

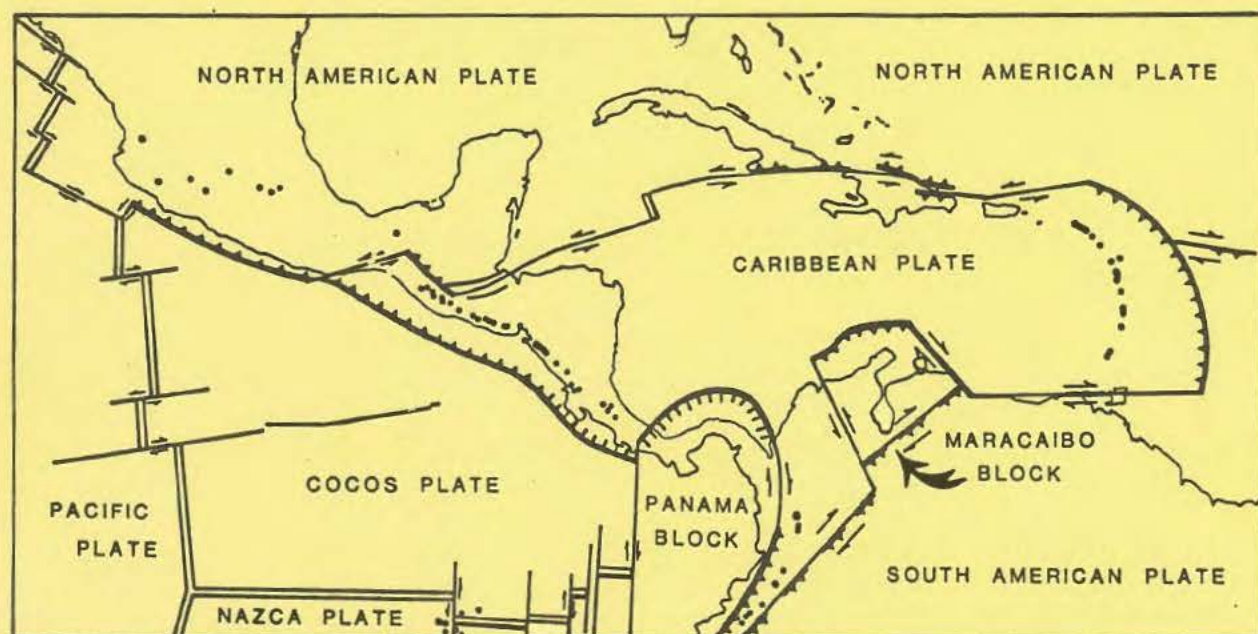
WORKSHOP ON THE CARIBBEAN PLATE AND GEODYNAMICS

25 JANUARY 1978
24 FEBRUARY 1978

LUNAR AND PLANETARY INSTITUTE

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WORKSHOP SUMMARY

CARIBBEAN PLATE AND GEODYNAMICS

Lunar and Planetary Institute

25 January 1978

24 February 1978

Minutes Compiled at LPI by

Thomas R. McGetchin

Assisted by

Carolyn Kohring

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1. SUMMARY AND PARTICIPANT LIST

1. SUMMARY AND PARTICIPANT LIST

1.1 Summary:(.

Two workshops were held at the LPI in January and February 1978 to discuss possible NASA research topics within the Caribbean area. The meetings explored these scientific topics, then focused on the few most interesting, namely current and past plate motions, earthquake prediction and volcanology. Briefings were also conducted on the NASA (JSC) earth observations program, NASA's remote sensing aircraft program and (by telecommunication) the NASA program plans in geodynamics which uses a laser ranging and interferometry network.

The Caribbean area has many interesting aspects from the viewpoint of the earth sciences - two active subduction zones, approximately 60 active volcanoes, two belts of intense seismic activity, economic deposits of fossil fuel, metallic ores and geothermal energy and an intriguing suite of important relations involving plate motions. In fact, the Caribbean area is a key and poorly understood piece in global geodynamics. Many problems within the region could be effectively approached utilizing NASA capabilities and facilities; problems of national US concern (energy and mineral resources, natural hazards, effects of spacecraft and SST aircraft operations on climate and climate prediction) can be effectively studied using the Caribbean region as a natural laboratory to observe important processes.

At the conclusion of the second meeting, a program plan was drafted which describes the first three years of a research program within the western Caribbean area. This plan is summarized in section 2 of this report. The program would utilize parts of both the technology and scientific community of the lunar and planetary sciences, to a problem on the earth namely geodynamics and its relationship to earthquakes and volcanic processes.

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Second Workshop, 24 February 1978

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2. LETTER TO DR. EDWARD A. FLINN WITH
RECOMMENDED PROGRAM FOR
NASA/OSTA GEODYNAMICS PROGRAM

UNIVERSITIES SPACE RESEARCH ASSOCIATION

THE LUNAR SCIENCE INSTITUTE

3303 NASA ROAD 1
HOUSTON, TEXAS 77058

TEL: (713) 488-5200

CABLE ADDRESS: LUNSI

March 3, 1978

Dr. Edward A. Flinn
OSTA/NASA Headquarters
Code: SS
Washington, D.C. 20546

Dear Ted:

Enclosed is a slightly revised Caribbean program document; at Sevier's suggestion we've added a section on the relationship to national needs and the OSTA-mission — an important issue to address explicitly, I think.

Also, you'll find a copy of a clean figure in case you have other uses for it.

Best regards,



Thomas R. McGetchin
Director

TRM:ck

Enclosures

cc: Caribbean Plate Workshop Attendees/all (w/enclosures)
C. Burke, UTA (w/enclosures)
C. Drake, Dartmouth (w/enclosures)
M. Duke, JSC (w/enclosures)

GEODYNAMICS IN
CENTRAL AMERICA

A PROPOSED NASA PROGRAM

NASA Geodetic and remote sensing techniques applied to the study of the Dynamics and Volcanism of the Western Caribbean and Southern Mexico.

1. Introduction
2. Tectonics of the Western Caribbean Study Zone
3. Problems to be Studied
4. Program Plan
5. Budget
6. Relationship of the Project to the NASA/OSTA Mission and National Concerns

GEODYNAMICS IN CENTRAL AMERICA — A PROPOSED NASA/OSTA PROGRAM

NASA Geodetic and Remote Sensing Techniques Applied to the Study of the Dynamics and Volcanism of the Western Caribbean and Southern Mexico

1. INTRODUCTION

With the advent of promising new methods for measurement of long baselines and changes in elevation as an outgrowth of NASA technology, coupled with emerging remote sensing techniques, the earth sciences have entered a new era. A series of technical sessions were held at the Lunar and Planetary Institute during January and February, 1978 to develop a plan for application of these techniques in a comprehensive study of a geologically active zone. The participants in these discussions included experts in remote sensing from the Johnson Space Center, and research scientists from the Lunar and Planetary Institute and various university groups. The capabilities of the various remote sensing aircraft operated by JSC, and the planned portable laser station were reviewed. Primary considerations in the selection of a study zone were that problems of fundamental importance were represented in the zone, and that it be within a reasonable distance of the United States. Specific problem areas considered were the following:

1. The dynamics of active plate margins with emphasis on earthquake prediction
2. The phenomenology of volcanic eruption with emphasis on prediction of eruptions, and constituents of volcanic emissions and their possible influence on weather patterns
3. The effectiveness of remote sensing techniques in delineating potential geothermal fields.

