AD-A082 243 COLORADO STATE UNIV FORT COLLINS DEPT OF EARTH RESOURCES F/G 14/5
APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT.(U)
FEB 80 W E MARLATT, E B JONES DCPA01-79-C-0268

UNCLASSIFIED NL

1 OF 1
AD
A082243

END
DATE
FILMED
4-80
DTIC

6

APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT

9

FINAL REPORT. 15 May 79 — 15 Feb 80

Contract DCPA01-79-C-0268

15

Work Unit 2111H

FOR

Federal Emergency Management Agency
Washington, D.C. 20472

"Approved for Public Release: Distribution Unlimited"

FEMA Review Notice

"This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency."

10

By

William E. Marlatt
Department of Earth Resources
Colorado State University
Fort Collins, Colorado 80523

E. Bruce Jones
Resources Consultants, Inc.
P. O. Box Q
Fort Collins, Colorado 80522

12 60

11

15 February 1980

408781

TABLE OF CONTENTS

	Page
FOREWARD	v
INTRODUCTION	1
FOUNDATIONS OF REMOTE SENSING	5
Data Acquisition and Interpretation	7
AVAILABILITY OF REMOTE SENSING TECHNOLOGY FOR DISASTER RESPONSE	13
Imaging Systems	13
Current and Near Future Satellite and Aircraft Remote Sensing Systems	14
Aircraft Systems	14
Satellite Systems	15
Communication Systems	26
Data Interpretation	26
UTILIZATION OF REMOTE SENSING IN DISASTER RESPONSE	28
Categories of Disasters	28
Phases of Monitoring Activities	30
RECOMMENDATIONS FOR UTILIZATION OF REMOTE SENSING TECHNOLOGY IN DISASTER RESPONSE	31
Specific Recommendations	31
SELECTED READING LIST	36
APPENDIX A: LIST OF WORKSHOP ATTENDEES	

A

LIST OF TABLES

Table		Page
1.	Number of World Major Natural Disasters By Causal Agent, 1947-67	2
2.	Injuries, Loss of Life, and Property Damage Resulting From Selected Natural Hazards in the United States, Annual Basis: 3- to 5-Year Average	3
3.	NASA U-2 Performance Characteristics	16
4.	NASA NC130B Specifications	16
5.	NASA WB57F Specifications	17
6.	U-2 Photographic Systems	17
7.	U-2 Imaging Electronic Sensor Systems	18
8.	WB-57F/C-130 Photographic Capabilities	18
9.	Sensor Characteristics of the Multispectral Sensor and Thematic Mapper	22
10.	Proposed Multispectral Resources Sampler (MRS) Sensor Characteristics	24
11.	Stereosat Proposed Mission Parameters	25
12.	Categories of Disasters	28
13.	Number of Major Disaster Declarations and Allocations From The President's Disaster Fund, 1961-1970	30

LIST OF FIGURES

Figure		Page
1.	The Electromagnetic Spectrum	6
2.	Spectral Characteristics of Energy Sources, Atmospheric Effects, and Sensing Systems	9
3.	Electromagnetic Remote Sensing of Earth Resources . .	11
4.	Multistage Remote Sensing Concept	12
5.	Spectral Sensitivity of the Four Landsat Bands Compared With the Spectral Sensitivity of the Three Emulsion Layers Used in Color and Color Infrared Film	20
6.	Landsat Orbital Passes Over the Conterminous United States	21

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Applications of Remote Sensing to Emergency Management		5. TYPE OF REPORT & PERIOD COVERED Final 5/15/79 - 2/15/80
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) William E. Marlatt		8. CONTRACT OR GRANT NUMBER(s) DCPA01-79-C-0268
9. PERFORMING ORGANIZATION NAME AND ADDRESS Earth Resources Dept., College of Forestry & Nat. Res., Colo. St. U., Ft. Collins, CO 80523		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Work Unit #2111H
11. CONTROLLING OFFICE NAME AND ADDRESS Federal Emergency Management Agency Washington, DC 20472		12. REPORT DATE February 15, 1980
		13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Disasters, emergency management, remote sensing technology

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

Disasters are not unknown to any locality in the United States. Unfortunately, it is difficult to specify the amount of damage, loss of life, etc. to permit uniform guidelines for management. Many small emergencies such as a tornado in a rural area can be managed by local officials. Larger emergencies often require management assistance from state and federal officials. Unfortunately, in the past, evidence shows that many of the problems of emergency management are compounded,

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408 771

if not caused, by a lacl of accurate, timely and detailed information. During and immediately after a disaster such as a hurricane or a power plant explosion, information must be accumulated quickly, analyzed and distributed to the decision makers who have responsibilities for allocating resources and setting priorities. The new Federal Emergency Management Agency has the overall responsibility for developing emergency management plans and developing technology for coordinating the handling of a wide variety of natural and man-made disasters.

In the past two decades, the United States has made great strides in developing new technology and instrumentation in remote sensing. It is obvious that this technology can be utilized much more effectively than it is as present in the field of emergency management. To this end, two workshops were held to identify areas where remote sensing technology has greatest utility and to develop recommendations for implementation of a remote sensing program into F.E.M.A.

It was recognized early in the first workshop that before any monitoring system could be recommended, it will be necessary for F.E.M.A. to undertake a study of the information requirements for specific categories of disasters. Experience has shown that remote sensing technology is best employed where there is an in-depth understanding of the data and information requirements for which that technology is to be used. It is apparent that remote sensing can and should become one of the tools for the operations branch of F.E.M.A. It is also apparent tht essentially all of the sensor systems probably needed by F.E.M.A. are available from other federal agencies.

The lack of information on what data are needed for any emergency or category of emergencies does not permit recommendations of specific remote sensing technologies to F.E.M.A. It was the concensus of the two workshops that the most impcrtant steps that F.E.M.A. can take at this time are to:

(1) determine the disaster spatial and temporal information needs (this will have to be done on a regional basis);

(2) determine where data bases exist and supplement these as needed in each region;

(3) establish interagency agreements to obtain the data required for each type of disaster;

(4) establish procedures for converting data into information usable to the decision maker;

(5) identify the person(s) requiring the information; and

(6) establish the communication links for the integrated systems

FOREWARD

Disasters are not unknown to any locality in the United States. Unfortunately, it is difficult to specify the amount of damage, loss of life, etc. to permit uniform guidelines for management. Many small emergencies such as a tornado in a rural area can be managed by local officials. Larger emergencies often require management assistance from state and federal officials. Unfortunately, in the past, evidence shows that many of the problems of emergency management are compounded, if not caused, by a lack of accurate, timely and detailed information. During and immediately after a disaster such as a hurricane or a power plant explosion, information must be accumulated quickly, analyzed and distributed to the decision makers who have responsibilities for allocating resources and setting priorities. The new Federal Emergency Management Agency has the overall responsibility for developing emergency management plans and developing technology for coordinating the handling of a wide variety of natural and man-made disasters.

In the past two decades, the United States has made great strides in developing new technology and instrumentation in remote sensing. It is obvious that this technology can be utilized much more effectively than it is at present in the field of emergency management. To this end, two workshops* were held to identify areas where remote sensing technology has greatest utility and to develop recommendations for implementation of a remote sensing program into F.E.M.A.

It was recognized early in the first workshop that before any monitoring system could be recommended, it will be necessary for F.E.M.A. to undertake a study of the information requirements for specific categories of disasters. Experience has shown that remote sensing technology

---

*List of workshop attendees is provided in Appendix A.

is best employed where there is an in-depth understanding of the data and information requirements for which that technology is to be used. It is apparent that remote sensing can and should become one of the tools for the operations branch of F.E.M.A. It is also apparent that essentially all of the sensor systems probably needed by F.E.M.A. are available from other federal agencies.

The lack of information on what data are needed for any emergency or category of emergencies does not permit recommendations of specific remote sensing technologies to F.E.M.A. It was the concensus of the two workshops that the most important steps that F.E.M.A. can take at this time are to:

(1) determine the disaster spatial and temporal information needs (this will have to be done on a regional basis);

(2) determine where data bases exist and supplement these as needed in each region;

(3) establish interagency agreements to obtain the data required for each type of disaster;

(4) establish procedures for converting data into information usable to the decision maker;

(5) identify the person(s) requiring the information; and

(6) establish the communication links for the integrated systems.

More detailed recommendations are provided in this report.

INTRODUCTION

The word disaster (Lat: dis-astrum, cf. ill-starred) can be defined as any natural or man-made occurrence causing widespread distress, often with loss of human life, usually with great loss of property and with considerable upheaval of the social system. The terms catastrophe and calamity are often used interchangeably with disaster, however they are also used to describe unfortunate events befalling single individuals. A cataclysm is a sudden and violent upheaval often associated with extreme geophysical events and usually implies such large scale damage that recovery is either impossible, or at least, very long term. In the Presidential Document creating the Federal Emergency Management Agency (hereinafter referred to as FEMA), "a civil emergency means any accidental, natural, man-caused, or wartime emergency or threat thereof, which causes or may cause substantial injury or harm to the population or substantial damage to or loss of property."

By the above definitions, there can be no doubt that we live in an age of disasters and emergencies. Hardly a day passes without a media report of a natural or man-caused disaster, an act of terrorism or an act of agression between nations somewhere in the world. Based on 1955 costs, the annual loss from natural disasters if now nearly $4.5 billion in the United States alone. Estimates in Table 1 indicate that over a recent 20 year period, major natural disasters of the world resulted in the loss of life for more than 388,000 persons. Table 2 shows that, in the United States, the annual loss of life from natural disasters exceeds 1,300. As the country becomes more densely populated, particularly in the urban areas, it is probable that this number will increase. In the worst disaster in American history, the Galveston flood of 1900, a total of

Table 1. Number of World Major Natural Disasters By Causal Agent, 1947-67.

Agent	Number of Disasters	Loss Of Life
Floods	209	173,170
Typhoons, hurricanes, cyclones	148	101,985
Earthquakes	86	56,100
Tornadoes (including swarms of contemporaneous ones)	66	3,395
Gales and thunderstorms	32	20,940
Snow storms	27	3,520
Heat waves	16	4,675
Cold waves	13	3,370
Volcanic eruptions	13	7,220
Landslides	13	2,880
Rainstorms	10	1,100
Avalanches	9	3,680
Tidal waves (alone)	5	3,180
Fogs	3	3,550
Frost	2	--
Sand and dust storms	2	10
Totals	654	388,775

Source: Hewitt and Sheehan, 1969.

Table 2. Injuries, Loss of Life, and Property Damage Resulting From Selected Natural Hazards in the United States, Annual Basis: 3- to 5-Year Average.

