerce, waste disposal and defense are all areas which are potentially impacted by the outputs of this proposed program.

The Geopotential Research Mission (GRM) will provide the best data to date on the global gravity field and geoid yet available and will enable an update of magentic field models in the 1990's. The knowledge gained from this program will be essential to scientific studies of the Earth's gravity and magnetic fields--which are in turn important for studies of energy and mineral resources.

1.9.2 Communications

NASA has two important communications initiatives currently under discussion. The first is the Advanced Communications Technology Satellite (ACTS) and the second is a Land Mobile Communications Satellite.

The objective of the ACTS program is to provide for the development of technologies which will increase the effectiveness and efficiency of communications satellites. These technological areas include spacecraft antennas, on-board switching, and signal processors. In addition, NASA will be working on the radio-frequency components necessary

for operating in the 30/20 GHZ band, which has five times the allotted capacity of the current bands used for satellite telecommunications (the C-band and the Ku-band). The development of this technology will insure that the continued growth in the use communications will not saturate the orbit-spectrum allocated for communications satellites.

In addition, NASA has been looking at the need for and viability of Land Mobile Communications via satellite. The Land Mobile Communication Satellite is planned for development in cooperation with the Canadian Communications Research Centre. It will have a large (30 ft. diameter) deployable antenna that will provide communications between small earth terminals on mobile vehicles and stationary base stations. NASA will focus on the development of the small earth terminals while the Canadians develop the satellite.

1.9.3 Geodynamics Program

The NASA Geodynamics Program contributes to the understanding of the solid Earth through the use of satellite laser ranging (SLR), lunar laser ranging (LLR) and very long baseline interferometry (VLBI) to: measure and study the movement and deformation of the major tectonic plates, regional crustal deformation at plate boundaries, and the Earth's rotational dynamics; and survey and model the Earth's global gravity and magnetic fields. The laser and VLBI techniques have been adapted to both fixed observatory-type facilities and mobil (truck mounted) stations that can be moved to prepared sites. The magnetic field information is obtained from direct surveys, i.e., magnetic field satellite (MAGSAT).

NASA has actively supported the involvement of other countries in its program. At present, 21 countries are participating with

NASA in data acquisition and/or data analysis. In FY 1984, NASA plans to negotiate agreements with 17 countries in the Caribbean Basin. The European WEGNER consortium was formed by the European and U.S. investigators to study the tectonics of the Mediterranean. Other reciprocal agreements have been established between NASA and other countries.

1.10 National Earthquake Hazards Reduction Program

In 1977 the United States Congress established the National Earthquake Hazards Reduction Program (NEHRP) to provide a comprehensive, integrated national program to reduce losses of life and property resulting from earthquakes. Federal responsibility lies principally with the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), the National Science Foundation (NSF), and the National Bureau of Standards (NBS). Leadership and coordination rests with FEMA; research is the responsibility of USGS, NSF, and NBS; mitigation is FEMA, USGS, and NBS: and Federal mitigation, preparedness, and response is the responsibility of FEMA. Information, dissemination and public awareness is the responsibility of all agencies. Other Federal agencies participate in the NEHRP. Many agencies involved have cooperative foreign programs. The NEHRP is presented here as an example of interagency cooperation on a national program related to disaster warning and management.

1.10.1 FEMA's Role

FEMA is the lead agency for NEHRP, responsible for program planning, direction, and coordination. It is also responsible for coordinating Federal emergency management activities (preparedness, response, recovery, and mitigation) for all types of disasters--national and man-made. When a major disaster or emergency is declared by the

President, FEMA administers Federal assistance to the State(s) affected, local governments, and individuals and coordinates the disaster relief efforts of other Federal agencies and voluntary agencies.

Among efforts of FEMA is impact assessment. Results of a joint FEMA/Department of Defense project assessing the effects of a major earthquake in California, are transferable to the NEHRP for preparedness planning and mitigation programs. In addition, contracts have been let to develop computerized techniques to assess damage and casualties in simulated earthquakes. Results of the analyses can suggest appropriate protective and response measures needed to reduce the impacts of real earthquakes.

Other FEMA efforts include coordinating the development of a national comprehensive plan for immediate response to a catastrophic earthquake. Mitigation efforts include review of seismic standard for buildings. FEMA provided funding to USGS in support of workshops for public officials and others to learn more about seismic hazards.

FEMA provides technical and financial assistance to state and local communities in all segments of emergency management (hazard awareness, assessment, preparedness, mitigation, response, and recovery) for all types of disasters.

FEMA's Emergency Information and Coordination Center (EICC) provides emergency management authorities wth 24-hour information, data and facilities for making accurate and timely decisions. During FY 1983, the EICC supported information and coordination activities for 212 technological hazard emergency or disaster situations and 323 natural hazard emergency or disaster situations, including 87 earthquakes.

As a natural disaster or emergency situation develops, the EICC receives information from the National Severe Storm Center, the Hurricane Center, the National Earthquake Information Center, the Pacific

Tsunami Warning Center, or the Volcano Center. Information is passed on to emergency action teams at the EICC and communicated to and coordinated with the National Operations Centers of the pertinent Federal agencies, the White House, and the pertinet FEMA Regional Offices and State/local Emergency Operations Centers. Each emergency action team includes an emergency action officer (EAO), emergency action specialist, communications operator for coordination and operation control, a message center clerk, and an electronics maintenance technician.

FEMA has been cooperating with USGS and the American Red Cross to develop, review, and implement information materials. Hazard awareness and eductional materials for use in both public and private sectors are part of FEMA's program. A variety of educational programs for schools have been developed or reviewed as part of the preparedness and mitigation efforts.