A zone including the Western Caribbean and Southern Mexico, shown in figure 1, was selected. Further discussion centered on specific problems to be studied within this zone.

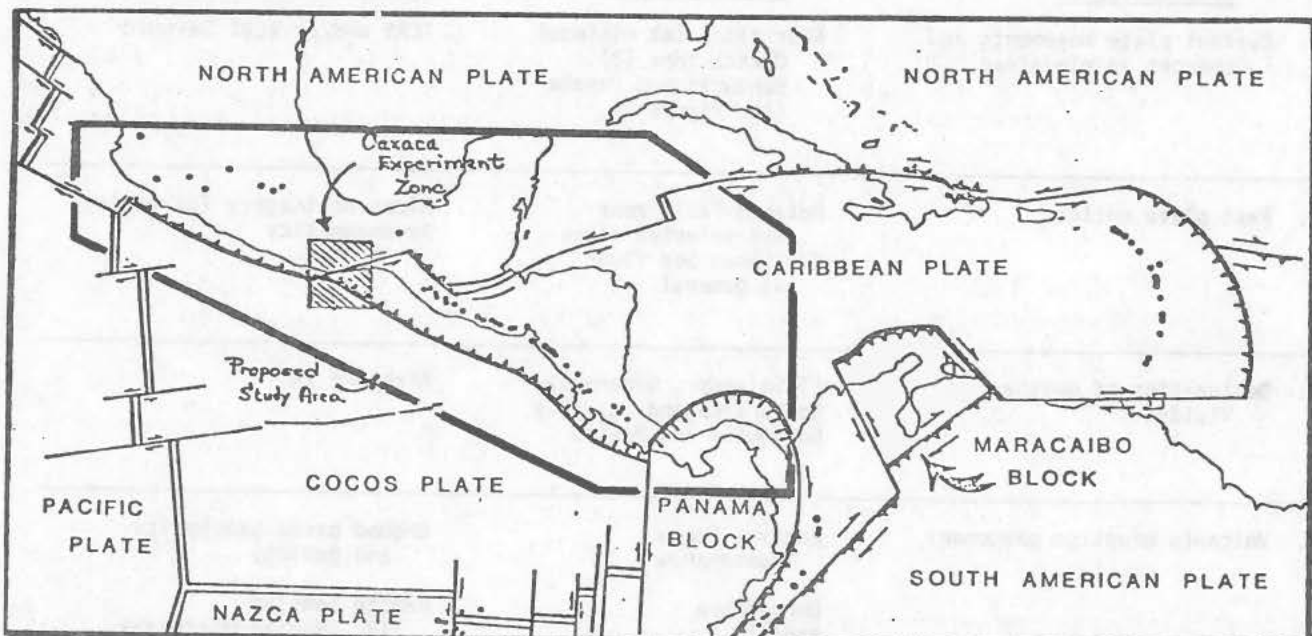


FIGURE 1: GENERALIZED TECTONIC MAP OF CENTRAL AMERICA AND THE CARIBBEAN, SHOWING THE PROPOSED AREA OF STUDY.

2. TECTONICS OF THE WESTERN CARIBBEAN STUDY ZONE

Collisions between the Cocos, Nazca, Caribbean, and North American plates have produced a zone of intense seismicity and volcanism stretching over 2,000 km from Southern Mexico to Panama. Approximately 200 earthquakes of magnitude 4 and greater occur in this zone each year, and about 40 volcanoes are currently active, or have been active, in this zone in historic time. The active boundary between the Caribbean and North American plates transects the zone through Guatemala, forming a triple junction. The boundary between the Cocos and Nazca plates (the Panama Fracture Zone) is located near the southeastern terminus of the study zone, and forms a second triple junction. The diversity of structural and tectonic styles, coupled with the high level of volcanic and seismic activity, make this region an ideal laboratory for study of many aspects of earthquake and volcanic phenomena. The Caribbean remains a mystery in reconstructing past plate movements. Thus, this zone is of fundamental importance in understanding global plate dynamics. A major seismic gap has been identified near the northern end of the zone in the state of Oaxaca, Mexico. Within this zone, we have an opportunity to study precursory phenomena, particularly land deformation, as part of this program. Well-defined geothermal fields exist in El Salvador, Nicaragua and Costa Rica. Logistical factors favor the area as well because the proposed study zone is accessible to supporting aircraft, ships, and personnel traveling from the United States and cooperative working arrangements with local scientists and governments already exist.

3. PROBLEMS TO BE STUDIED

Broad problem areas and suggested measurement techniques to be applied in the study zone are summarized in Table 1. Specific scientific problems within the region are summarized in figure 2.

Table 1. Problem Areas, Possible Sites, and Suggested Measurements.

| <u>Problem Topics</u> | <u>Possible Sites</u> | <u>Measurement Techniques</u> |
|--|---|---|
| 1. Current plate movements and changes in elevation. | Four sites (at minimum) Oaxaca zone (2), Honduras and Panama (see figure 2). | TLRS and/or VLBI Seismic |
| 2. Past plate motions | Motaqua Fault zone and selected sites Caribbean Sea floor in general | Airborne imagery for geology Aeromagnetics |
| 3. Delineation of geothermal fields | El Salvador, Nicaragua, Costa Rica and possibly Guatemala and Mexico | Airborne IR |
| 4. Volcanic eruption phenomena | Pacaya, Fuego Acatenango Cerro Negro Arenal two Mexican sites | Ground based geophysics and geology Remote Sensing IR, Imaging Microwave, Raman spectroscopy (remote gas analysis), photography Sampling (gas, ash, lava) |