Hazard	Injuries	Loss of Life	Property Damage (Millions of $)
Hurricanes	6,755	41	448.7
Tornadoes	2,019	124	180.0
Excessive Heat		236	
Winter Storms (excessive cold)	500	366	182.1
Lightning	248	141	33.5
Floods	610	62	399.5
Earthquakes	112	28	102.7
Tsunami	40	24	21.0
Transportation Accidents related to weather, etc.	237	288	18.9
Drought			78.6*
Hail			22.1*
Excess Moisture			27.7*
Wind			11.8*

*Farm crop losses only

Source: The U. S. Department of Commerce

6,000 lives were lost. According to a United States' government estimate, a 7.5 Richter scale shock along the Newport-Inglewood fault, which runs south through downtown Los Angeles, could kill between 20,000 and 200,000 people, seriously injure another million and make two to three million homeless. Such a disaster is not improbable. Indeed, it is almost certain to happen; only the time and date are unknown.

For the past 50 years, the United States has developed many kinds of programs to study, monitor and predict the occurrence of natural and man-caused disasters. Some of these efforts, particularly those involving weather hazards, have been somewhat successful; others have been notable failures. One of the difficulties in developing a coordinated program has been the fragmentation of activities throughout federal government. By one count there are more than 150 separate groups, often with several subgroups, concerned with disaster-related research. For example, the National Academy of Sciences -- National Research Council has approximately 40 committees and boards with disaster related responsibilities.

Under the President's Emergency Preparedness Reorganization Plan (Executive Order 12148, July 20, 1979), section 2.201(c) all civil defense and civil emergency functions, resources, and systems of Executive agencies are to be developed, tested and utilized to prepare for, mitigate, respond to and recover from the effects on the population of all forms of emergencies. The agencies which were merged into FEMA as part of this plan are the Defense Civil Preparedness Agency, the Federal Preparedness Agency, the Federal Disaster Assistance, the Federal Insurance Administration, and Fire Prevention and Control Administration. FEMA has also been assigned responsibilities for coordination of emergency warning and federal response to consequences of terrorist incidents.

In the last decade, and particularly in the last few years, the technology of monitoring by remote sensing has made rapid strides forward. This report discusses the potential application of this technology to areas of FEMA responsibility.

FOUNDATIONS OF REMOTE SENSING

Remote sensing is the acquisition of information about an object, area or phenomenon through analysis of data acquired by a device that is not in intimate contact with the object, area or phenomenon under investigation. The remotely collected data can be in many forms, including such things as variations in force distributions, acoustic wave distributions or electromagnetic energy distributions. Most of the newer technology, and in particular, that with which we are concerned in this study, has been in the electromagnetic energy system.

The most familiar form of electromagnetic energy is visible light. The human eye acquires data on variations in the visible portion of the electromagnetic energy distribution. Visible light, however, is only one of many forms of electromagnetic energy. Radio waves, heat, ultraviolet and X-rays are other familiar forms which are utilized in remote sensing. All wavelengths together from Gamma rays to radio waves, form the electromagnetic spectrum (Figure 1). Each object on earth reflects, absorbs or radiates in some portion of the electromagnetic spectrum according to its own particular structure and composition. The reflected and emitted energy either wavelength or intensity (or both) are like fingerprints which can be used to help identify or characterize the object. Such "fingerprints" are referred to as spectral signatures.

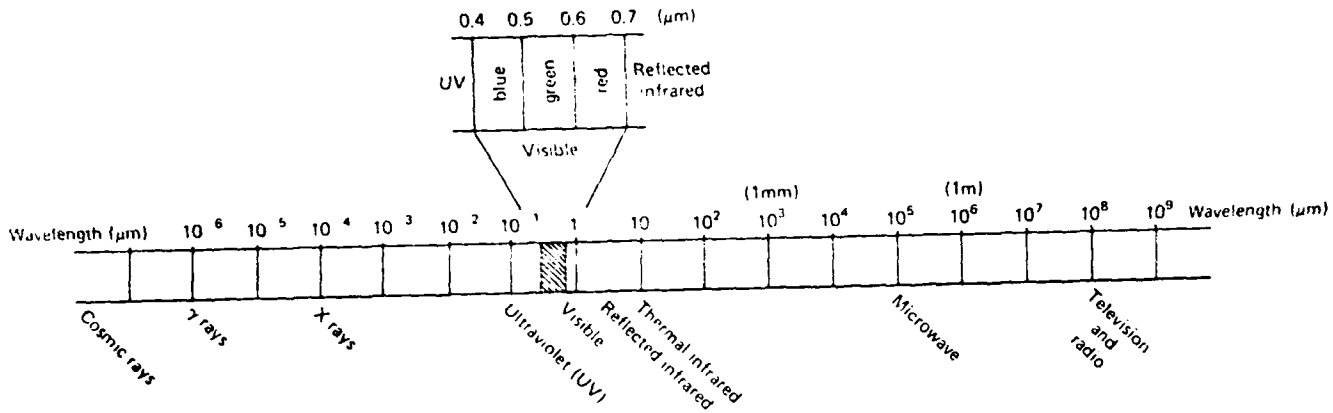

Figure 1. The Electromagnetic Spectrum.

The visible portion of the spectrum is extremely small, however, with this band, the human eye and several types of photographic film are multi-spectral remote sensors which are able to discriminate between shades of grey (intensity) or between wavelength (colors). There is much information about the earth in the reflective ultraviolet, near infrared, thermal infrared and microwave portions of the spectrum. Data in these portions of the electromagnetic spectrum can be obtained either photographically or electronically using new devices developed by NASA and the Department of Defense.

Data Acquisition and Interpretation

In remote sensing, the term "photograph" is reserved for scenes that are detected as well as recorded on film. Photographic systems have the advantage of being relatively simple and inexpensive and with high quality lenses provide a high degree of spatial integrity. Electronic sensors generate an electric signal (voltage or frequency) that corresponds to variations in reflected or emitted energy variations in the scene. Although often considerably more expensive and complex, electronic sensors can have a greater sensitivity to narrow wavebands, more precise calibration and the ability to transmit data by radio.

The photographic film acts as both the detecting and recording medium. Electronic sensor data are usually recorded onto magnetic tape which may be converted later into a film, such as with a television camera or thermal scanner.

The term image is the generic term for any pictoral representation of scene data. In applications where spectral "fingerprints" are not

easily distinguished, it is often more useful to analyze the data from electronic sensors numerically rather than pictorally. Computer programs are now generally available for processing of electronically scanned data; often this greatly increases the information content of electronic scanner output.

Many applications of remote sensing to natural or man-caused disasters have spatial and temporal requirements. Temporal effects are those factors that change the spectral characteristics of a scene over time. Spatial effects refer to factors that cause the same objects to have different characteristics at different locations at the same time. Spatial and temporal effects are valuable tools in interpreting remotely sensed data (such as mapping of vegetated areas which are undergoing stress following a drought, spraying with herbicide, etc.).

In addition to changes in spectral signatures caused by spatial and temporal variations of the scene, all electromagnetic radiation received by the remote sensor has passed through some distance, or path length, of atmosphere. While the atmospheric effects vary greatly with wavelength, the spatial and temporal variations of the atmosphere (i.e., water vapor, dust, clouds, etc.) can have a profound effect upon the intensity and spectral composition of the signal received by any sensor system (Figure 2).

As a result of the spatial and and temporal effects of the surface and atmosphere, many earth surface feature spectral fingerprints are not as distinctive as one would wish. As a result no single combination of sensor and interpretation procedure is appropriate to all inventorying and monitoring applications.

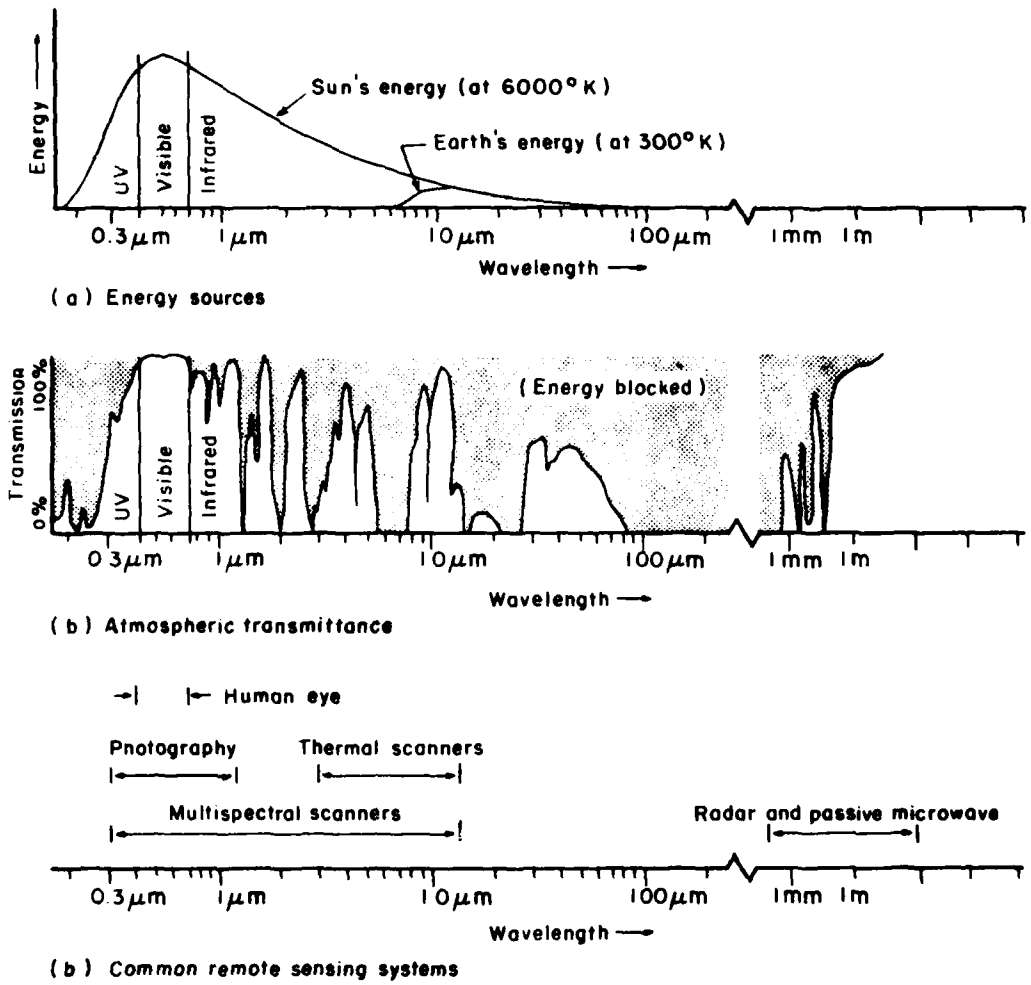

Figure 2. Spectral Characteristics of Energy Sources, Atmospheric Effects, and Sensing Systems. (Note that wavelength scale is logarithmic.)