As part of the effort to assist state and local preparedness programs, FEMA focuses on the preparation of response plans that address the extraordinary problems caused by major earthquakes in high-risk, high-population areas. Initially, based on estimates of past and potential seismic activity in the area, vulnerability analyses are conducted to probable primary and secondary earthquake effects, estimates of possible casualties and injured requiring hospitalization, and estimates of potential damage to critical/special facilities and lifelines needed for immediate response. Using data from the analyses, FEMA assists state and local governments in determining the resources required for lifesaving and other emergency operations and to develop response plans. The plans include implementation measures, such as guidelines, procedures, and specific assignments. The final phase of the planning efforts consists of

scheduled training exercises.

During FY 1983, FEMA was involved in state and local preparedness programs in the Central United States, completing its report on the estimated effects of a catastrophic earthquake in the New Madrid seismic zone; developed a Central U.S. Earthquake Consortium; developed a State Earthquake Safety Program (SESP); created a Technical Advisory Panel; and developed a report on the status of seismic codes and ordinances in the seven state area. Other areas FEMA assisted include: Southern California, the San Francisco Bay area, San Diego, Hawaii, Puget Sound, Alaska, Charleston, S.C., and Boston.

In the area of multihazard emergency management, FEMA has embarked on an improved method for implementing its programs--the Integrated Emergency Management System (IEMS). IEMS stresses an integrated approach to management across the full spectrum, including natural disasters, technological disasters, resource shortages, and attack. Those disasters such as catastrophic earthquake events or war are accorded special attention and greater Federal involvement and assistance. General principles applying to the development of IEMS include providing maximum flexibility to State and local governments in achieving commonly accepted goals as well as integrating emergency management planning into mainstream state and local government planning and decision-making.

Several pilot multihazard projects have been initiated by FEMA. These include: a workshop held by the National Academy of Sciences to develop multihazard mitigation strategies; a contract to a private consultant to develop guidelines for state implementation mechanisms; Puerto Rico Earthquake and Hurricane Project; preparedness and mitigation plans in Alaska; and seismic assessments of dams in Utah, which led to the State of Utah Multihazards Project--Earthquake/Dam

Safety/Floods. In Utah, by focusing on a lead hazard (dam failure), the project was able to be initiated quickly and with the requisite support within the State. The work plan for the preparedness model is complete, the candidate site-selection criteria for site application for the model is in place, and the final report on the model (including application experience) is expected in early 1984. The multihazard project concept will be applied in other regions of the country. These efforts will focus on strengthening the model, utilizing an appropriate "lead hazard" for the given area and incorporating particular local needs into the assessment. FEMA will utilize the results of the various efforts to develop generic multihazard preparedness and mitigation guidelines.

1.10.2 U.S. Geological Survey's Role

The U.S. Geological Survey (USGS) conducts a national research effort to reduce hazards and risk from future, potentially damaging earthquakes in the U.S. The USGS Earthquake Hazards Reduction Program supports fundamental and topical research in earthquake hazards and prediction to provide earth science data and information. The program fosters hazard reduction through land-use planning, earthquake-resistent design, and emergency preparedness decisions. The program has five elements: Regional Monitoring and Earthquake Potential Studies; Earthquake Prediction Research Regional Earthquake Hazards Assessments; Data and Information Services; and Engineering Seismology.

USGS also participates in foregoing earthquake investigations and a number of international cooperative projects in observational seismology, studies of strong ground motion, and earthquake prediction to accelerate and ennance earthquake research in the United States. USGS conducts an active outreach program to transfer earthquake

hazards information to the public and user communities.

The USGS makes seismologial and geologic analyses of seismic activity, active geologic faults, and earthquake potential of seismic regions in the U.S. The studies are designed to: delineate seismically active areas and the extent of seismic zones with regional seismographic networks; determine the geometry and structure of seismic zones through geologic mapping and geophysical analyses; and, ultimately estimate fault slip rates, maximum earhquakes, and recurrence intervals for active faults and seismogenic zones. Substantial progress has been made in the past several years in estimating the long-term earthquake potential of various seismic zones. The estimates are based on detailed analyses of current tectonics of seismically active regions as interpreted from geological and geophysical observations. These studies have provided quantitative estimates of slip rates along active faults. They have also defined tectonic structures that give rise to the seismic activity.

Regional seismographic networks, in seismically active areas, provide important baseline data through prompt location of earthquake events and high-resolution determination of their parameters. In FY 1983, the USGS made significant advances in the development of on-line, real-time automatic seismic data processing systems. Network data are telemetered to a central collection point where a microprocessor system, constantly monitoring the network in real-time, automatically identifies and picks P-waves arrivals as they occur. Computer determination of the earthquake hypocenters automatically follows, usually within a few minutes, thus providing early and accurate information on the location and progress of an earthquake sequence while it is occuring. These systems allow for the direct observation of crustal changes that precede, accompany, and follow earthquakes.

The USGS was involved in an extensive investigation of the Coalinga, California earthquake. In FY 1983, two independent studies of the long-term possibilities of large earthquakes along the San Andreas fault system were completed. Two separate seismological teams completed a study of earthquake potential in the Pacific Northwest. The Pacific Northwest studies were jointly funded by the USGS and the National Science Foundation (NSF).