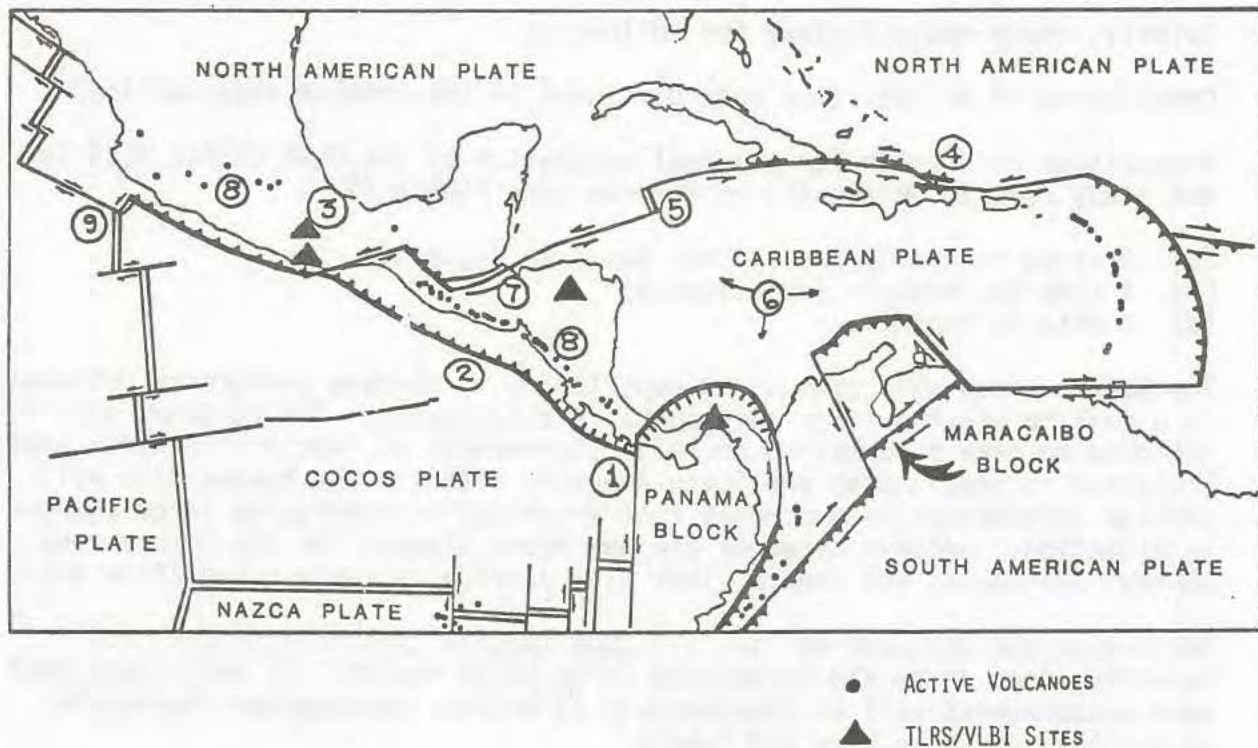


FIGURE 2. GEODYNAMIC PROBLEMS WHICH CAN BE EFFECTIVELY STUDIED WITHIN THE WESTERN CARIBBEAN REGION INCLUDE CURRENT DYNAMICS OF MAJOR PLATES, PAST PLATE MOTIONS AND MANY ASPECTS OF THE EFFECTS OF PLATE MOTION SUCH AS SEISMICITY, VOLCANOLOGY AND GEOTHERMAL ENERGY. SITES (INDICATED BY NUMBER) WHERE SOME OF THESE PROBLEMS CAN BE EFFECTIVELY STUDIED ARE:

(1) THE TRIPLE JUNCTION BETWEEN THE COCOS, CARIBBEAN AND NAZCA PLATE (PANAMA BLOCK) IS NOT UNDERSTOOD AND IS PARTICULARLY INTERESTING BECAUSE THE CARIBBEAN PLATE MAY BE FROZEN IN PLACE - THAT IS, NOT MOVING WITH RESPECT TO UNDERLYING MANTLE; (2) THE FOREARC BASIN WEST OF CENTRAL AMERICA IS AN ACTIVE SUBDUCTION ZONE - AN EXCELLENT LABORATORY FOR EARTHQUAKE PREDICTION; (3) THE TRANSITION ZONE BETWEEN THE CENTRAL AMERICAN AND MEXICAN SEISMIC-VOLCANIC BELT IS A PUZZLE BECAUSE IF THE SUBDUCTION ZONE IS CONTINUOUS IT MUST BE BENT; (4) THE PUERTO RICO TRENCH AREA IS ONE OF LONGSTANDING INTEREST BECAUSE DEEP LAYERS OF THE OCEANIC CRUST ARE EXPOSED ON STRIKE-SLIP AND POSSIBLY THRUST FAULTS; (5) THE AVAILABLE MAGNETIC DATA SUGGEST THE CAYMAN RISE IS A YOUNG SPREADING CENTER; (6) THE SEA FLOOR ANOMALY DATA FOR THE CARIBBEAN ARE NOT YET FULLY COMPILED AND SHOULD PROVIDE VALUABLE INSIGHTS INTO PLATE MOTIONS; (7) THE MOTAQUA FAULT ZONE IS A COMPLEX AREA OF GRABENS AND SPLAYED FAULTS, THE LANDWARD EXTENSION OF THE SWAN FAULT ZONE; (8) THE ACTIVE VOLCANIC BELTS OF CENTRAL AMERICA AND MEXICO ARE THE DIRECT CONSEQUENCE OF PLATE MOTIONS AND PRESENT REAL PROBLEMS FROM VOLCANIC ERUPTION HAZARDS BUT ARE WELL SUITED FOR STUDYING PRECURSOR ACTIVITY TO ERUPTIONS AND ERUPTION PROCESSES, INCLUDING ATMOSPHERIC EFFECTS; AND (9) THE TRIPLE JUNCTION BETWEEN THE PACIFIC, NORTH AMERICAN AND CARIBBEAN PLATE, WHILE OUTSIDE THE STUDY AREA DISCUSSED HERE, IS OF PARTICULAR INTEREST BECAUSE IT IS VERY SIMILAR TO THE STRUCTURE OF THE GORDA RISE AND THE CASCADE VOLCANIC PROVINCE IN THE PACIFIC NORTHWEST OF THE UNITED STATES.

4. PROGRAM PLAN

We assume that many related studies will continue in the study zone. Here we specify only the program elements proposed for NASA sponsorship.

Briefly, these would include the following:

1. Compilation of all existing data pertinent to the problem areas defined.
2. Preparation of 4 sites for eventual occupation by the TLRS and/or VLBI in the study zone to be located as follows (see figure 2)
 - (a) 2 sites in the Oaxaca seismic gap (see figure 2)
 - (b) 1 site in Honduras (Tegucigalpa)
 - (c) 1 site in Panama

The Oaxaca sites will give us an opportunity to measure precursory deformation in a zone in which a large earthquake is anticipated. The Honduras site is intended to give information on rates of movement of "nuclear" Central America (relative to other North and South American sites). The Panama site will provide information in a complex zone which may be undergoing large changes in elevation. Seismic networks are now being planned for the Oaxaca zone, Central Guatemala, and Panama, that will provide valuable correlative data.

3. Collection and analysis of high altitude imagery (possibly, radar) for selected zones as an aid in mapping large scale faults. We anticipate that such measurements will be concentrated in Oaxaca, southwestern Guatemala or portions of Costa Rica and Panama.
4. Collection and analysis of aeromagnetic data for key areas in which existing data are inadequate.
5. Collection, processing and analysis of thermal IR data for one or more geothermal fields, and active volcanoes.
6. Volcanic studies, should be focused initially on compilation of existing data, but could utilize JSC aircraft capability and communications for eruption studies later. Previous erupting history of the active volcanoes should be compiled, together with all data relating to their structural and petrologic evolution. Very early a commitment to a selected subset (approximately six volcanoes) should be made emphasizing both scientific interest and hazards — probably the Guatemala City group (Fuego, Acatenango, Pacaya), Arenal, Cerro Negro and two Mexican sites. Fairly extensive data already exists on these sites but compilation of existing NASA data (space imagery, aircraft overflights) and acquisition of some new data will permit modeling of two problems of interest to proceed, namely eruption precursor activity and eruption processes themselves. From the viewpoint of geodynamics, the relationship of the volcanoes, their products and activity should be explored with the goal of relating them to plate motions and the subduction zone. Applications of these ideas are in geothermal energy, ore genesis and volcanic hazards.
7. Consideration should be given to communication of data in real-time using satellites; JSC Houston could serve as the center for receiving and dispersing information. Seismicity and volcano monitoring could be done in this mode, particularly in areas showing large increases over background activity levels.