Figure 3 shows the generalized procedure for bringing remote sensing technology into emergency management. In order to incorporate this technology successfully into the FEMA program, the following steps must be carefully considered: (a) a clear definition of the specific event to be monitored; (b) a determination of the potential for using remote sensing technology; (c) an identification of the sensor(s) applicable and the data processing requirements; (d) a determination of the spatial and temporal resolution requirements; and (e) the development of specific criteria for judging the quality and usefulness of the information collected.

For certain types of events, the application of remote sensing techniques may involve multispectral sensing, multitemporal sensing and even multistage sensing. The multistage approach may include data from satellites, high and low aircraft platforms and ground based sensors (Figure 4). Information extracted at high altitude provides a synoptic view of the object or event. Each successively lower observation level may provide more detailed information over smaller geographical areas.

Thus, not only must the right mix of sensor systems' spatial and temporal criteria and data recording, reduction and interpretation techniques be chosen, it must be recognized that remote sensing for disaster monitoring is not an end unto itself. In many, if not all cases, it is a tool best applied in concert with "conventional" techniques. Indeed, there may be many monitoring problems that are not amenable to remote sensing technology at all.

Unfortunately, no clear articulation of the information requirements for pre-, trans- and post-disaster periods was provided to the workshop attendees. Without this. specific recommendations on which sensor systems spatial and time frame monitoring of individual disaster events proved essentially impossible.

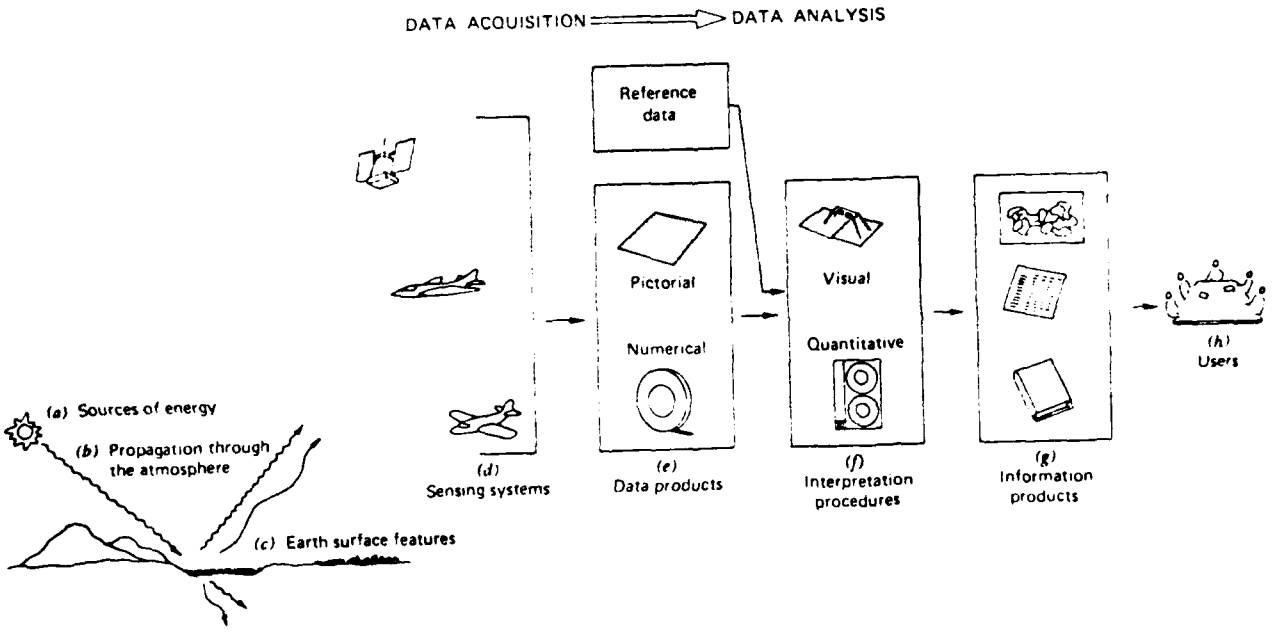

Figure 3. Electromagnetic Remote Sensing of Earth Resources.

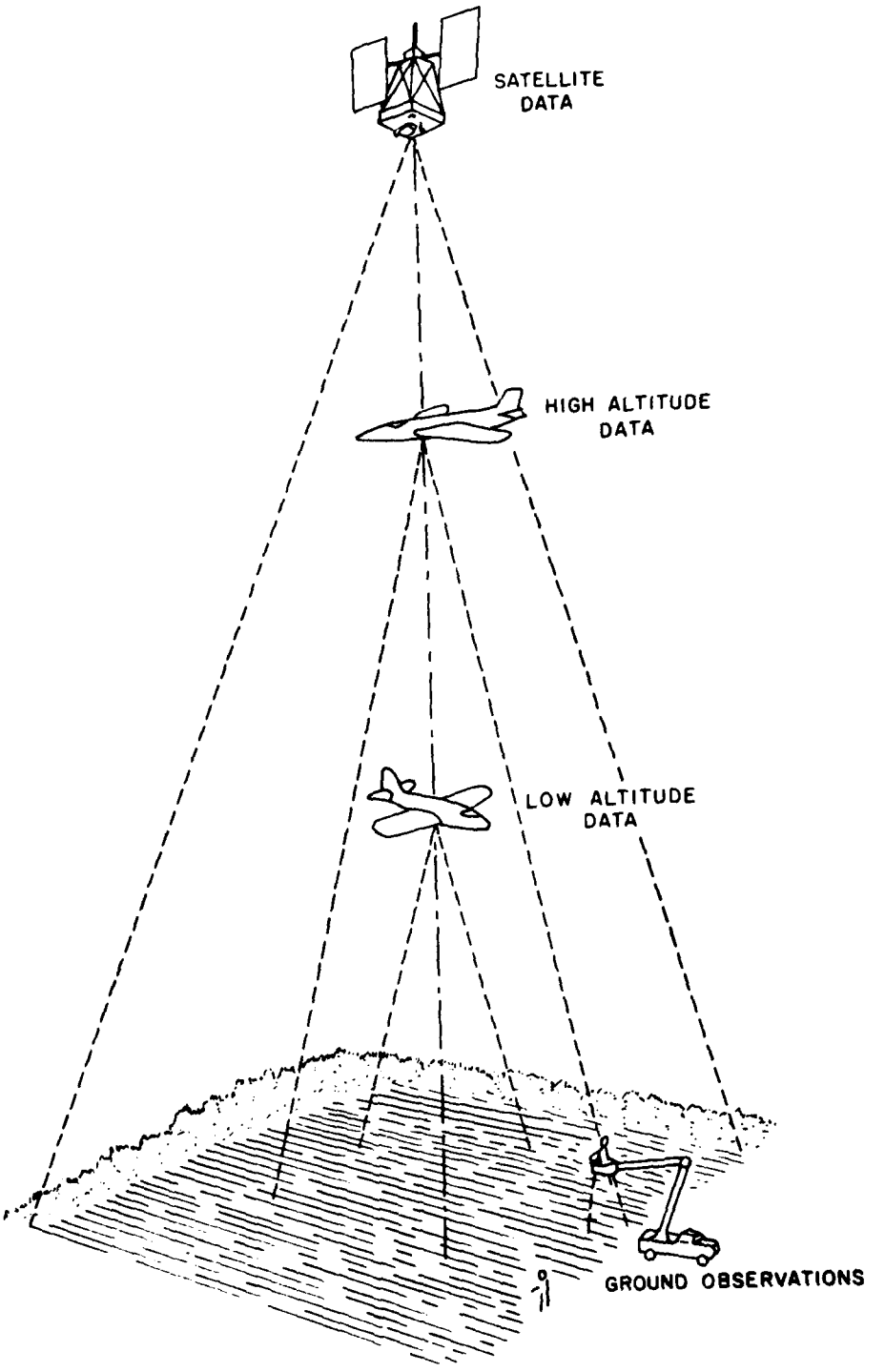

Figure 4. Multistage Remote Sensing Concept.

AVAILABILITY OF REMOTE SENSING TECHNOLOGY FOR DISASTER RESPONSE

Imaging Systems

In the past 15 years the development of sensor technology has progressed to the level that aircraft and spacecraft systems can now be designed to respond specifically to almost any selected information requirements. Synchronous orbiting satellites provide continuous coverage of cloud cover while orbiting satellites provide high resolution imagery of the earth's surface in many spectral bandpasses. Aircraft carrying sophisticated active and passive sensors are available in the private sector as well as several civilian and military federal agencies.

While both aircraft and orbiting platforms have many advantages for monitoring of earth features, they each do have certain limitations as well. Synchronous satellite sensors have low spatial resolution; orbiting satellites have temporal limitations, i.e. they are limited to repeat coverage depending upon their orbital characteristics -- usually days. Aircraft are sometimes limited by adverse weather and requirements for multiple overflights to obtain complete coverage of a target area. In many emergency management situations, therefore, it appears logical to consider use of combinations of satellite and aircraft remote sensing systems. During the pre-disaster period, in most cases, mapping and monitoring can be best accomplished by satellites. If amenable and predicted, short-term warning information most likely will come from aircraft monitoring. Because disasters are not scheduled to match satellite overpass time, it is expected that most monitoring

information during the trans-disaster period will come from aircraft overflights. Information required for post-disaster rehabilitation and reconstruction can come from either system, depending upon spatial and temporal time frames required.

Current and Near Future Satellite and Aircraft Remote Sensing Systems

The following information on remote sensing capabilities of NASA are provided to give the reader a general understanding of the potential for monitoring using remote sensing technology. Even more advanced technology is available within the Department of Defense, however, most of the military technology is classified and would not normally be expected to be available to the local, state or regional offices involved in emergency management. Other agencies, such as the U.S.G.S., U.S.F.S and D.O.E. also have aircraft equipped with various remote sensing instrumentation.

Aircraft Systems

At the present time, NASA has some 24 rotary and fixed wing aircraft supporting programs in instrumentation and technique development, for astronomical observations and for making in-situ measurements in the upper atmosphere. NASA's airborne research activity, which includes high altitude aircraft such as the U-2 and WB-57F and airborne observations like the C-141 and Convair 990, resides at the Ames Research Center in California and at the Johnson Space Center in Texas. Most terrestrial observation programs are managed by the Office of Space and Terrestrial Applications, NASA Headquarters, Washington D. C.