1.10.2.1 Earthquake Prediction Research

The goal of the program is to give warning of large, potentially damaging earthquakes at timed intervals long enough to allow appropriate action by the public and private sectors, and with enough precision to avoid a sustained disruption. To accomplish this, the USGS conducts earthquake prediction research that involves Government scientists, interacts with foreign earthquake prediction programs, and provides support for earthquake prediction studies in the academic community and private sector. USGS investigations have been focused on central and southern California, Alaska, and other selected areas in the U.S. and around the world. Earthquakes in most parts of the U.S. occur too infrequently to provide field observations and valid tests of possible earthquake precursors, therefore, worldwide investigations are necessary.

USGS earthquakes prediction research is directed toward: collection of baseline geophysical data in areas of seismic risk and development of a fundamental understanding of the physical laws governing the earthquake cycle; development of earthquake prediction methods and techniques to provide a rational basis for estimate of increased earthquake potential and short-term predictions; evaluation in probablistic terms of the relevance of various geophysical, geochemical,

and hydrological data to increase earthquake potential; development of theoretical and laboratory models of the earthquake process to guide observational experiments and to test empirical, predictive techniques; and determination of the physical mechanism for reservoir-induced seismicity and development of techniques for predicting and mitigating this potential hazard. Significant advancements in prediction have occurred during the last several years. Long-term forecasts of the recurrence of large and great earthquakes in seismic gaps (segments of plate boundaries that have experienced long periods of seismic quiescence) have proved successful. Eleven large shocks in the Circum-Pacific region have occurred in major seismic gaps that were identified as sites of high seismic potential. The average interval between major earthquakes on several faults, including the San Andreas, has been identified, permitted estimation of earthquake probabilities. The concept of seismic cycle has unified geologic and seismologic understanding of earthquake occurrence, allowing for the siting and execution of experimental earthquake prediction experiments by which the time window of prediction may be progressively narrowed.

USGS and its contractors continue to develop monitoring techniques and gather basic data on geophysical and geodetic changes associated with strain accumulation and release. Because of the likelihood of a major earthquake in California, most of these observations are made along the San Andreas fault system of California.

Crustal strain monitoring is conducted by USGS. Detection of changes in the state of crustal strain preparatory to earthquake fault slips are of primary importance for evaluating long-and short-term earthquake potential. Resurveys of triangulation networks provide a measure of strain deformation. A system of 25 geodetic strain networks in California and Nevada containing several hundred survey lines

were remeasured in FY 1983. Strain accumulation along the major fault systems is monitored on an annual basis, with additional remeasurements made when needed. The observed changes are several parts per million per decade. Materials that are being stressed at a constant rate will typically deform at a different rate dust before failure. Monitoring activities were designed to determine the time frame and scale of such anomalous deformations in the earth proceeding earthquakes. Nearly continuous train observations were made at several sites with two-color laser device, and short-base crustal deformation and fault offset observations were made at over 200 sites.

Strain monitoring systems are complimented by seismographic networks, which provide a means of locating active faults and for monitoring the status of strain release processes on those faults. With rapid processing of seismic data, it provides a basis for recognizing immediate premonitory phenomena such as foreshock activity. The seismic monitoring effort in California consists of about 500 seismographs. Last year over 8 million seismograms were analyzed and approximately 18,000 earthquakes were located. Following the initial processing, the data undergo an extensive quality control procedure and many events are relocated. The distribution of earthquakes in time and space provides a means of remotely monitoring failure processes at depths to 13 miles and illustrates the complexity of deformation occurring at the boundary between the Pacific and North American plates.

Various other geochemical and geophysical observations were made at approximately 140 sites. The latter data, which include resistivity, magnetometer, water-well level, randon or helium concentration and other geochemical observations, measure second-order

effects of rock strain and failure. As such, they are usually more difficult to interpret but may exhibit much larger percentage changes than the strain data.

A prototype operational prediction effort is a necessary revolutionary step toward the goal of a earthquake prediction capability. The Congress has requested development of a detailed program plan for completion of a prototype prediction system by FY 1988. Emphasis in the prototype system would be on integrated monitoring of earthquakes and crustal-strain phenomena. Proposed improvements include a network of crustal deformation observatories, with state-of-the-art instrumenation and borehold siting of senors; a network of digital seismometers; robust telemetry; an imminent alert system utilizing real-time processing; and enhanced data collection, processing, retrieval, and analysis facilities.

Specific studies were conducted in Parkland, California. Studying the behavior of past earthquakes, scientists have made projections on the next likely earthquake. Other researchers at USGS have developed a computer model simulation of fault behavior to predict the size, location, and time of the next Parkfield earthquake, and the history of ground deformation leading up to the earthquake. The geometic network has been supplemented in the area with a cluster of geophysical instruments to monitor changes in strain, tilt, and fault creep, and to record foreshocks that may precede the next Parkfield earthquake.

1.10.3 Regional Earthquake Hazard Assessments

The USGS evaluates the earthquake hazards of areas in the U.S. that are at risk due to earthquakes. During FY 1983, the USGS completed and published a new series of maps depicting the earthquake ground-shaking hazard in the coterminous U.S. and Alaska. The maps show maximum bedrock horizontal acceleration and velocities expected from

earthquakes during exposure times of 10, 50 and 250 years at the 90 percent probability level of nonexceedance. The maps provide the most detailed evaluation ever of the ground-shaking hazard in the U.S. incorporating new geologic information to define seismogenic zones.

The accelerated progress in the understanding of earthquakes and global tectonic during the past two decades is due in large part to the deployment of global seismograph networks that have generated a seismic data base unprecented in quality and scope. The USGS supports the operation of two of these networks: the World-Wide Standarized Seismographic Network (WWSSN), and the Global Digital Seismograph Network (GDSN).