BUDGET PAGE OMITTED

6. RELATIONSHIP OF THE PROJECT TO OSTA MISSION AND NATIONAL CONCERNS

The nation faces pressing problems; their solution will require resourcefulness and wise application of our collective knowledge, including space technology and scientific approaches to these problems. Foremost among these challenges are: (1) scarcity of energy and mineral resources, (2) alteration of the environment by man, and the closely related matter of the possible effects of minor climate changes on agricultural productivity, and (3) unpredictable natural disasters. The research program we propose in Central America will aid the nation in meeting these needs by developing effective means for solving relevant geoscience problems utilizing space technology — these methods and solutions bear directly on national needs in energy-mineral resources, the environment-climate problem and disaster prediction. Our point is that Central America is an excellent natural laboratory — scientifically interesting, important to its countries and citizens but also very important to the U.S. national interest as an efficient place to learn about significant geodynamic processes.

To be more specific, Central America and the western Caribbean contain significant deposits of fossil fuel, metallic ores and geothermal energy. The research program we outline, while directed at understanding geodynamics and its consequences, utilizes and develops methods for exploration by remote sensing, and coordinated space, airborne and ground based geoscience activities. These methods and results can be utilized for both resource assessment and site evaluation for utilization for both energy and mineral resources. The possible long term effects on climate of the activities of man such as CO₂ release by deforestation, the burning of fossil fuels and also the effects of space operations and SST exhaust on the ozone layer — the earth's greenhouse, can also be studied utilizing data from this project. Assessment of these effects rests with large scale climate models — volcano eruptions provide the best natural experiments to test these models. Several times each decade in Central America, an eruption occurs of sufficient violence to place ash, aerosols and gas through the tropopause and into the stratosphere where it is dispersed worldwide. Observation of the processes of injection and dispersal of these products, sampling and analyses, and modeling of the processes are crucial input to climate change projections due to natural causes, as well as man-made ones. Finally the ability to predict violent natural disasters — storms, earthquakes and also volcanic eruptions are important problems within the U.S. (The Caribbean area of course is the spawning ground for hurricanes which devastate the Gulf Coast — but meteorology and oceanography are outside the scope of this proposal.) The seismic belt of western Central America is intensely active and the research program there is a laboratory for earthquake prediction; the results add significantly to our knowledge of earthquake precursor phenomenology for worldwide application, including the western U.S. and Alaska. One explicit goal of the project is to tie earthquake prediction to plate motions, their ultimate cause. The work proposed here would compliment that planned for the San Andreas by providing data from an earthquake zone which is several times more active — hence providing relevant data faster and hopefully bring the empirically based prediction models to fruit faster. Lastly, while volcanic eruptions are not daily concerns within the U.S., when they do occur they can be devastating to property and in some instances life. The Cascade and Alaskan volcanoes are dangerous types and, although generally dormant, they are definitely not extinct. The recent activity at Mt. Baker Washington in 1975 was a local nuisance, but an eruption (or mud flow) was a real possibility. The possible large effects are abundantly evident in the Quaternary record of the Pacific Northwest; for example Tacoma is built on such a geologically recent mud flow from Mt. Ranier, some 100 km distant. The intense activity level of the Central American volcanoes is an ideal laboratory for studying the behavior of volcanoes, their precursor activity

before eruptions, the effects of eruptions, how these relate to plate motions and the directly applied aspects — volcanogenic ore deposits and geothermal energy.

To summarize, the unique geological structure of western Central America is an excellent geodynamics laboratory — a place to relate plate motions to a number of fundamental processes (earthquakes, volcanic eruptions), geological structures of practical importance (deposits of fossil fuels, metals, and geothermal energy) and which can be effectively studied utilizing the unique capabilities of NASA (such as aircraft based at JSC, possible satcom telemetry, space imagery and the NASA-academic geoscience community). These studies bear directly on U.S. national needs by applying these techniques and knowledge to problems in (1) energy and mineral resources by developing methods for resource assessment, (2) climatic effects on agriculture by providing important fundamental data for climate modeling, and (3) natural disasters by addressing directly the relationship of plate motions to earthquakes and volcanic processes. Hence, this project is scientifically sound and exciting, will provide important and direct input to solution of problems of natural concern and therefore will aid NASA/OSTA fulfill its mission.



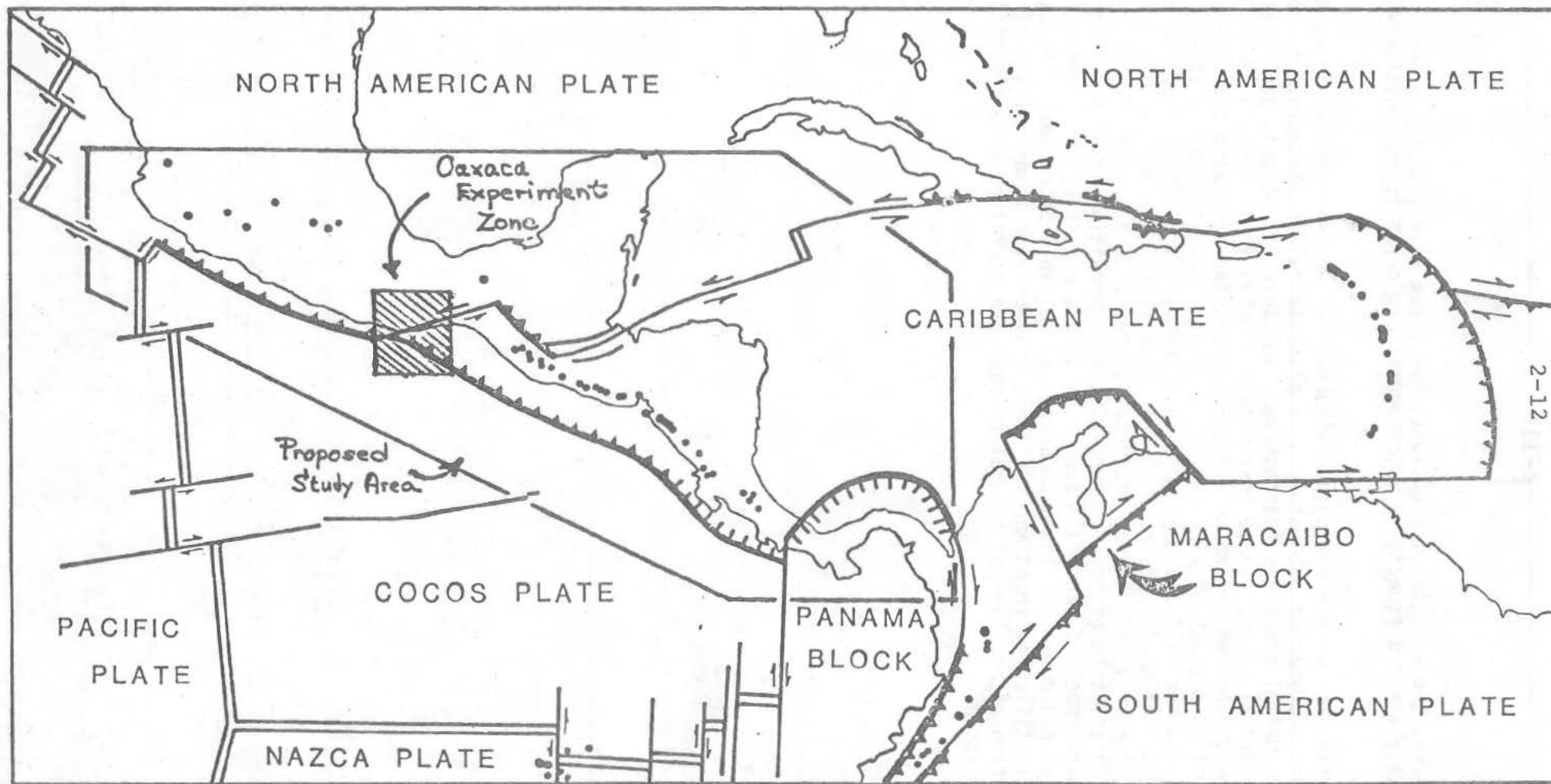


FIGURE 1: GENERALIZED TECTONIC MAP OF CENTRAL AMERICA AND THE CARIBBEAN, SHOWING THE PROPOSED AREA OF STUDY.