Tables 3, 4 and 5 provide information on the performance characteristics of three of the NASA aircraft which might be utilized for emergency monitoring under an interagency agreement. Tables 6, 7 and 8 show the photographic and electromagnetic scanner capability currently available on these aircraft. Since they are research platforms, the instrument packages may be expected to change. They could not, therefore, be depended upon to collect data with all of these sensors at any given time.

NASA is presently evaluating a much improved version of the U-2 aircraft known as the ER-2. The justification for this aircraft is strongly tied to user needs and economics. It might be expected, therefore, that an arrangement could be made whereby FEMA could have access to a remote sensing system aboard an aircraft capable of reaching any point in the continental United States in a matter of a few hours and mapping targets of interest at any altitude from the surface to above 70,000 feet.

Satellite Systems

Remote sensing from space has been in existence since the 1891 patent to Rahrmann in Germany for his "New and Improved Apparatus for Obtaining Bird's Eye Photographic Views" -- a rocket propelled camera system recovered by parachute. From this early beginning, technology has been developed to the extent that it is now possible to read the numbers on license plates on vehicles along highways from photographs obtained from Vidicon cameras aboard orbiting satellites.

With the increasing capability to obtain, process and apply remotely sensed data from space, it is often assumed that remote sensing

Table 3. NASA U-2 Performance Characteristics.

Range	4700 km (2500 n.m.)
Mission Endurance	6 hours at Mach 0.69
Cruise Speed	740 km/hr (400 knots) TAS
Mission Altitude	20 km (65,000 feet)
Maximum Payload	665 kb (1,450 lbs)

Table 4. NASA NC130B Specifications.

ENGINE:	4 Turboprop
ALTITUDE:	30,000 Feet
DURATION:	8 Hrs: 6 Hrs Data Acquisition
PAYLOAD:	Standard and Experimental; 20,000 Pounds Maximum
CREW:	3 Crew, Plus Operators and Principal Investigators
FEATURES:	Standard Complement
	Walk-on Payload Capability
	Remote Integration Capability

Table 5. NASA WB57F Specifications.

ENGINE:	2 Turbofan (2 Jet)
ALTITUDE:	60,000 Feet
DURATION:	6 Hrs; 4 Hrs. Data Acquisition
PAYLOAD:	Universal Pallet System; 4,000 Pounds
CREW:	Pilot and Scientific Equipment Monitor
FEATURES:	Universal Pallet
	Standard Interface
	Remote Integration Capability

Table 6. U-2 Photographic Systems.

Designation	Lens	Film Format, in.	Ground Coverage @ 65,000 ft	Nominal Resolution @ 65,000 ft
Vinten (Four)	1-3/4 in. F.L.	2-1/4x	14 X 14 n. mi.	10-20 m
I^2S Multispectral (Four Bands)K-22	100 mm F.L. F 2.8	9 X 9 (4 @ 3.5)	9 X 9 n. mi.	6-10 m
RC-10	6 in., F4	9 X 9	16 X 16 n. mi.	3-8 m
RC-10	12 in., F4	9 X 9	8 X 8 n. mi.	1.5-4 m
HR-732	24 in., F8	9 X 18	4 X 8 n. mi.	0.6-3 m
HR-73B-1	36 in., F10	18 X 18	5.3X5.3 n. mi.	0.5-2 m
ITEK Panoramic	24 in., F3.5	4.5 X 50	2 X 37 n. mi.	0.3-2 m
R.C.S.	24 in., F3.5	2.28 X 30	1.1 X 11 n. mi.	8"-12"

Table 7. U-2 Imaging Electronic Sensor Systems.

o	HEAT CAPACITY MAPPING RADIOMETER
o	OCEAN COLOR SCANNER
o	MULTISPECTRAL SCANNER

Table 8. WB-57F/C-130 Photographic Capabilities.

CAMERAS:	Metric, High-Resolution, Multiband
FILM TYPES:	Color, Color Infrared, Black & White, Black & White Infrared
FILM SIZES:	9-1/2 Inch, 5 Inch, 70-MM
RESOLUTION:	Approximately 1.5 M at 20,000 Ft. 6" F.L. Metric Cameras
	Approximately 5 M at 60,000 Ft. Altitude
	1 Meter for High Resolution Cameras at 20,000 Ft. Altitude
FILM PRODUCTS:	Positive and Negative Transparencies
	Continuous and Frame Paper Prints, Color & Black & White
	Transparency and Paper Print Enlargements
	Film Calibration & Analysis (Densitometry & Sensitometry)
	Microdensitometry
	Image Enhancement
	Film/Filter Selections

from satellites is already an operational process. In fact, however, with the exception of meteorology, there are at present no officially "operational" space remote sensing programs, no programs of indefinite duration which provide specific products and services.

The most useful satellites at the present time are the LANDSAT series of which LANDSAT 3 is in operation (launched March, 1978) and LANDSAT D (4 after launch) which is scheduled for launch in 1981. The primary sensor system aboard the LANDSAT is a four channel electromechanical device called the Multispectral Scanner or MSS. Figure 5 shows the spectral bandpasses of the MSS. The LANDSAT 3 MSS covers a 185 km swath width with an instantaneous field of view at nadir of 79 X 79 meters. LANDSAT 3 is in near polar orbit at an altitude of between 880 km and 940 km with an equator crossing time of approximately 0942 giving a repeat coverage of 18 days (Figure 6). The LANDSAT orbit does not compensate for changes in solar altitude, azimuth or intensity. These variations, plus cloud cover and atmospheric turbidity, make this system generally unreliable for monitoring of disasters.

In addition to the MSS, LANDSAT D will carry a next generation electromechanical scanner named the thematic mapper (TM). The TM provides 30 meter "footprints" (nadir IFOV) in six spectral bands from the visible to 2.4 μm infrared and a 120 meter "footprint" in the 10-12 μm thermal IR spectral region (Table 9).

Electromechanical scanners such as MSS and TM have inherent difficulties providing near real time, high resolution imagery useful for emergency management. Even if the satellite crossing time corresponded to the disaster period, the skies were cloudless and all sensors were working, since the LANDSAT program is research and not operational,

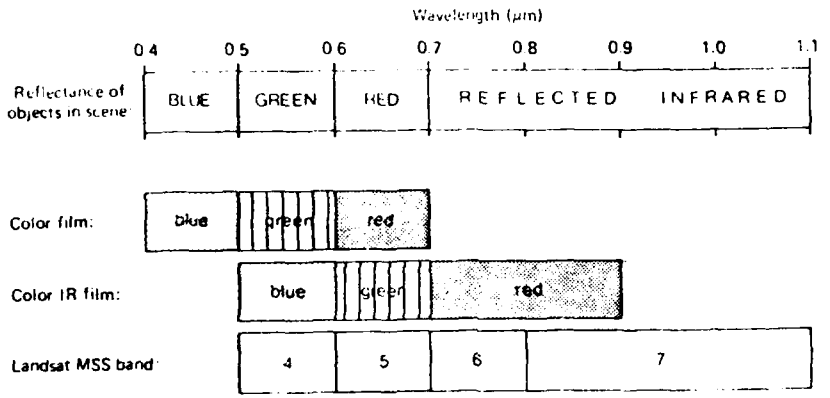

Figure 5. Spectral Sensitivity of the Four Landsat Bands Compared With the Spectral Sensitivity of the Three Emulsion Layers Used in Color and Color Infrared Film.

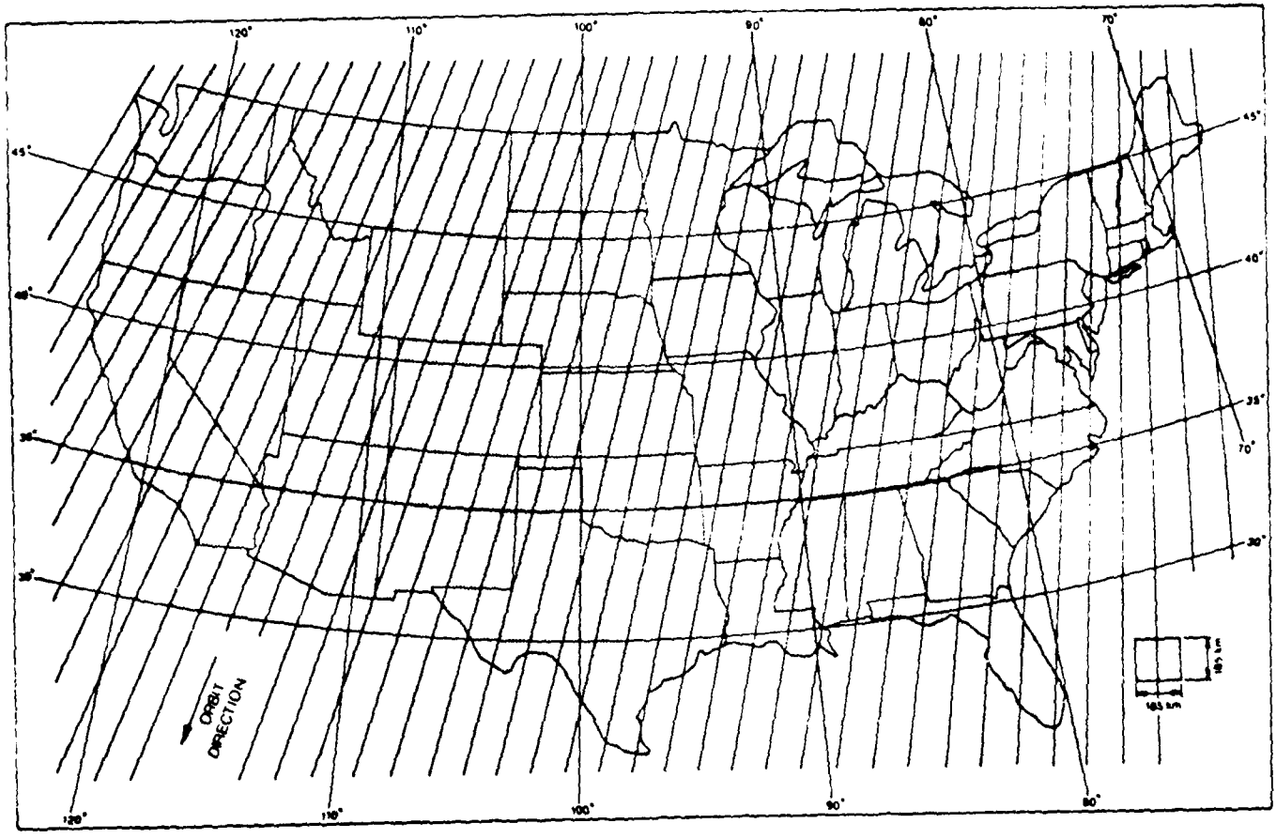

Figure 6. Landsat Orbital Passes Over the Conterminous United States.