The World-Wide Standardized Seismograph Network was established in the early 1960's as a part of Project Vela Uniform, a program of fundamental and applied research in seismology managed by the Defense Advanced Reseach Projects Agency. Key elements of the WWSSN are standarized three-component long-and short-period seismographs with uniform calibration, and the means of distributing the seismograms to the earthquake research community. Today, WWSSN comprises 110 stations operating in 54 countries. Management responsibility for WWSSN was transferred to the U.S. Coast and Geodetic Survey in 1963 and both were transferred to USGS in 1978.

Since the inception of the WWSSN, more than 5 million original seismograms have been microfilmed and 60 million high-quality film copies have been supplied to researchers. Despite the superiority of the more recently available digital seismic data for many purposes, the analog seismograms from WWSSN remain the foundation for much of the fundamental seismological research carried out.

The USGS assumed responsibility for the Global Digital Seismoraph Network in FY 1980. It was established by DARPA. GDSN, which provides extremely high quality, digital seismic data for research, is a unique international information resource. Digital recording provides much greater resolution and recording range, and the data are available in a format that is suitable for computer processing an analysis. Data from this network and analog data from the WWSSN are provided to government, university, and private seismological researchers. Data from these networks are used in studies of plate tectonics, earth structure, and earthquake source mechanisms, and are the key elements in observational research and in the verification of theoretical hypothesis in all areas of seismology.

1.10.3.1 National Earthquake Information Service

The National Earthquake Information Service (NEIS) rapidly locates and evaluates the large earthquakes that occur throughout the world, provides data support for the Tsunami Warning System, and acquires fundamental data critical for seismic risk appraisal. Products of the NEIS include weekly, monthly, quarterly, and annual reports on earthquake activity, maps of earthquake distribution, and information services to the public. A 24-hour alert service is provided and appropriate authorities are notified following every potentially damaging earthquake within the U.S.. This alert allows for the early inspection of critical facilities for possible damage. The NEIS also carries out research on the internal structure of the Earth and its effect on earthquake location and severity, seismicity patterns related to the occurrence of large earthquakes, and on the specification of earthquake sources.

1.10.3.2 Engineering Seismology

Theoretical and interpretive studies that explain the characteristics of strong ground motion and cast observational data in forms more useful to engineers, have been part of the USGS EHRP for many years. In FY 1983, responsibility for the National Strong Motion Network, a network of instruments designed specifically to record strong earthquake ground shaking, was transferred to USGS from NSF. The network consists of 500 strong motion accelerographs designed to record very strong ground motion near the source of damaging earthquakes. Information gathered by this program element aids engineers, designers, private institutions, and government agencies concerned with the siting, design, and costruction of facilities and the establishment of seismic design provisions of building codes.

1.10.3.3 Foreign Investigations

The USGS participates in foreign earthquake investigations and a number of international cooperative projects in observational seismology, studies of strong ground motion, and earthquake prediction to accelerate and enhance domestic earthquake research. USGS scientists joined a multinational investigation of the Yemen earthquake to monitor aftershock acivity.

USGS conducts 14 projects under an Earthquake Studies Protocol signed by the U.S. and the Peoples' Republic of China (PRC). The USGS Director and Vice-Director of PRC State Seismologial Bureau signed an agreement establishing a cooperative project to design, construct, and operate a China National Digital Seismic Network. The network will povide high-quality digital seismic data that will afford an opportunity to analyze characteristics of large damaging earthquakes in of

the most seismically active regions of the world.

In southern China, USGS and SSB scientists are working cooperatively to predict earthquakes. Yunan Province is a region of high seismicity where a major damaging earthquake is believed imminent. At the SSB prediction research site, a well-planned set of experiments are carried out, many of which are located in strategically distributed tunnels. The USGS has provided much of the equipment in the tunnels and training and assisting Chinese personnel in data measurement and analysis. The SSB tunnel experiment permits the simultaneous measurement of different geophysical properties at a common site. Independent measurements of possible earthquake precursors can be made and compared in a multivariate manner. The USGS team concluded that the Chinese have one of the world's most advanced and complete earthquake prediction experiments.

1.10.3.4 Implementation of Research

The USGS has convened a dozen regional workshops since FY 1978 to foster implementation of measures to reduce earthquake hazards in earthquake-prone areas of the U.S. These forums have proved important catalysts to successful mitigation of earthquake hazards. Five workshops were held in FY 1983: workshop hazards in the U.S. Virgin Islands; the 1886 Charleston earthquake and its implications; continuing actions to reduce losses from earthquakes in the Northeastern U.S; site-specific effects of soil and rock on ground motion and the implications for earthquake-resistant design; and continuing actions to reduce losses from earthquakes in Arkansas and nearby states.

1.10.4 National Science Foundation

The National Science Foundation's (NSF) activities related to earthquake hazard mitigation includes research in the earth

scienes; earthquake engineering, architecture, and planning; and the social sciences. These activities are supported through the Earth Sciences Division and the Civil and Environmental Engineering Division.

1.10.4.1 Plate Tectonics

The main goal of research on plate tectonics is to better understand plate motions and interaction which will give a better understanding of many processes in the Earth, including prediction of earthquakes. Recent projects include studies of continental lithosphere tectonics and related seismic activity. The Consortium for Continental Reflection Profiling (COCORP) has carried out a deep seismic reflection profiling program producing interesting results on the structure and tectonics of the lithosphere and on the relation of these topics to seismic activity.