3. AGENDA, MEETING #1

L S I W O R K S H O P

TOPIC: Caribbean Plate-Geosciences from Earth Orbit

GOALS: To define possible research topics utilizing earth orbit (or other unique NASA capabilities) with the Caribbean Plate as a restricted geographic, multi-discipline and interesting focus

TIME/PLACE: LSI - Hess Room

9:00 a.m. - 12:00 noon

Friday, January 20, 1978

AGENDA:

1. Introduction - McGetchin
2. Caribbean Plate, an overview and topical studies under way - Latham, Dorman/
M. A. Tomoto/
Stoiber
3. Shuttle Science/Space Lab - Garriott
4. JSC/Earth Observation Program - Johnston
5. NASA/OA - Reorganization, goals - McGetchin/Flinn
6. Discussion:
 - a. Uniqueness of NASA facilities capabilities
 - b. Space-based experiments/coordinated observations, experiments
 - c. CR Problems
 - d. Recommendations to OA
 - e. Follow-up items/Possible

4. AGENDA, MEETING #2

AGENDA

CARIBBEAN PLATE WORKSHOP NO. 2

24 February 1978

9:00 a.m. to 1:00 p.m.

LPI

1. Introduction - McGetchin
2. Review of JSC Instrumented Aircraft Program
(*Olay Smistad/JSC*)
3. NASA/OSTA (Office of Space and Terrestrial Applications)
Plans and Programs
(*Telecomm. with Ted Flinn*)
4. Plate Motions in the Caribbean
(*Tom Jordan/UCSD*)
5. Status of Compilation of Magnetic Data:
(*Hall, Srnka, Worzel*)
6. Topical Problem Discussion

Assistant: *Carolyn Ann Kohring*

NOTE

Noontime Seminar
Hess Room

Tom Jordan
UCSD

"Implications of Lateral
Inhomogeneities in the
Earth's Mantles"

5. SUMMARY OF MEETING #1

SUMMARY

CARIBBEAN PLATE WORKSHOP

LSI, 20 January 1978

The goal of the workshop was to discuss possible research topics utilizing earth orbit (or other unique NASA capabilities) with the Caribbean Plate as a restricted geographic focus within which many interesting and important geological problems exist. This half-day discussion was attended by ten people representing JSC, LSI, and several universities active in the Caribbean.

The agenda included a review of the NASA earth observations program and JSC's role in it, a brief review of shuttle science plans, a review of existing research in the Caribbean — including activities of WG-2 of the geodynamics project, discussion of several specific research topics of particular interest in earthquake prediction, plate motions, and volcanology (seismic monitoring, eruption prediction, effects and modeling). A tour of the JSC Earth Observations Division Laboratories was held in the early afternoon; both the electronic and photographic-cartographic capability were of considerable interest.

Principal conclusions of the discussions were:

- It is essential that any such programs should be narrowly focused to solutions of *well defined specific scientific problems and questions*.
- It is clear that several such problems exist in the Caribbean area and that identifiable individuals exist who are eager to pursue them.
- JSC/EOD capabilities are significant, and their management is clearly interested in cooperating with individuals or with a project, should one develop.
- Existing (spacecraft and aircraft) data base for the region is enormous, and it should be assessed for pertinent material already in existence.
- The problems of obvious interest are:
 - plate motions and the (unresolved) role of the Caribbean plate in global reconstructions
 - earthquake prediction, utilizing the intensely active mid-America trench subduction zone as a "laboratory" for development of prediction techniques
 - volcano science — seismicity and eruption prediction, eruption modeling, and climatic effects due to particulate, aerosols and gas injection can be effectively investigated using the volcanic belts of Central America, the Antilles arc and Mexico

SUMMARY, CARIBBEAN PLATE WORKSHOP
LSI, 20 January 1978

- 2 -

- sea floor geophysics, especially completion of the magnetic anomaly map of the Caribbean.

Aircraft data may be more useful than space-based data because of D. O. D. constraints — (e.g., limitations on permissible photographic resolution from orbit precludes geodetic work).

Actions recommended:

There was general and enthusiastic agreement that the topic was worth pursuing further. Next meeting is scheduled for Friday, 24 February 1978, 9:00 a.m. at the LSI.

Minutes, including supporting documents regarding previous NASA programs and JSC facilities, will be circulated to all participants, and also to other interested people (e.g., Drake, Stoiber, Birnie, Dartmouth; Burke, U. Texas; WG-2 members; Lowman, GSFC; Muehlberger, U. Texas).

At the February meeting, a briefing on the JSC aircraft program will be held.

The *principal* action item for scientists is to define potential research programs — everyone interested is encouraged to give this some thought before 24 February.

NASA Headquarters personnel should be encouraged to participate; Ted Flinn was contacted and invited for February. Minutes will be sent to OA (Calio, Rasool, Roberson, Thomas, and Flinn).



CARIBBEAN AREA PROBLEMS DISCUSSED

| PROBLEM | BACKGROUND REMARK | SPECIFIC PROBLEM | RESEARCHERS | APPROACH | REMARKS |
|--------------------------|---|---|---------------------------------|--|--|
| PLATE MOTIONS | The Caribbean is one of the smallest tectonic plates, with large relative motions. It is <i>not</i> understood in global reconstructions | Direct measurements of relative plate motions | Jordon (?) | Undefined | Large relative rates |
| | | Magnetic strips on sea floor | Worzel, Srnka, Hall | Compilation of existing data from ship profiles | Compilation only partial to date |
| | | Geological reconstruction | Hall, Muehlberger, Drake, Burke | ERTS-Landsat and field studies | |
| EARTHQUAKE PREDICTION | Very active subduction zones on the west (central America trench) and east (Antilles Island Arc) and strike slip motions on north-south make this plate/region an ideal "laboratory" for developing earthquake prediction tools | Seismic arrays | Latham | Compilation of data from several seismic arrays in Central America | Satellite communications could be effectively utilized 5-6 |
| VOLCANO SCIENCE | Antilles, central American and Mexican volcanoes present a variety of volcanoes and problems. Very active, dangerous — frequent eruptions; geothermal energy and hazards — both important | Seismicity | Matomoto, Decker | | Satcomm could be effective |
| | | Gas monitoring | Stoiber | | Eruption studies could be enhanced by comm links, also ground studies (by SWAT-Teams supported by aircraft and spacecraft data acquisition |
| | | Eruption hydrodynamics, thermal modeling | McGetchin, Matomoto | | |
| | | Petrology, geochemistry | | | |
| | | Geothermal applications | | | |