Table 9. Sensor Characteristics of the Multispectral Sensor and Thematic Mapper.

	TM			MSS	
	MICROMETERS	RADIOMETRIC SENSITIVITY (NE$\Delta\rho$) (1)	(2)	MICROMETERS	RADIOMETRIC SENSITIVITY (NE$\Delta\rho$)
SPECTRAL BANDS 1	0.52 - 0.60	.35%	.57%	0.5 - 0.6	.57%
2	0.63 - 0.69	.43%	.57%	0.6 - 0.7	.57%
3	0.74 - 0.80	.42%	.56%	0.7 - 0.8	.65%
4	0.80 - 0.91	.32%	.42%	0.8 - 1.1	.70%
5	1.55 - 1.75	.60%	1.68%		
6	10.40 - 12.50	0.5K(NEΔT)		10.40 - 12.60	1.4K (NEΔT)
GROUND IFOV	30 m (BANDS 1-5)			78 m (BANDS 1-4)	
	120 m (BAND 6)			234 m (BAND 5)	
DATA RATE	110 MB/S			15 MB/S	
QUANTIZATION LEVELS	256			64	
INTERBAND REGISTRATION	0.1 IFOV			0.25 IFOV	
LONG TERM SCAN STABILITY	0.5 IFOV			1.5 IFOV	
EQUATORIAL CROSSING TIME	1100 hrs. local			0930 hrs. local	
ALTITUDE	705 km			900 km	
WEIGHT	270 kg			54 kg	
SIZE	0.9 x 0.9 x 1.8 m			0.35 x 0.4 x 0.9 m	
POWER	250 WATTS			42 WATTS	

(1) OPTIMISTIC CASE

(2) WORST CASE

Source: NASA, Goddard Space Flight Center
CORSPERS Committee Briefing, Nov., 1975

it is doubtful if the data products delivery time would allow these monitoring systems to be useful for the time of imminent warning and during the actual disaster period.

It is apparent that, if space remote sensing is to have major usefulness for emergency management, increases in spectral and spatial resolution and temporal coverage will be necessary. It is anticipated that by the mid-1980's, operational domestic geosynchronous and orbiting satellites will be equipped with off-axis pointable zoom sensors. These sensors may be capable of up to ten meter spatial resolution, within a 20 n. mi. wide landpass array. The Multispectral Resource Sampler (MRS), tentatively scheduled for launch in 1984, will use multispectral linear array technology. Characteristics of this sensor system are provided in Table 10.

Another future system scheduled to use the new linear array scanning technology is STEREOSAT. STEREOSAT is being designed to provide sterioscopic imagery from which one can derive parameters such as slope of the ground, direction and offset of faults, etc. Table 11 shows the probable mission parameters of STEREOSAT.

Other space systems that are currently in operation or planned for the next decade include the Heat Capacity mapping mission (two thermal channels, 600 meter IFOV, nine day interval) SEASAT (synthetic aperture radar) and the Space Shuttle. The Space Shuttle, with its spacelab will allow scientists to make visual observations, note unique features or events and concentrate on specific areas for a limited time. On-board computers will provide near real-time processing and improved data handling capabilities.

Table 10. Proposed Multispectral Resources Sampler (MRS) Sensor Characteristics.

SPECTRAL RANGE:	0.36 μm to 1.0 μm
SPECTRAL BANDS:	4 Arrays, Each With 2000 Detectors 5 Selectable Filters/Array Bandwidths $\geq$ 20 nm Polarization filters
SPATIAL RESOLUTION:	15 Meters Max
SWATH WIDTH/MODES:	15 kms at 15 m (4 Bands) 30 kms – At 15 m (2 Bands) At 15 m (4 Bands, 50% Sampling) At 30 m (4 Bands)
RADIOMETRIC SENSITIVITY:	Approximately 0.5% NE$\Delta\rho$ (8 Bit)
DATA RATE:	15 Mega Bits/Second
POINTABILITY:	2 Axes $\pm$ 40° Across Track $\pm$ 55° Along Track
SPEED OF POINTING:	30°/Second Across Track 5°/Second Along Track

Table 11. Stereosat Proposed Mission Parameters.

CAMERA SYSTEM:	Three Pushbroom Scanners: Fore, Aft, and Nadir
SENSOR:	Two 2,048 Linear Arrays Per Camera
ORBIT:	LANDSAT Capability: 700 km, 98.2^{o} Inclination; Sun Synchronous
SWATH WIDTH:	61 km
RESOLUTION:	15 Meter IFOV
BASE-TO-HEIGHT RATIO:	1.0 and 0.47
COVERAGE CYCLE:	48 Days
DATA TRANSFER:	TDRSS
LAUNCH:	1984

Other new space remote sensing activities of the next decade include a multimission modular spacecraft (MMS) and a multimission platform with an array of applications in sun synchronous orbit to be developed and launched by the French Government (SPOT-1).

Communication Systems

The F.E.M.A. contract's Statement of Work did not specify any contractor responsibility in the area of communications and data flow requirements. The workshop attendees, however, expressed the importance of development of a system that could be used for both voice communication and to transmit and log remotely sensed and other data.

Following the first workshop, Dr. Morrell of the Mitre Corporation, provided this project office with a copy of a report entitled, "Advanced Technology Direction and Control Communication Systems" prepared for DCPA and dated August, 1979. The reader is referred to the Mitre report (Contract #DCPA-01-78-C-0259 by Leuppert and Morrell, Mitre Corporation, Washington C^3 Operations, 1820 Dolly Madison Avenue, McLean, VA 22102).

Data Interpretation

Data interpretation of remote sensing includes both the visual analysis of pictorial imagery and the numerical evaluation of spectral patterns, usually brightness patterns. The visual techniques make use of the human eye and mind to qualitatively evaluate spatial patterns in a scene. Subjective judgement based on visual evaluation is often sufficient for interpretation and decision making. The human eye is limited, however, in its ability to discern tonal values and spectral characteristics in a scene. In addition, visual interpretation can be very labor

intensive when numerous scenes must be evaluated simultaneously. In recent years, computer assisted analysis techniques have been developed which allows the data analysis process to be largely automated and which can provide quantitative information on the spectral characteristics of the elements within a scene.

Information extracted through the process of computer reduction and enhancement of airphotos, thermal scanners, side looking radar, etc. is almost always "mapped" in some sense. That is, the decision maker usually prefers to have the information displayed so that the interpreted information can be interpreted in a spatial context. Perhaps the simplest method for merging information that can be displayed on a map is the map overlay method, in which each data set is prepared on a transparent map sheet. One of the principal advantages of the map overlay method is that it requires little specialized equipment. For emergency management applications, it suffers at least three distinct limitations. First, the time requirements for preparing the overlays may be greater than the time frame in which the decision is necessary. Second, the scale of interest often changes between phases of the disaster. Thus, large scale overlays useful for pre-disaster planning may be of limited value during the actual disaster period. Third, it is often difficult to quantify the results of the overlay analysis using only manual computation of areas on the composite map.

By computer coding map information, the data are stored according to location in some spatially ordered geo-based file. Systems designed to store, manipulate and display remotely sensed data are available through NASA and other federal agencies and are also available through contract service companies.

UTILIZATION OF REMOTE SENSING IN DISASTER RESPONSE

Categories of Disasters

The workshop was instructed by FEMA Emergency Operation System Research to consider the application of remote sensing technology to a specific list of disasters. It was found that these could be categorized into one or more of four areas: (a) atmospheric events; (b) tectonic events; (c) failure of man-made structures; and (d) overt acts of agression. Table 12 shows the individual topics considered under each category.

Table 12. Categories of Disasters.

Atmospheric	Tectonic	Failure of Man-Made Structures	Overt Acts of Agression and Other
Floods	Avalanche	Explosion	Arson
Blizzards	Land Slide	Dam Failure	Telecommunications
Snowstorms	Earthquake	Expansive Soils	Gas Shortage
Drought	Land Subsidence	Land Subsidence	Terrorism
Hail	Tsunamis	Water Erosion	Strike
Hail Damage	Volcano	Oil Spills	Riot
Hurricane		Hazardous Materials	
Tornado		Hazardous Chemicals	
Air Pollution		Radiation Hazard	
Inversions		Blackout	
		Nuclear Waste	

A few topics were included in the list provided by FEMA that were not considered by the workshops to be hazards or disasters or were insufficiently defined to be able to evaluate. These were: crop(s), emergency medical services, heating oil, natural gas, data processing, mitigation and relocation.

Another method of categorizing disasters would be:

a) no warning - local

b) no warning - regional or nationwide

c) advance warning - local

d) advance warning - regional or nationwide

Examples of these might be:

a) arson, explosions, oil spills and landslides

b) nuclear accident, hazardous material release, telecommunication disruption, power blackouts

c) volcano eruption (usually), hail, strike, air pollution. An example of a local disaster with warning and time known but exact location unknown was the return of Skylab to earth.

d) hurricanes, drought, blizzards, tsunamis, gas shortage. One example of a regional disaster with location known but exact time of occurrence unknown is the next major earthquake along the San Andreas fault in California.

Rank ordering of disasters by importance is generally not possible, being entirely a function of the potential impact upon the person doing the ranking. River flooding is the most widespread geophysical hazard in the United States with a greater property loss than any other type of disaster. Serious flood potential exists for seven percent of the total

United States' land area directly affecting some ten million persons. Table 13 shows that allocation from the President's disaster fund for floods during 1961-1970 was only seven percent of the total. The cost of flood damages paid from federal or state funds usually does not include agricultural production losses, disrupted transportation or long term effects on floodplain ecology.

Table 13. Number of Major Disaster Declarations and Allocations From The President's Disaster Fund, 1961-1970. (Office of Emergency Preparedness)

Disaster	% Occurrence	% Allocation of Disaster Funds
Severe Storms	45	44
Floods	22	7
Hurricanes/Typhoons	12	31
Tornadoes	12	7
Earthquakes and Tsunamis	2	8
Forest Fires	2	2
Other	5	1

Phases of Monitoring Activities

Ideally, a monitoring program would include remotely sensed and conventionally acquired data during the period before, during and after the event takes place. Some disasters such as explosions, telecommunication failure and the like are not amenable to using remote sensing in the pre-vent event phase. In general, remote sensing is probably most valuable in pre-disaster planning for slowly developing disasters, quantification

of hazard analysis and post-disaster evaluation of damage, evacuation routes, rehabilitation and reconstruction. In the case of large storms such as hurricanes and typhoons, satellite and aircraft remote sensing is proving to be an exceedingly valuable tool for monitoring the storm track, size and intensity. Multiband and doppler radar are also being used in most areas of the state to monitor severe storms.