1.10.4.2 The Earthquake Process

Present understanding of the details of the earthquake process comes mainly from seismic signals measured at large distances from the source. However, the prediction of earthquakes and destructive ground motion hinges on a thorough understanding of the mechanical processes leading to and causing an earthquake. The failure criteria of crustal rocks and the role of pre-earthquake deformations must be understood in order to calculate the re-initiation of motion on the fault and to determine the total seismic energy that is released.

The systematic study of earthquake perimeters using digital data from the Global Digital Seismograph Network (GDSN) and the International Deployment of Accelerometers (IDA) Network is now in its third year. Centroid-movement tensor (CMT) solutions were evaluated for 308 events that occurred during 1982, and so far results have been obtained for about 150 earthquakes of 1983. Each month the results are sent to the

National Earthquake Information Service (NEIS), which incorporates them in the monthly listings of the preliminary determinations of epicenters. Collected data are published in international journals as well. At present, the tapes with data arrive at Harvard University 2 to 2 1/2 months after an event has occurred. The technology exists for transmission of the data in real time. The CMT method provides vary rapid estimation of the size and mechanism of an event. The ability to provide such values within 1 to 2 hours after an earthquake has occurred would have important implications for society as well as for science. In addition to prediction of the tsunami effect for earthquakes that occur in populated but remote areas, estimates of the potential damage could help in planning the rescue effort.

Other studies underway are in the area of stress in the crust and earthquake focal mechanisms and rock friction constitutive experiments as related to theory of earthquake instability.

1.10.4.3 Siting and Geotechnical Earthquake Engineering Research

It is important to understand the dynamic earthquake response to surface and subsurface ground conditions because of destructive landslides, tsunami waves and liquefaction of inland areas beyond areas hit by tsunamis. Siting and geotechnical earthquake engineering research programs sponsored by NSF encompass measurements and analysis of strong ground motions, studies of soil/structure interactions and investigations of the stability of ground structures such as dams and abutments, and studies of potential ground damage to lifeline structures such as utility lines and communication systems.

1.10.4.4 Earthquake Ground Motion Projects

Studies to measure and analyze destructive ground motions for hazard mitigation continue with 5,500 strong-motion instruments now installed and operational inseismically active and earthquake prone areas in the U.S. and around the world. Ground motion data, collected from over 55 destructive earthquakes, have helped to narrow uncertainty limits and asses probably site-specific effects of earthquakes in the area. Since 1978, NSF has initiated research programs for installation of instrument arrays at designated high-priority sites around the world. To date, cooperative projects have been initiated with India, Mexico, Taiwan, the People's Republic of China, and the Soviet Union for the installation of strong-motion arrays.

The innovative instrument array code, SMART-1, deployed in Taiwan, has produced a high rate of data acquisition, recording strong-motion data from nearly 20 earthquakes to date. A network of 12 digital, strong-motion accelerographs, installed in a cooperative venture between the Institute of Geophysics Planetary Engineering Institute and the National University of Mexico is in operation. The data obtained have enabled a comparative evaluation of digital and analog instrumentation. Based on recorded data to date, the first-generation digital recording devices promise great advantages over analog methods because of greater dynamic range and increased flexibility for recovering the intiial motions and rapid playback. Other efforts in this area include ongoing studies of modeling and simulation.

1.10.4.5 Tsunamic Engineering Research

NSF-sponsored research efforts represent a major portion of the tsunami engineering research performed in the U.S. Recent studies have advanced understanding of tsunami characteristics based on tide gauge records. Complex numerical modeling is being used to determine specific nonlinear interactions among tsunami. Other related work includes predicting transient response of harbors to nonlinear tsunami impinging on the shore. The numerical model handles a variable-depth harbor with vertical boundaries. Using the model, estimates of the effect of run-up and run-down at a harbor and dissipation of tsunami energy in the shoreline by "roughness elements" can be made.

Available warning systems are inadequate for warning of impending tsunami, especially during the first hour of tsunami generation. Development of an effective tsunami prediction and warning systems will rely on technological improvements in existing warning systems and in wave gauge data system. Research on numerical modeling techniques is continuing; however, engineering analysis based on site-specific seismic data is needed to verify these models and effect technology transfer for use as a preparedness and mitigation tool.

1.10.6 Corps of Engineers--Seismic Instrumentation Program

The Corps of Engineer's Strong-Motion Instrumentation Program (SMIP) provides insight into the safety of existing and new Corps structures and a measure for project performance as well as a data base for earthquake research. As of 1982, there were a total of 104 instrumentation projects underway in 34 states and one Territory, including 360 accelerographs, 59 seismoscopes, and 27 peak recording accelerographs. Future goals are to revise and update analytical procedures for assessing

the seismic stability of structures and to install devices on Corps structures to minimize on-site inspections after earthquakes.

1.10.7 NASA

The activities of NASA's Geodynamics Program contribute to the NEHRP by providing scientific understanding of how and why the plates are moving, of the extent of crustal deformation associated with plate interaction, and the accumulation and release of crustal strain. In addition, NASA-developed technology has been provided to the other agencies for operational use. Overall, NASA activities are coordinated with NOAA, USGS, NSG, and the Defence Mapping Agency.

1.10.8 Office of Foreign Disaster Assistance

The Agency for International Development Office/Office of Foreign Disaster Assistance (AID/OFDA) has supported activities in earthquake hazards reduction in the developing world since 1979. The OFDA warning and disaster preparedness program of siesmic monitoring, tsunami modeling and hazards analysis, earthquake risk and hazards mitigation, engineering seismology and related training has increased more than eightfold in the past 4 years. This expansion reflects the increasing importance AID has placed on early warning preparedness and mitigation as means of reducing the disaster death toll resulting from geological hazards.