L S I

W O R K S H O P

TOPIC: Caribbean Plate-Geosciences from Earth Orbit

GOALS: To define possible research topics utilizing earth orbit (or other unique NASA capabilities) with the Caribbean Plate as a restricted geographic, multi-discipline and interesting focus

TIME/PLACE: LSI - Hess Room
9:00 a.m. - 12:00 noon
Friday, January 20, 1978

AGENDA:

1. Introduction - McGetchin
2. Shuttle Science/Space Lab - Johnston/Armitage
3. JSC/Earth Observation Program - Wilmarth/Armitage
4. Caribbean Plate, an overview and topical studies under way - Latham/Matomoto/Stoiber
5. Geodynamics Project WG-2 Activities - McGetchin
6. Discussion:
 - a. Uniqueness of NASA facilities capabilities
 - b. Space-based experiments/coordinated observations, experiments
 - c. C2 Problems
 - d. Recommendations to OA
 - e. Possible follow-up items

6. PRESENTATIONS OF MEETING #1 - 25 JANUARY 1978

- 6.1 McGetchin (LPI) - Introduction
- 6.2 Armitage (JSC)- - Overview of Earth Observations Division,
JSC Activities (EOD)
- 6.3 Wilmarth (JSC)- - JSC EOD Missions and Prior Results
- 6.4 Dornbach (JSC)- - JSC EOD Facilities and Operations
- 6.5 Latham (UTC)- - - Seismology and Caribbean Geodynamics
- 6.6 Matsumoto (UTG) - Volcano Seismology in Central America
- 6.7 McGetchin (LPI) - Some Problems in Modeling Volcanic
Processes
- 6.8 Discussion and Summary

ENCLOSURES

| | |
|---|--------------|
| McGetchin/Introduction | 6-3 to 6-7 |
| Matsumoto/Central American Volcano Seismicity | 6-9 to 6-16 |
| Armitage-Wilmarth-Dornbach/EOD-JSC | 6-17 to 6-29 |
| McGetchin/Volcanic Phenomenology | 6-31 to 6-35 |

1. The first part of the paper is devoted to a general discussion of the problem.

2. The second part is devoted to a detailed analysis of the case.

3. The third part is devoted to a discussion of the results.

4. The fourth part is devoted to a discussion of the conclusions.

5. The fifth part is devoted to a discussion of the future work.

6. The sixth part is devoted to a discussion of the references.

7. The seventh part is devoted to a discussion of the acknowledgments.

8. The eighth part is devoted to a discussion of the appendix.

9. The ninth part is devoted to a discussion of the bibliography.

10. The tenth part is devoted to a discussion of the index.

11. The eleventh part is devoted to a discussion of the conclusion.

12. The twelfth part is devoted to a discussion of the summary.

13. The thirteenth part is devoted to a discussion of the abstract.

14. The fourteenth part is devoted to a discussion of the introduction.

15. The fifteenth part is devoted to a discussion of the main body.

77-006

THE CARIBBEAN PLATE
SOME INTERESTING ASPECTS

FEATURES

EARTHQUAKES

VOLCANOES

PLATE

OIL AND GAS

ORE DEPOSITS

OCEANOGRAPHY

METEOROLOGY

SEA FLOOR GEOPHYSICS

GEOLOGY

CROP INVENTORY

OCCULT

REVOLUTION AND VACATIONS

PROBLEMS/APPLICATIONS

PREDICTION; AT LEAST ONE QUAKE PER YEAR

PREDICTION; SURVEILLANCE - ONE QUAKE PER YEAR

ITS MOTION; CORRELATION OF EVENTS - EPISODES

RESOURCE ASSESSMENT; GULF COAST AND VENEZUELA

RESOURCE ASSESSMENT

SYNOPTIC MOTION; HISTORY OF THE GULF STREAM

WEATHER PREDICTION, HURRICANES, LONG TERM CLIMATE

CRUSTAL STRUCTURE; SEDIMENTATION

MULTISPECTRAL MAPPING; NARROW BAND STUDIES

(BANANA YIELD, UNITED FRUIT . . .)

(BERMUDA TRIANGLE AND THE ATLANTIS LEGEND)

(SOMETHING FOR EVERYONE!)