RECOMMENDATIONS FOR UTILIZATION OF REMOTE SENSING TECHNOLOGY IN DISASTER RESPONSE

Attendees at both workshops expressed strongly the fact that it is not productive to address the technology of remote sensing until there is a good understanding of the problems, the solutions to which additional data and information are required. It was recognized that FEMA is a new agency. No groups were identified from within the organizations merged into FEMA that had expertise in the acquisition, handling and interpretation of remote sensing products for emergency purposes. The recommendations of this report are synthesized from comments and suggestions made by the workshop attendees and are predicated on the concensus that: (1) remote sensing technology can and should become a viable part of FEMA's operations; and (2) FEMA will develop the institutional capability to incorporate this technology into its emergency management plans.

Specific Recommendations

1. The first and most important activity that must be undertaken is to develop a clear understanding of the pre-, trans- and post-disaster information requirements. To do this, it is recommended that scenario study groups be organized to identify and prioritize disaster sensitive

areas, determine the probability of occurrence, the population, cost and other requirements. This activity should be conducted at both the national and regional level. It is suggested that, rather than conduct such scenario studies for all conceivable disasters, the following classes of disasters be considered: (a) atmospheric, (b) tectonic, (c) failure of man-made structures, and (d) overt actions. Information should be developed for each of the five disaster related phases: (a) preparedness, (b) warning, (c) emergency, (d) rehabilitation, and (e) reconstruction.

2. Using the results from (1) above, study groups of individuals who have had first hand experience in the disaster classes should develop the type of information needed for each of the disaster phases -- its dimensions, accuracy, time frame needed, etc.

3. From the results of (2) above, it would then be possible to establish regional data bases for meeting the needs of emergency management personnel. It is the strong belief of the workshop attendees that, while many data bases exist in federal, state and local agency offices, FEMA must get a mandate from the White House if necessary, to establish strong disaster information data base centers in each region. These centers should be given access as needed to the other data bases, but should have the responsibility of providing the data and information products identified. These regional centers should be part of a National Emergency Center within FEMA with communication capabilities to allow pooling of information on short notice. In addition, the regional centers should develop direct coordination links with the NASA Remote Sensing Data Center at Sioux Falls, South Dakota and with the NESS Regional Meteorological Satellite Support groups which are just now being formed.

The regional centers should have responsibility for developing the data bases of current conditions and would have a continuing research effort on the space and time monitoring requirements for each type of emergency.

4. When the results of the study groups on types of information needs are complete, it can be determined which of these needs can be met with remotely sensed data products. An exercise on this was recently completed by the Committee on International Disaster Assistance of the National Academy of Sciences (National Research Council, 1979) in which the possible uses for remote sensing in freshwater and seawater floods and storm surges, earthquakes and droughts were analyzed. Since the uses of remote sensing would be markedly different for a flood on the Mississippi River in Louisiana and one on the Big Thompson River in Colorado, for example, it is believed that the determination of remote sensing requirements (spatial, temporal and spectral) can best be made at the regional center level.

A valuable, yet inexpensive, resource in remote sensing applications available to FEMA exists in the MODBES (Mobilization Designee) Program, This program, which is to be supported by FEMA beginning in FY 81, is known to contain several individuals that could contribute significantly in planning and as consultants, as their civilian occupations are directly related to aspects of remote sensing. One such individual was called upon to contribute to this study. That program should be surveyed for skills that could contribute to the FEMA remote sensing program and the resource utilized.

5. At the time of the workshop, it was understood that no inter-agency agreements had been signed between FEMA and NASA, USDA, USDI, DOD, etc. FEMA can and should provide strong political, moral and

financial support to NASA, DOD and other agencies involved in acquisition and interpretation of satellite and aircraft remote sensing. Binding interagency agreements should be developed to give FEMA first priority on getting satellite and aircraft imagery during the phases of warning, emergency and rehabilitation for specified emergencies.

6. Discussions leading to interagency agreements between NASA, DOD and FEMA on the dedicated use of specified aircraft for high and low level overflights. The type of emergency, the timing and heights of the overpass flights and the sensors should be determined in advance by the regional centers based on the results of recommendation (2).

7. It is recommended that FEMA not attempt to develop its own remote sensing capability either in-house or under contract at this time. The agency should, however, evaluate the capability that DOE has developed in this area for possible future implementation.

Since it is expected that FEMA cannot meet the personnel and financial requirements to establish regional data base information centers recommended in (3) above in all areas of the country at once, the workshop attendees recommend following the activities of recommendations (1) and (2). FEMA conduct the following experiment:

1. Select two regions having different climate, population patterns and types of potential emergencies.
2. Prepare a ranked list of the most serious emergencies to be anticipated in each of the test areas.

3. Develop a complete operations plan for meeting one or two of the most serious emergencies -- including all data bases of importance (population patterns, transportation, power grids, etc.) for these potential emergencies.
4. Identify all the remote sensing monitoring that will be useful in upgrading the data base for pre-, trans- and post-event conditions. Determine where these data can be acquired for that region.
5. Conduct a paper scenario experiment to determine whether the remote sensing information needed for that "disaster" can be acquired in a time and space scale that is useful. This includes requesting the required data from the sources identified in (4).
6. Determine whether the remote sensing input is adequate (both time and space); if not: determine if this can be rectified by better agreements with source agencies -- or organizations, or if FEMA needs to develop their own monitoring arm.

This experiment will provide further refinement of the requirements of the regional data bank information centers when they are established.

From the workshop analyses, it is apparent that a serious need exists for better methods of gathering, transmitting and analyzing data prior to, during and following a natural or man-caused disaster, an act of terrorism or a military attack. It is equally apparent that remote sensing can aid in providing at least part of the data needed. Given the variety of both classified and unclassified sensor systems and technologies for monitoring from satellites and aircraft, the capability exists to obtain nearly all-weather high resolution continuous coverage of any area of the United States within an appropriate time frame -- given sufficient national priority is attached to this effort.

SELECTED READING LIST

Ahmad, M. S., et al. 1978. "Floodplain Mapping in the Indus Basin Using LANDSAT Imagery." Proceedings of the Twelfth International Symposium on Remote Sensing of Environments, April 20-26, Manilla, Phillipines. Ann Arbor, Michigan, Environmental Research Institute of Michigan.

American Society of Photogrammetry. 1968. Manual of Color Aerial Photography. Falls Church, Virginia.

American Society of Photogrammetry. 1975. Manual of Remote Sensing. Falls Church, Virginia.

American Water Works Association. 1973. "Emergency Planning for Water Utility Management." New York. p. 37.

Anderson, W. A. 1969. "Disaster and Organizational Change, A Study of the Long-Term Consequences in Anchorage of the 1964 Alaska Earthquake." Monograph Series 6. Columbus, Ohio, The Ohio State University Disaster Research Center.

Anderson, W. H. 1977. "Assessing Flood Damage to Agriculture Using Color Aerial Photography -- An Example From the 1975 Red River Valley Flood of North Dakota and Minnesota." Sioux Falls, South Dakota, EROS Data Center.

Andrews, H. C. and B. R. Hunt. 1977. Digital Image Restoration. Prentice Hall, Englewood Cliffs, New Jersey.

Avery, T. E. 1977. Interpretation of Aerial Photographs. 3rd Edition. Burgess Publishing Company, Minneapolis, Minnesota.

Barrett, E. C. and L. F. Curtis. 1976. Introduction to Environmental Remote Sensing. Halsted Press, Wiley, New York.

Batson, R. M., K. Edwards and E. M. Eliason. 1976. "Synthetic Stereo and Landsat Pictures." Photogrammetric Engineering and Remote Sensing, Vol. 42, No. 10, pp. 1279-1284.

Beer, H. 1968. "International Disaster Relief: New Problems, New Solutions." Document 29. Geneva, Switzerland: International Council of Voluntary Agencies.

Bernstein, R. and D. G. Ferneyhough, Jr. 1975. "Digital Image Processing." Photogrammetric Engineering and Remote Sensing, Vol. 41, No. 12, pp. 1465-1476.

Brace, William F. 1975. "The Physical Basis for Earthquake Prediction." Technology Review. March/April, pp. 26-29.

Brandli, H. W. 1978. "The Night Eye in the Sky." Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 4, pp. 503-505.

Cardamone, P., D. M. Lechi, A. Cavallin, C. M. Marino and A. Zanferrari. 1977. "Applications of Conventional and Advanced Technologies for the Interpretation of LANDSAT-2 Images for the Study of Linears in the Friuli Earthquake Area." Proceedings of the 11th International Symposium on Remote Sensing of Environment, April 25-29. Ann Arbor, Michigan, Environmental Research Institute of Michigan.

Comptroller General of the United States. 1976. "Observations on the Guatemala Earthquake Relief Effort." U.S. Government Printing Office, Washington, D. C.

de Ville de Goyet, C. 1978. "Assessment of Health Needs Following Natural Disasters." Paper presented at the Fourth Annual Meeting for Designated Epidemiologists, Pan American Health Organization, Washington, D. C. May.

de Ville de Goyet, C. 1979. "Surveillance Epidemiologique lors de Desastres." Bulletin of the World Health Organization, 5757:2.

Douglas, John H. 1974. "Alternatives to Doomsday." Science News, Vol. 106, October 26, p. 269.

Doyle, F. J. 1978. "The Next Decade of Satellite Remote Sensing." Photogrammetric Engineering and Remote Sensing, Vol. 44, No. 2, pp. 155-164.

ECON, Inc. 1974. "The Economic Value of Remote Sensing by Satellite: An ERTS Overview and the Value of Continuity of Service." Prepared for the National Aeronautics and Space Administration, 13 Vols. Princeton, New Jersey.

Estes, J. E. and L. W. Senger (eds.). 1974. Remote Sensing: Techniques for Environmental Analysis. Santa Barbara, California.

Estes, John E. and Bernard T. Nolan. No Date. "NASA's Aircraft and Satellite Remote Sensor Systems. NASA Jet Propulsion Laboratory, Pasadena, California and NASA Headquarters, Washington, D. C.

Estes, J. E., M. R. Mel and J. O. Hooper. 1977. "Measuring Soil Moisture With an Airborne Imaging Passive Microwave Radiometer." Photogrammetric Engineering and Remote Sensing, Vol. 43, No. 10, pp. 1273-1281.

Everitt, B. 1974. Cluster Analysis. Wiley, New York.