The goal of the AID earthquake hazards reduction activities is to reduce death and human suffering caused by earthquakes, volcanoes, tsunamis and landslides. This is being accomplished by assisting disaster-prone countries in achieving a high degree of self-sufficiency and technical competence in seismic-related disaster avoidance and mitigation. The following OFDA objectives will be accomplished, in

part, by FY 1985:

- o Increase lead-time for seismic-related disaster early warning and contingency planning (i.e., earthquake forecasts from probabilistic assesments of seismic potential).
- o Integrate early warning systems output with hazard reduction activities, country preparedness and AID detail.
- o Integrate early warning systems output with hazard reduction activities, country preparedness and AID development objectives.
- o Evaluate relative vulnerability of less-developed countries to seismic-related disasters and develop regional mitigation/preparedness strategies.
- o Strengthen Third World seismological institutions and orient foreign scientists and civil defense officials in the application of new technologies for earthquake disaster mitigation.

Results of these activities will be directed toward the establishment of a comprehensive U.S. Strategy for international earthquake hazards mitigation and disaster preparedness.

In the past 2 years, AID/OFDA has implemented the following major activities related to earthquake hazards mitigation in the less-developed countries:

- o Installation of a radio-telemeterd seismic network in the Fuji Islands; study of hazards related to the Suva/Mbennga seismic zone; and an evaluation of seismic risk in the Fiji-Vanuatu region of the southwest Pacific Ocean.
- o Development of comprehensive simulation models of the Pacific Basin tsunami hazard for both open ocean and near-shore wave propagation following hypothetical earthquake events along the west coast of South America.

- Installation of an advanced seismological and strain meter network for central Peru and an automatic earthquake detection and data processing facility in Lima.
- Investigation and analysis of earthquake risk and disaster mitigation in the Andean region in cooperation with the U.S. Geological Survey (USGS) and central Regional de Sismologia para America del Sur (CERESIS).
- Development of national earthquake hazards reduction programs including upgrading of seismic networks in Panama, Equador, El Salvador, Guatemala, Dominican Republic, and Costa Rica.
- Establishment of an orientation program in engineering seismology and earthquake engineering for Southeast Asian nations in cooperation with the Southeast Asian Association of Seismology and Earthquake Engineering (SEASEE) and USGS.
- Establishment of a Southeast Asian regional earthquake hazards mitigation program through SEASEE with upgrading of selected national seismic monitoring networks.
- Coordination of the first International Workshop for Mitigation of Natural Hazards in Latin America at Lima, Peru, in cooperation with the American Institute of Architects Foundation (AIAF) and Latin American counterpart organizations.
- Provision of emergency funding assistance to USGS in support of continuing operation of the Global Seismic Network (GSN).
- Establishment of a portion of the U.S./Japan Cooperative Program in conducting international seminars on seismology and earthquake engineering.

- Development of a prototype near-shore, real-time tsunami warning system for Chile using Geostationary Operational Environmental Satellite (GOES) telemetry in cooperation with the National Oceanic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory.
- Development of an earthquake monitoring and earthquake risk analysis program with the National Autonomous University of Mexico under the U.S./Mexican Agreement for Cooperation on Natural Disasters.
- Establishment of a technical assistance program in cooperation with the European Economic Community to draft uniform building codes for wind and seismic effects in the leeward Island of the Caribbean Basin.
- Provision of financial support to the 1983 City of Los Angeles International Earthquake Conference, including funding for the attendance of many foreign participants.

1.11 National Research Council

The National Research Council conducted a workshop in Woods Hole in July 1983 to discuss and plan an international geosphere-biosphere program. While many of the program elements require long-range observation, their experience is instructive in that it shows the need for international cooperation and interdisciplinary efforts. The research areas for such a program were: the atmosphere, oceans, lithosphere, bisphere, and solarterrestrial system. The notion of global change, from the slow recurrence of the Ice Ages to short transient phenomnea, was a unifying and pervasive theme of the workshop.

Some of the related programs and plans include:

- International Magnetospheric Study (IMS)

  IMS produced a data base for exploratory research into links between climatic and weather variations and geomagnetic phenomena. About 50 countries participated in a spacecraft, ground-based, balloon, aircraft, and rocket programs.

- Middle Atmosphere Program (MAP)

  MAP is an ongoing initiative of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). The program is attempting to determine what role the middle atmosphere plays in determining climate and climatic changes, and what the processes are by which the sun, acting through the middle atmosphere, may be able to affect weather.

- World Climate Research Program (WCRP)

  WCRP, conducted jointly by the World Meterological Organization and the International Council of Scientific Unions, is attempting to determine what extent climate can be predicted and the extent of man's influence on climate. The

Preliminary Plan, prepared in January 1981, recommended: the study of climatologically significant processes; the development of physical-mathematical models; and the statistical analysis of observed climate variables.

- World Climate Data Program

  The program is part of the World Climate Program organized under the WMO. The thrust of the program is to aid individual countries to upgrade their capabilities in climate data management to rescue, digitize, quality control, store, retrieve, and use climate data.

- Global Atmospheric Research Program (GARP)

  GARP, organized by the WMO-ICSU Joint Organizing Committee, is a program for studying those physical processes in the troposphere and stratosphere that are essential for understanding transient behavior of the atmosphere as manigested in the large-scale fluctuations that control changes in the weather and the factors that determine the statistical properties of the general circulation of the atmosphere. The program has distinct but several interrelated parts: design and testing by computational methods of a series of theoretical models of relevant aspects of the atmosphere's behavior; and observational and experimental studies of the atmosphere to provide the data required for the design of the theoretical models and the testing of their validity.