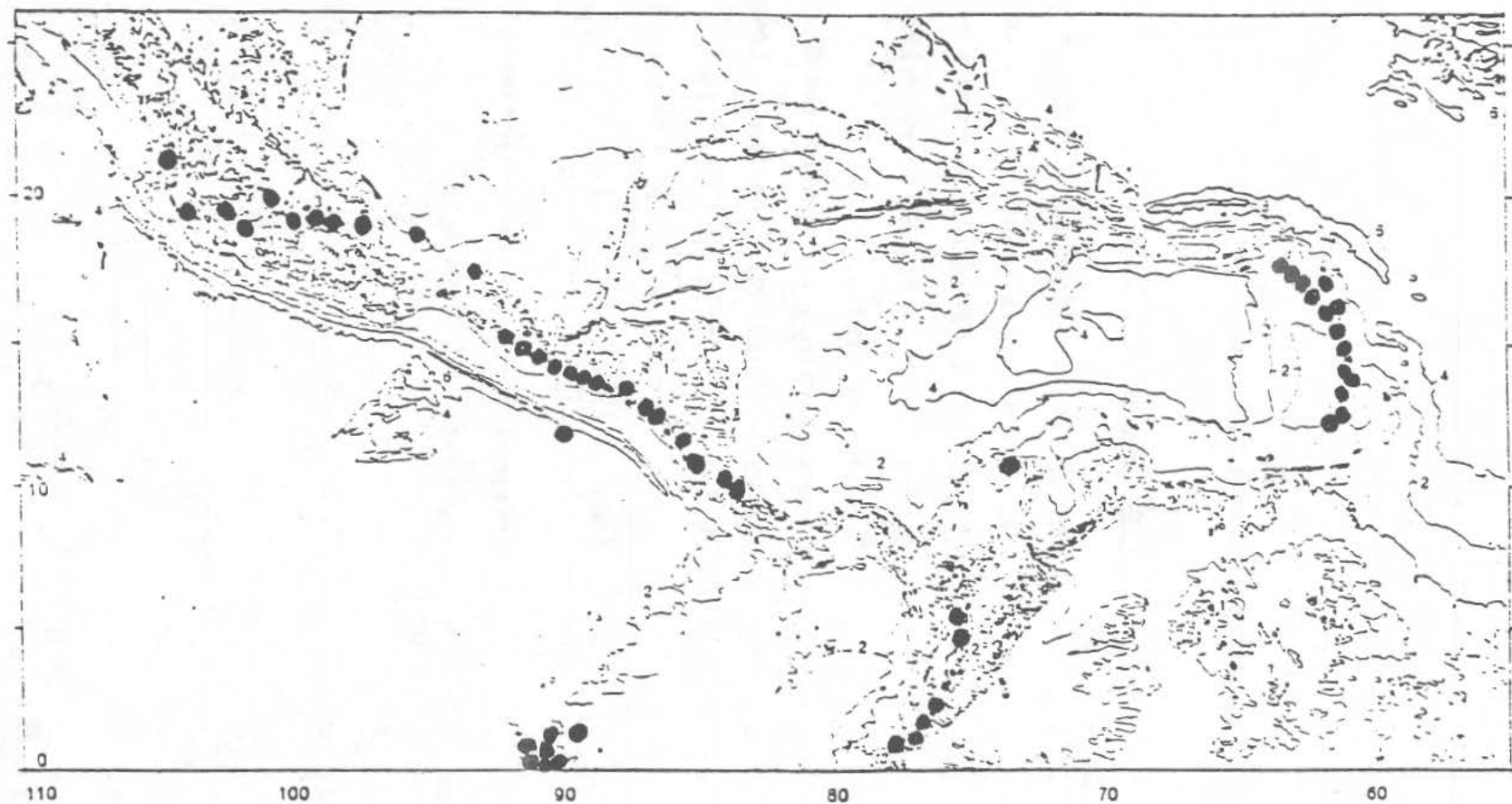


Figure 2. Topography and volcanoes of the Caribbean region. On land, contours are at elevations of 200, 1,000, 2,000, 3,000, and 4,000 m (from *Times Atlas of the World*, 1957). At sea, contours are at depths of 200, 2,000, 4,000, and 6,000 m (from Uchupi, 1971; Chase and Menard, 1964). Solid circles indicate locations of active volcanoes (Hantke and Parodi, 1966; Mooser and others, 1958; Robinson and Tomblin, 1966).

77-004

CARIBBEAN PLATE PROJECT

SOME ADVANTAGES AND UNIQUENESSES

- INTERESTING PLATE
 - HIGH INTRINSIC SCIENTIFIC INTEREST — TWO SUBDUCTION ZONES, TRENCH, GOOD GEOLOGY, FAULTS AND HIGH SEISMICITY, VERY ACTIVE VOLCANIC BELTS, INTERESTING PETROLOGY, OCEANOGRAPHY, STRUCTURAL, SEDIMENTATION PROBLEMS
- ENTIRE PLATE ACCESSIBILITY
 - PERMITS SYNOTIC COVERAGE
DIFFERENTIAL MEASUREMENTS
- FREQUENT EVENTS
 - | | | |
|-------------|---|------------------|
| EARTHQUAKES | } | SEVERAL PER YEAR |
| ERUPTIONS | | |
| STORMS | | |
- MANY APPLIED ASPECTS OF INTEREST
 - OIL AND GAS, ORE DEPOSITS, AGRICULTURE, SEVERE METEOROLOGY
- INTERNATIONAL ASPECTS
 - SCIENTIFIC COOPERATION — GEODYNAMICS PROJECT
EARTHQUAKE, ERUPTION AND STORM PREDICTION
DISASTER ASSISTANCE
REGIONAL PLANNING
- PILOT PROJECT
 - PROTOTYPE — TECTONICS OBSERVATORY IN SPACE
- GOOD LOCATION
 - UTILIZES JSC CAPABILITY AND LOW EARTH ORBIT