Fleming, M. D., J. S. Berkebile and R. M. Hoffer. 1975. "Computer-Aided Analysis of LANDSAT-1 MSS Data: A Comparison of Three Approaches Including a 'Modified Clustering' Approach." LARS Information Note 072475, Laboratory for Application of Remote Sensing, Purdue Univ.

General Electric Space Division. 1975. "Total Earth Resources System for the Shuttle Era." General Electric Space Division, Valley Forge, Pennsylvania.

Gonzalez, R. C. and P. Wintz. 1977. Digital Image Processing. Addison-Wesley, Reading, Massachusetts.

Grey, Jerry, Peter Downey and Bruce Davis (eds.). 1977. "Space, A Resource for Earth." New York American Institute of Aeronautics and Astronautics, p. 67.

Harnage, J. and D. Landgrebe (eds.). 1975. "LANDSAT-D Thematic Mapper Technical Working Group - Final Report." L. B. Johnson Space Center. June, 156 p.

Harper, D. 1976. Eye in the Sky: Introduction to Remote Sensing. Multiscience, Montreal.

Healy, Richard J. 1969. Emergency and Disaster Planning. John Wiley, New York.

Hewitt, Kenneth and Lesley Sheehan. 1969. "A Pilot Survey of Global Natural Disasters of the Past Twenty Years." Natural Hazard Research Working Paper No. 11. University of Toronto/University of Colorado, Boulder.

Hood, Valerie A. 1975. "A Global Satellite Observation System for Earth Resources: Problems and Prospects." A Report to the National Science Foundation on the Application of International Regulatory Techniques to Scientific/Technical Problems. American Society of International Law, Washington, D. C.

International Astronautical Federation, Committee on Application Satellites, Working Group One. 1974. "Ground Systems for Receiving, Analyzing and Disseminating Earth Resources Satellite Data." Paris.

Jensen, H., L. C. Graham, L. J. Porcello and E. N. Leith. 1977. "Side Looking Airborne Radar." Scientific American, Vol. 237, No. 4, pp. 84-95.

Kreps, G. A. 1978. "The Organization of Disaster Response: Some Fundamental Theoretical Issues." Disasters: Theory and Research. E. L. Quarantelli (ed.). Sage Publications, London, England.

Kroeck, D. 1976. Everyone's Space Handbook. Pilot Rock, Arcata, California.

Krumpe, P. F. 1977. "The Application of LANDSAT Technology to the Problems of Disaster Preparedness (Early Warning) and Relief (Damage Assessment). Agency of International Development/Office of U. S. Foreign Disaster Assistance, Washington, D. C.

Leachtenauer, J. C. 1977. "Optical Power Spectrum Analysis: Scale and Resolution Effects." Photogrammetric Engineering and Remote Sensing, Vol. 43, No. 9, pp. 1117-1125.

Leberl, F. 1978. Radargrammetry for Image Interpreting. Second Edition, International Institute for Aerial Survey and Earth Sciences, Enschede, The Netherlands.

Lillesand, Thomas M. and Ralph W. Kiefer. 1979. Remote Sensing and Image Interpretation. John Wiley and Sons, New York.

Lintz, J. and D. S. Simonette (eds.). 1976. Remote Sensing of Environment. Addison-Wesley, Reading, Massachusetts.

Manning, D. 1976. Disaster Technology: An Annotated Bibliography. Pergamon Press, New York.

McCullough, David G. 1968. The Johnstown Flood. Simon and Schuster.

Murthy, H. G. S. 1978. "United Nations Role in Rmote Sensing." Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, Manilla, Phillipines. Ann Arbor, Michigan: Environmental Research Institute of Michigan.

National Academy of Sciences. 1977. "Resource Sensing From Space: Prospects for Developing Countries." Washington, D. C.

National Aeronautics and Space Administration. 1974. Skylab Earth Resources Data Catalog. No. 3300-00586, U. S. Government Printing Office, Washington, D. C.

National Aeronautics and Space Administration. 1976. LANDSAT Data Users Handbook. Doc. No. 76SDS4258, Goddard Space Flight Center, Greenbelt, Maryland.

National Aeronautics and Space Administration. 1977. "Skylab Explores The Earth." SP-380, NASA Scientific and Technical Information Office, Washington, D. C.

National Oceanic and Atmospheric Administration. 1973. "Final Report of the Disaster Survey Team on the Events of Agnes: Natural Disaster Survey Report 73-1." U. S. Department of Commerce, Washington, D.C.

National Photographic Interpretation Center in association with Agency for International Development. 1976. "Utilization of U-2 Photography in the Guatemalan Earthquake, February, 1976." Washington, D. C.

National Research Council. 1976. "Resource and Environmental Surveys From Space With the Thematic Mapper in the 1980's." Committee on Remote Sensing Programs for Earth Resource Surveys, Commission on Natural Resources, National Academy of Sciences, Washington, D. C.

National Research Council. 1978. "The Role of Technology in International Disaster Assistance." Proceedings of the Committee on International Disaster Assistance Workshop, March 1977. National Academy of Sciences, Washington, D. C.

National Research Council. 1979. "Assessing International Disaster Needs." National Academy of Sciences, Washington, D. C.

Piech, K. R. and J. E. Walker. 1971. "Aerial Color Analyses of Water Quality." Journal of Surveying and Mapping Division, American Society of Civil Engineers, Vol. 97, No. SV2, pp. 185-197.

Rhode, W. G., et al. 1976. "Inventory and Mapping of Flood Inundation Using Interactive Digital Image Analysis Techniques." Proceedings of the 2nd Annual William T. Pecora Memorial Symposium (Sioux Falls, South Dakota: American Society of Photogrammetry and U. S. Geological Survey), October, pp. 131-143.

Richason, B. F., Jr. (ed.). 1978. Introduction to Remote Sensing of the Environment. Kendall/Hunt, Dubuque, Iowa.

Robinove, C. J. 1975. "Worldwide Disaster Warning and Assessment With Earth Resource Technology Satellites." Project Report (IR) NC-47, U. S. Department of the Interior, Washington, D. C., p. 10.

Rosenfeld, A. and A. C. Kak. 1976. Picture Processing by Computer. Academic Press, New York.

Rossi, P. H., R. A. Bank, J. D. Wright and S. R. Wright. 1977. "Research Program on Natural Disasters Recovery Process: Relief, Rehabilitation, and Preparedness." Project No. AEN76-15441. National Science Foundation, Washington, D. C.

Sabins, F. F. 1978. Remote Sensing Principles and Interpretation. W. H. Freeman and Company, San Francisco, 407 pp.

Schanda, E. (ed.). 1976. Remote Sensing for Environmental Sciences. Springer-Verlag, New York.

Sharp, W. L. 1978. "Water Management and Control Via the Global Meteorological Satellite System." Proceedings of the Twelfth International Symposium on Remote Sensing on Environment, April 20-26, Manila, Phillipines. Ann Arbor, Michigan, Environment Research Institute of Michigan.

Siegal, B. S. and F. G. Snider. 1978. "Remote Sensing for Nuclear Power Plant Siting, Battan Peninsula, Republic of the Phillipines." Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, Manila, Phillipines. Ann Arbor, Michigan, Environment Research Institute of Michigan.

Swain, P. H. and S. M. Davis (eds.). 1978. Remote Sensing: The Quantitative Approach. McGraw-Hill, New York.

Thomson, F. J., J. D. Erickson, R. F. Nalepka and J. D. Weber. 1974. "Multispectral Scanner Data Applications Evaluation." NASA JSC-09241, December, 357 pp.

United Nations. 1976. "User Needs for Satellite Remote Sensing Data." Report by the Secretary-General (A/AC.105/157), New York.

United Nations, Committee on the Peaceful Uses of Outer Sapce. 1976. "Actual and Predicted Costs and Benefits Involved in the Practical Application of Remote Sensing Technology." Report of the Secretariat (A/AC.105/153), New York.

United Nations Disaster Relief Organization. 1977. "Disaster Prevention and Mitigation: A Compendium of Current Knowledge." UNDRO, New York.

U. S. National Aeronautics and Space Administration. 1976. "A Forecast of Space Technology, 1980-2000." NASA Report, No. SP-387, Washington, D. C.

U. S. National Aeronautics and Space Administration. 1976. "Outlook for Space: Report to the NASA Administrator by the Outlook for Space Study Group." NASA Report, No. SP-386, Washington, D. C.

Vincent, R. K. and G. N. Scott. 1978. "Correlation Studies Between Linear Features Observed in LANDSAT Imagery and Earthquake Epicenters for a Region North of Peking, Peoples Republic of China." Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, Manila, Phillipines. Ann Arbor, Michigan, Environment Research Institute of Michigan.

Warren, Cliff (ed.). 1977. "Proceedings of the Third Biennial Infrared Information Exchange." AGA Corporation, Secaucus, New Jersey.

Way, D. 1973. Terrain Analysis, A Guide to Site Selection Using Aerial Photographic Interpretation. Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania.

Webre, Alfred L. and Phillip H. Liss. 1974. The Age of Cataclysm. Berkeley/Putnam, New York.

White, Gilbert F. and Eugene J. Haas. 1975. Assessment of Research on Natural Hazards. M.I.T. Press, Cambridge, Massachusetts.

Whitman, Ruth I. 1978. "The LANDSAT Program: The Present and Prospects." Proceedings, Earth Observation From Space and Management of Planetary Resources, Paris, European Space Agency, pp. 187-195.

Williams, R. S. and W. D. Carter (eds.). 1976. ERTS-1, A New Window on Our Planet. U. S. Geological Survey Professional Paper 929, Washington, D. C.

APPENDIX A

LIST OF WORKSHOP ATTENDEES

FEMA Workshop Attendees

September 6-7, 1979

Dr. John Davies
Vice President
Barringer Research, Inc.

Dr. Robert Vincent
President
Geospectra Corporation

Mr. Jack Doyle
EG & G, Inc.

Mr. Harold Wollenberg
Lawrence Berkeley Labs

Dr. John Estes
NASA Headquarters

Mr. Clotaire Wood
Executive Director
National Research Council

Mr. James Morrell
MITRE Corporation

Mr. L. Joe Deal
Department of Energy

Contractor Representatives: Dr. William E. Marlatt
Professor
Colorado State University

Dr. E. Bruce Jones
President
Resource Consultants, Inc.

FEMA Personnel: James W. Kerr
FEMA/Research

Dr. Carol Lee Hilewick
FEMA/Research

Lt. Col. Frank Brooks
FEMA/Research

Karl R. Siebentritt, Jr.
FEMA/Plans and Preparedness

FEMA Workshop Attendees

November 5-6, 1979

Dr. Victor Whitehead
Johnson Spaceflight Center
NASA

J. Lackey
EG & G, Inc

Dr. Eugene Maxwell
Professor
Colorado State University

David L. Dietrich
Graduate Research Assistant
Colorado State University

Contractor Representatives: Dr. William E. Marlatt
Professor
Colorado State University

Dr. E. Bruce Jones
President
Resource Consultants, Inc.