- World Weather Watch (WWW)

  The WWW, a program of WMO, makes available to each Member State the basic meteorological and environmental information required for efficient and effective meteorological services. WWW includes three operational elements: the Global Observing System, the Data Processing System, and the Global Telecommunication System.

- Tropical Oceans and Global Atmosphere (TOGA) Program

  TOGA, part of the WCRP, has as its overall objective to understand the relation between heat-flux anomalies in the tropical oceans and the associated changes in the global atmospheric circulation.

- Equatorial Pacific Ocean Climate Studies (EPOCS)

  EPOCS, a NOAA program, investigates large-scale tropical Pacific ocean-atmosphere interactions and their impact on seasonal-interannual climate fluctuations.

- Integrated Global Ocean Services System (IGOSS)

  IGOSS, cosponsored by the Intergovernmental Oceanographic Commission of UNESCO and the World Meteorological Organization, promotes, develops, and coordinates the global acquisition and exchange of ocean data. Major real-time ocean analysis products currently produced by Member States for various ocean areas include sea-surface and subsurface temperatures, mixed-layer depths, and ocean frontal positions. Delayed-mode summaries produced include currents, salinity, distributions of pollutants, and weekly and monthly temperature means.

- Global Environmental Monitoring System (GEMS)

  GEMS is one component of Earthwatch (proposed at the UN Conference on the Human Environment in 1972 and now part of the United Nations Environment Programme (UNEP). UNEP established a Program Activity Center for GEMS in 1972 which coordinates international monitoring activities conducted mainly under the aegis of the UN and consisting of networks of nationally operated monitoring systems. As with UNEP as a whole, the GEMS Center is not operational in the sense that it does not itself operate monitoring stations. GEMS monitoring activities include: health-related monitoring, climate-related monitoring, renewable resource monitoring, ocean monitoring, and international disaster monitoring.

1.12 World Data Center

In February 1981, a new organization was established concerned exclusively with volcano monitoring and volcano observatories named the World Organization of Volcano Observatories (WOVO). The mission of WOVO is distinct from other international organizations such as IAVCEI which focuses on volcanology in general.

WOVO plans to: create or improve ties between institutions and observatories involved in volcano monitoring; convene periodic meetings to facilitate the exchange of views and information; maintain an up-to-date inventory of instrumentation and personnel which could be made available to any of the member institutions if a situation arises which requires scientific reinforcement; and promote funding from international organizations which could help to defray travel and related expenses of scientific reinforcement teams.

1.12.1 World Data Centers

The World Data Centers are a legacy of the International Geophysical Year 1957-58. Originally, they were to collect the geophysical data collected during that year, however they have continued to archive and redistribute geophysical and solar data world-wide since then. WDC-A is located in the United States; WDC-B is in the USSR; and WDC-C comprises a number of separate discipline centers in various nations, particularly Japan and Western Europe.

The WDC's collect and exchange data in the following disciplines: solar-terrestrial physics: solar and interplanetary phenomena, ionospheric phenomena, flare-associated events, geomagnetic variations, aurora, cosmic rays and airglow; rockets and satellites; meteorology: atmospheric chemistry, atmospheric radioactivity, solar radiation, ozone, noctilucent clouds, atmospheric electricity, surface and upper air observations; oceanography; glaciology (snow and ice): snow cover, glacier fluctuations, avalanches, polar ice masses, sea ice, permafrost, paleoglaciology; and solid earth physics: seismology, tsunamis, gravimetry, earth tides, recent movements of the Earth's crust, rotation of the Earth, marine geology and geophysics, magnetic measurements, paleomagnetism and archeomagnetism, volcanology, and geothermics.

Guides for each segment of the WDC are periodically updated in an attempt to provide more up-to-date and useful information. New sections are defined by concerned association, commissions, and committees to cover disciplines not previously served. For example, the WMO established the World Weather Watch Programme, GARP, and MAP (Middle Atmosphere Programme). Manuals are prepared to ensure a reasonably high

degree of standardization of methods of measurement and a degree of uniformity in presentation of data among the Centres.

1.13 ESA-EARSeL Symposium

The European Association of Remote Sensing Laboratories (EARSeL), the European Space Agency (ESA) and the Austrian Solar and Space Agency (ASSA) sponsored a symposium, in April 1982, on "Satellite Remote Sensing for Developing Countries". The purpose was to determine the role EARSeL members could play in assisting the exploitation of remote sensing technology. Abstracts of six of the papers can be found in the ITC Journal 1983-1. The papers presented ranged from technical considerations of mobile ground stations to the use of remote sensing data to more philosophical considerations of the ways European agencies could and should aid the developing countries.

In addition to the papers, a round table discussion was held to discuss ways and means by which EARSeL can assist developing countries, either as a group or as individual laboratories. Finances, applicability of satellite remote sensing data as a source of information, the availability of data in a usable form, lack of training, and the type of data most useful to users.

1.14 United Nations Educational, Scientific and Cultural Organization - UNESCO

UNESCO was established in 1946 "for the purpose of advancing, through the educational, scientific and cultural relations of the peoples of the world, the objectives of international peace and the common welfare of mankind".

UNESCO convenes conferences and meetings, and coordinates international scientific efforts; it helps to standardize procedures of

documentation and provides clearing house services; it offers fellowships; and it publishes a wide range of specialized works, including source books and works of reference.

1.14.1 Natural Sciences and Technology

While the main emphasis in UNESCO's work in science and technology is on harnessing these to development, and above all on meeting the needs of developing countries, the Organization is also active in promoting and fostering collaborative international projects among the highly industrialized countries. UNESCO's activities can be divided into three levels: international, regional and sub-regional and national.

At the international level, UNESCO has over the years set up various forms of intergovernmental cooperation concerned with the environmental sciences and research on natural resources. Examples of these are the Man and the Biosphere Program (MAB) which at present has 900 projects under way in 90 countries, using an inter-disciplinary approach to solving practical problems of environmental resource management in such areas as arid lands, humid tropical zones, mountain ecosystems, urban systems, etc.; International Hydrological Program (IHP), dealing with the scientific aspects of water resources assessment and management; and the Intergovernmental Oceanographic Commission which promotes scientific investigation into the nature and resources of the oceans through the concerted action of its member states.

Another program, UNISIST, ensures worldwide cooperation in the field of scientific and technological information. In the basic sciences, UNESCO helps promote international and regional cooperation in close collaboration with the world scientific communities, with which it maintains close cooperative links particularly through its support to ICSU and member unions.

1.14.2 Bureau of Studies and Programming

UNESCO's General Information Program is an intergovernmental program concerned with the development and promotion of information systems and services in the fields of scientific and technological information, documentation, libraries and archives at the national, regional and international levels. Its activities, including those directed to the development of UNISIST, fall into the following categories:

- promotion of the formulation of information policies and plans;
- promotion and dissemination of methods, norms and standards for information handling;
- contribution to the development of information infrastructures;
- contribution to the development of specialized information systems;
- promotion of the training and education of information specialists and users.

1.15 World Meteorological Organization

The WMO started activities and was recognized as a Specialized Agency of the UN in 1951, aiming to improve the exchange of weather information and its application.

In addition to the operational weather observation programs, the WMO participates in a substantial number of Research and Development projects and activities. Significant research activities with relevance to global habitability are listed.

1.15.1 Research and Development Program

The Commission for Atmospheric Sciences promotes the coordination of members' research activities in the field of atmospheric sciences, to facilitate the exchange of scientific information, to sponsor and/or organize scientific conferences and symposia including joint research projects between member countries.

In the field of environmental prediction research, WMO implemented the Global Ozone Research and Monitoring Project in collaboration with UNEP.

The Global Atmospheric Research Program (GARP), was organized jointly with the International Council for Scientific Unions to study the physical and mathematical basis of weather prediction and climate variation.

1.15.2 Meteorological Applications and Environment Program

WMO engages in international projects or in joint action with other international organizations, and special bodies are set up for the purposes of this program, which includes, among others, increasing the contributions of meteorology to the preservation of life and environmental conservation.

Projects under the Environment Program deal mainly with the organization of global, standardized observations of substances and parameters which have or may have a long term effect on the state of the environment and on climate.

In BAPMN, the Background Air Pollution Monitoring Network, more than 70 countries, with more than 100 stations, participate. Monitoring of pollution in media other than air, in particular the oceans and also soil and biota, contributes to the study of biogeochemical cycles.

Such monitoring is to establish global and regional levels of relevant substances, their variation and trends as well as their long range transport.

The Operational Hydrology Program concerns standardization of all aspects of hydrological data, including instruments, methods of observation and transmission, systems of forecasting and their application to water resources projects. WMO collaborates with other international efforts such as the International Hydrological Program at UNESCO.

The World Climate Program, is comprised of five components: World Climate Data Program (WCDP); World Climate Applications Program (WCAP); World Climate Impact Study Program (WCIP); World Climate Research Program (WCRP). The implementation of the WCIP is the responsibility of UNEP, with the WCRP as a joint effort between WMO and ICSU.

1.16 United Nations Institute for Training and Research - Unitar

Established in 1965 as an autonomous body within the framework of the United Nations. UNITAR undertakes specific studies to discover the long term trends in such fields as energy, raw materials, population, food environment, and technology. The intention is to carry out, for the United Nations, a continuous examination of major world problems and trends that may have implications for the future of mankind and to throw light on areas in which action is considered necessary.

1.17 United Nations Environment Programme - UNEP

The United Nations Environment Program was established in 1972 by the UN General Assembly following recommendations of the 1972 UN Conference on the Human Environment, to provide the machinery for international

cooperation in matters relating to the human environment.

UNEP plans programs to be put into practice by governments and other United Nations bodies and monitors them. To this end, it has set up a Global Environmental Monitoring System, (GEMS), a network of stations providing information on the ecological state of the world. The stations monitoring changes in climate are operated by WMO, those monitoring water pollution by WHO, and those monitoring changes in tropical forests by FAO.

UNEP has drawn up a program to develop the Mediterranean, reduce pollution and protect its marine environment. The program is in three parts, the first of which is a Convention and two protocols signed in Barcelona, Spain, in 1976 which became international law in February, 1978. By September 1980, it had been ratified by 16 Mediterranean states (excepting Albania and Turkey).

The second part is a diagnostic investigation of the Mediterranean being carried out by 16 countries. The third part, to be carried out over the next 10 or 15 years, consists of five or six priority programs and a long-term study of the development plans of the Mediterranean governments. In 1980, there were 84 marine laboratories working on these projects. In May, 1980, at a conference in Athens, the Mediterranean countries approved a treaty for the control of pollution of inland origin (factory waste, sewage, agricultural chemicals, etc.).

Countries have approached UNEP to make similar studies of the Red Sea, the Persian Gulf, the Gulf of Guinea, the Strait of Malacca and the area of the South Pacific Islands.