DISTRIBUTION LIST

Federal Emergency Management Agency
Mitigation and Research
ATTN: Administrative Officer
Washington, D. C. 20472 (60)

Defense Technical Information Center
Cameron Station
Alexandria, VA 22314 (12)

Civil Defense Research Project
Oak Ridge National Laboratory
ATTN: Librarian
P. O. Box X
Oak Ridge, TN 37830

Dr. John Billheimer
Systan, Inc.
P. O. Box U
Los Altos, CA 94022

Dr. William W. Chenault
Human Sciences Research, Inc.
Westgate Research Park
7710 Old Springhouse Road
McLean, VA 22101

Dr. Jiri Nehnevajsa
Professor of Sociology
Department of Sociology
University of Pittsburgh
Pittsburgh, PA 15213

Dr. Conrad Chester
ERDA, Holifield National Laboratory
P. O. Box X
Oak Ridge, TN 37830

Ryland Research, Inc.
5266 Hollister Avenue
Suite 325
Santa Barbara, CA 93111

Mr. John Mecozzi
System Development Corporation
2500 Colorado Avenue
Santa Monica, CA 90406

Mr. Don Johnston
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, NC 27709

Mrs. Lori O'Neill
Department of Energy
Emergency Electric Power Adm.
2000 M St., N.W. - Room 8212
Washington, D. C. 20461

Mr. Richard K. Laurino
Center of Planning & Resarch, Inc.
2483 East Bayshore Road
Palo Alto CA 94304

The Dikewood Corporation
1009 Bradbury Drive, S.E.
University Research Park
Albuquerque, NM 87106

Ohio State University
Disaster Research Center
127-129 West 10th Avenue
Columbus, OH 43201

Stanford Research Institute
Attn: Mr. Willard Tiffany
333 Ravenswood Avenue
Menlo Park, CA 94025

URS Research Company
155 Bovet Road
San Mateo, CA 94402

Dr. Gerald Klonglan
Department of Sociology and
Anthropology
Iowa State University
Ames, IA 50010

Mr. Howard McClennon, President
International Association of
Fire Fighters
1750 New York Avenue, N.W.
Washington, D. C. 20006

General Manager
International Association of
Fire Chiefs
1329 18th Street, N.W.
Washington, D. C. 30036

Mr. Bjorn Pedersen
International Association of
Chiefs of Police
11 Firstfield Road
Gaithersburg, MD 20760

Mr. Ferris Lucas
National Sheriff's Association
Suite 320 - 1250 Connecticut Ave., N.W.
Washington, D. C. 20036

National Fire Protection Association
Library
470 Atlantic Avenue
Boston, MA 02210

National Bureau of Standards
Disaster Research Coordinator
Attn: Mr. C. G. Culver
Office of Federal Building Technology
Center for Building Technology
Washington, D. C. 20234

Command and Control Technical Center
The Pentagon - BE 685
Washington, D. C. 20301

Mr. Louis V. Spencer
Radiation Theory Section
National Bureau of Standards
Room C-313--Building 245
Washington, D. C. 20235

National Academy of Sciences (JH-312)
Commission on Sociotechnical Systems
Committee on Fire Research
2101 Constitution Avenue, N.W.
Washington, D. C. 20418

Gov. Leo A. Hoegh
Tinpa Road
Chipita Park, CO 80811

Dr. Joseph E. Minor
Texas Tech University
Department of Civil Engineering
P. O. Box 4089
Lubbock, TX 79409

Rosenthal, Farr & Associates
3731 Wilshire Blvd., Suite 800
Los Angeles, CA 90010

Computer Science Corporation
6565 Arlington Blvd.
Falls Church, VA 22046

Arinc Research Corporation
2551 Riva Road
Annapolis, MD 21401

Scientific Service, Inc.
1536 Maple Street
Redwood City, CA 94063

Locus, Inc.
Box 740
State College, AP 16801

The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, VA 22102

The Council of State Governments
Attn: Mr. Hubert A. Gallagher
Disaster Assistance Project
1225 Connecticut Avenue, N.W.
Suite 300
Washington, D. C. 20036

APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT

FINAL REPORT

Contract # DCPA01-79-C-0268

Work Unit 2111H

FOR

Federal Emergency Management Agency
Washington, D.C. 20472

"Approved for Public Release: Distribution Unlimited"

FEMA Review Notice

"This report has been reviewed in the Federal Emergency Management Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Emergency Management Agency."

By

William E. Marlatt
Department of Earth Resources
Colorado State University
Fort Collins, Colorado 80523

E. Bruce Jones
Resources Consultants, Inc.
P. O. Box Q
Fort Collins, Colorado 80522

February 1980

EXECUTIVE SUMMARY

The United States has made great strides in the past decade in developing new technology and instrumentation in the field of remote sensing. This technology appears to have a high degree of usefulness in providing information during times of national or regional emergencies. To this end two workshops were held to identify areas where remote sensing technology has its greatest utility in emergency situations and to develop recommendations for implementation of an appropriate remote sensing program into the newly formed Federal Emergency Management Agency.

Two workshops were instructed by FEMA Emergency Operation System Research to consider the application of remote sensing technology to a specific list of disasters of emergency conditions. These are listed and categorized as follows:

Atmospheric	Tectonic	Failure of Man-Made Structures	Overt Acts of Agression and Other
Floods	Avalanche	Explosion	Arson
Blizzards	Land Slide	Dam Failure	Telecommunications
Snowstorms	Earthquake	Expansive Soils	Gas Shortage
Drought	Land Subsidence	Land Subsidence	Terrorism
Hail	Tsunami	Water Erosion	Strike
Hail Damage	Volcano	Oil Spill	Riot
Hurricane		Hazardous Materials	
Tornado		Hazardous Chemicals	
Air Pollution		Radiation Hazard	
Inversions		Blackout	
		Nuclear Waste	

In addition, crops, food supplies, energy sources, medical facilities, and items that could impact mitigation and relocation were considered. These disasters or emergency situations could be further categorized as to warning time and regional extent. Ranking of disasters in the order of importance is generally not feasible or even practical; however, it has been shown that severe storms, floods, and hurricanes have historically received a high percentage of the disaster funding.

Ideally, a monitoring program to meet FEMA needs and requirements would include remotely sensed and conventionally acquired data during the periods before, during, and after the events take place. Some disasters are naturally not amenable to data collection before they occur. It is believed, however, that remote sensing could have a pre-event role by retrieving previously archived remote sensing data to use as a partial or supplementary base line. Remote sensing definitely has a major potential role in quantifying the event and in the post-disaster damage evaluation and quantification. It also appears to have an important role in post-disaster cases where evacuation and recovery operations must be considered.

Given FEMA's mission, the general recommendations of the workshops were that remote sensing technology should definitely become a viable portion of the FEMA operation and that FEMA should proceed as quickly as possible to develop the institutional capability to incorporate this technology into its emergency management plans. However, with the potential for strong support in the field of remote sensing from other federal agencies, the workshop attendees saw no need for FEMA to develop its own remote sensing acquisition and interpretation capability, either in-house or under contract, at this time.

The workshop attendees strongly expressed the opinion that it is not productive to address the technology of remote sensing operations under emergency conditions until there is a good understanding of the problems and data requirements. Thus they recommend that scenario study groups be organized to identify and prioritize disaster sensitive conditions; and determine the probability of occurrence, the population directly and indirectly impacted, and other pertinent conditions and their attendant data requirements. It was suggested that this type of scenario study be conducted at both national and regional levels. It was further suggested that the scenarios be broken into five segments: 1) preparedness, 2) warning, 3) event, 4) recovery and 5) rehabilitation. It is believed this approach will show the needs for remotely sensed data and indicate how these data can be integrated with the conventionally acquired data. After the data requirements have been established on a scenario basis, regional data bases can be considered.

Regardless of whether or not the scenario approach is used, it was the consensus of the two workshops that the most important steps that FEMA can take at this time are to:

1. Determine the spatial and temporal data requirements and information needs and the role that remote sensing can effectively play.
2. Determine the locations of existing data bases of remotely sensed data appropriate to FEMA requirements.
3. Establish interagency agreements to acquire and interpret the remotely sensed data required for specific types of disasters.

4. Establish procedures for converting remotely sensed data into information usable for the decision-maker.
5. Identify the person(s) requiring the information.
6. Establish the appropriate communication links for integrating the remotely sensed data with the conventionally obtained data.

In addition to the current programs, it appears significant that in Fiscal Year 1981 FEMA will support the Mobilization Designee Program (MOBDES) in which individuals not necessarily federal employees can be called upon to assist with regional problems. This concept should be encouraged to meet specific personnel requirements.

APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT

Unclassified Earth Resources Department
College of Forestry and Natural Resources
Colorado State University
Fort Collins, CO 80523

February 1980 58 Pages

Contract # DCPA01-79-C-0268 Work Unit # 2111H

Abstract: Two workshops considered how remote sensing technology can be applied to emergency management. Current remote sensing systems are described and recommendations provided on steps to integrate remote sensing into the F.E.M.A. programs.

APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT

Unclassified Earth Resources Department
College of Forestry and Natural Resources
Colorado State University
Fort Collins, CO 80523

February 1980 58 Pages

Contract # DCPA01-79-C-0268 Work Unit # 2111H

Abstract: Two workshops considered how remote sensing technology can be applied to emergency management. Current remote sensing systems are described and recommendations provided on steps to integrate remote sensing into the F.E.M.A. programs.

APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT

Unclassified Earth Resources Department
College of Forestry and Natural Resources
Colorado State University
Fort Collins, CO 80523

February 1980 58 Pages

Contract # DCPA01-79-C-0268 Work Unit # 2111H

Abstract: Two workshops considered how remote sensing technology can be applied to emergency management. Current remote sensing systems are described and recommendations provided on steps to integrate remote sensing into the F.E.M.A. programs.

APPLICATIONS OF REMOTE SENSING TO EMERGENCY MANAGEMENT

Unclassified Earth Resources Department
College of Forestry and Natural Resources
Colorado State University
Fort Collins, CO 80523

February 1980 58 Pages

Contract # DCPA01-79-C-0268 Work Unit # 2111H

Abstract: Two workshops considered how remote sensing technology can be applied to emergency management. Current remote sensing systems are described and recommendations provided on steps to integrate remote sensing into the F.E.M.A. programs.