77-005

CARIBBEAN PLATE
POSSIBLE EXPERIMENTS FROM SPACE

THERMAL IR

SYNOPTIC PHYSICAL OCEANOGRAPHY

CURRENT METER
TRANSPORTERS

PHYSICAL OCEANOGRAPHY

GEODESY/
LASER RANGINGWHOLE PLATE MOTION
EPISODES

SPECTRAL STUDIES

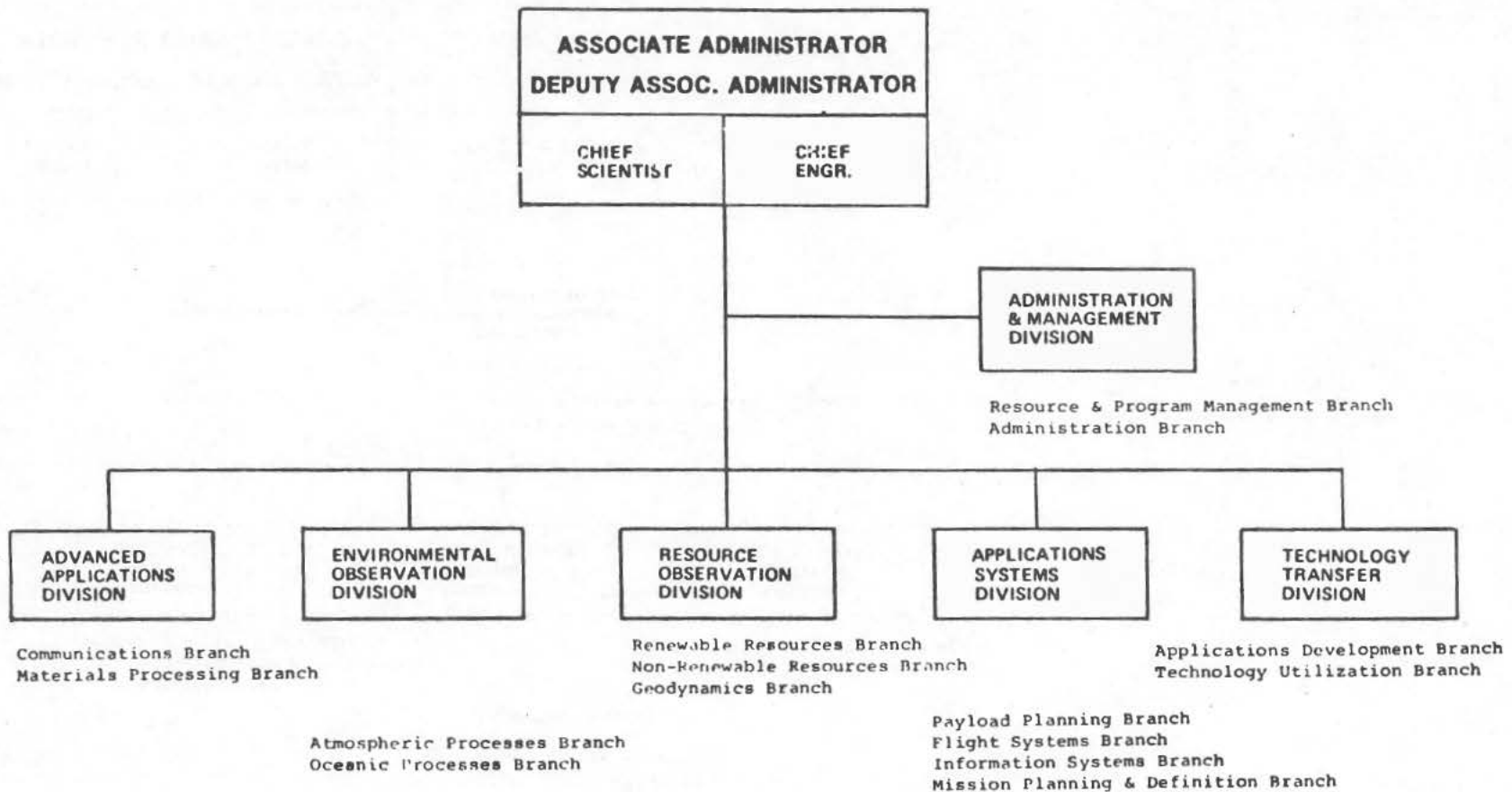
MINERALOGY
GEOLOGY
CROP INVENTORY

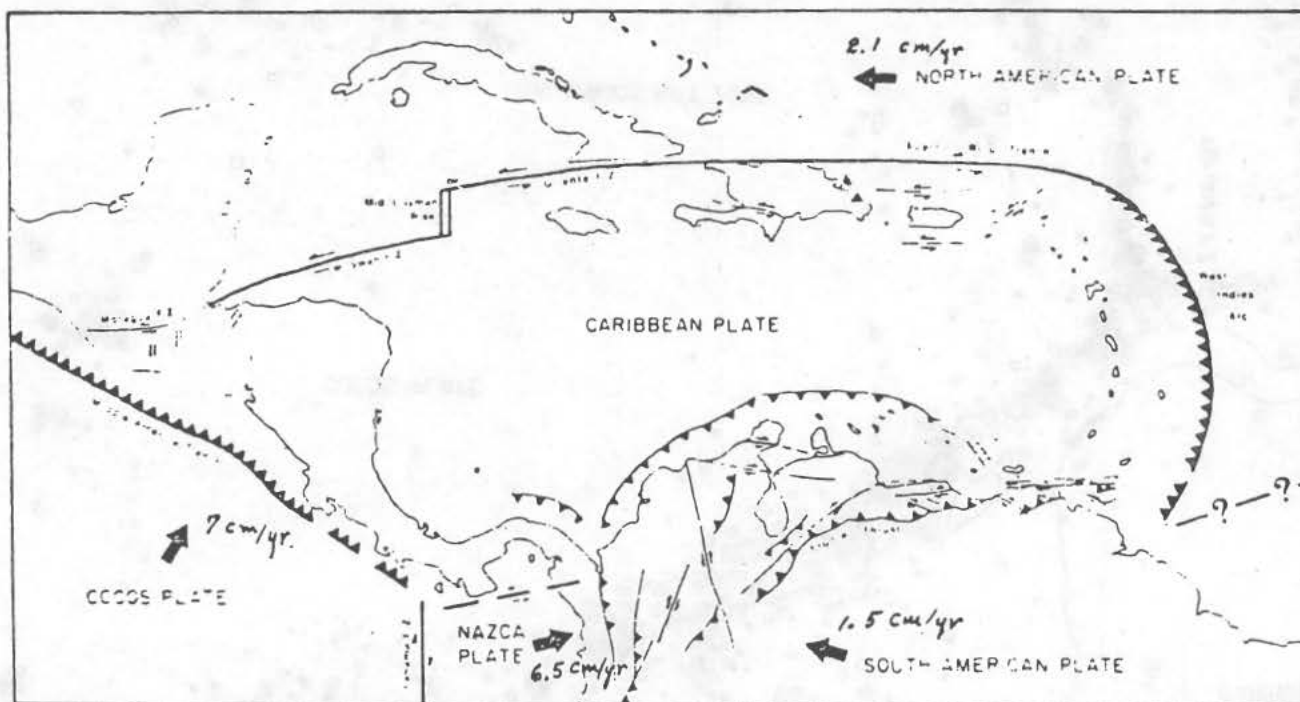
PHOTOGRAPHY

METEOROLOGY
GEOLOGYVOLCANIC GAS-
INPUT AND
DISTRIBUTION

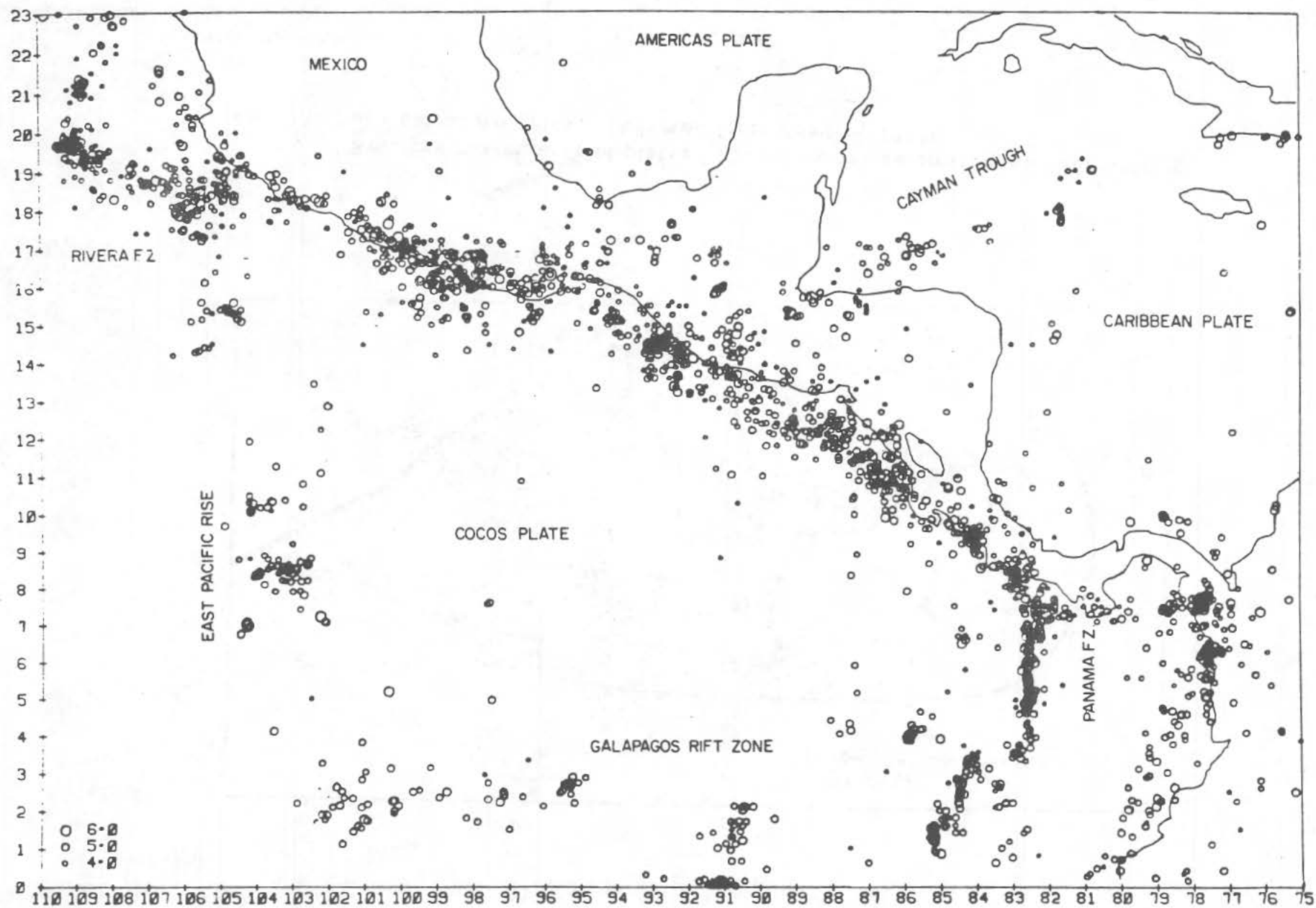
ATMOSPHERIC SCIENCES

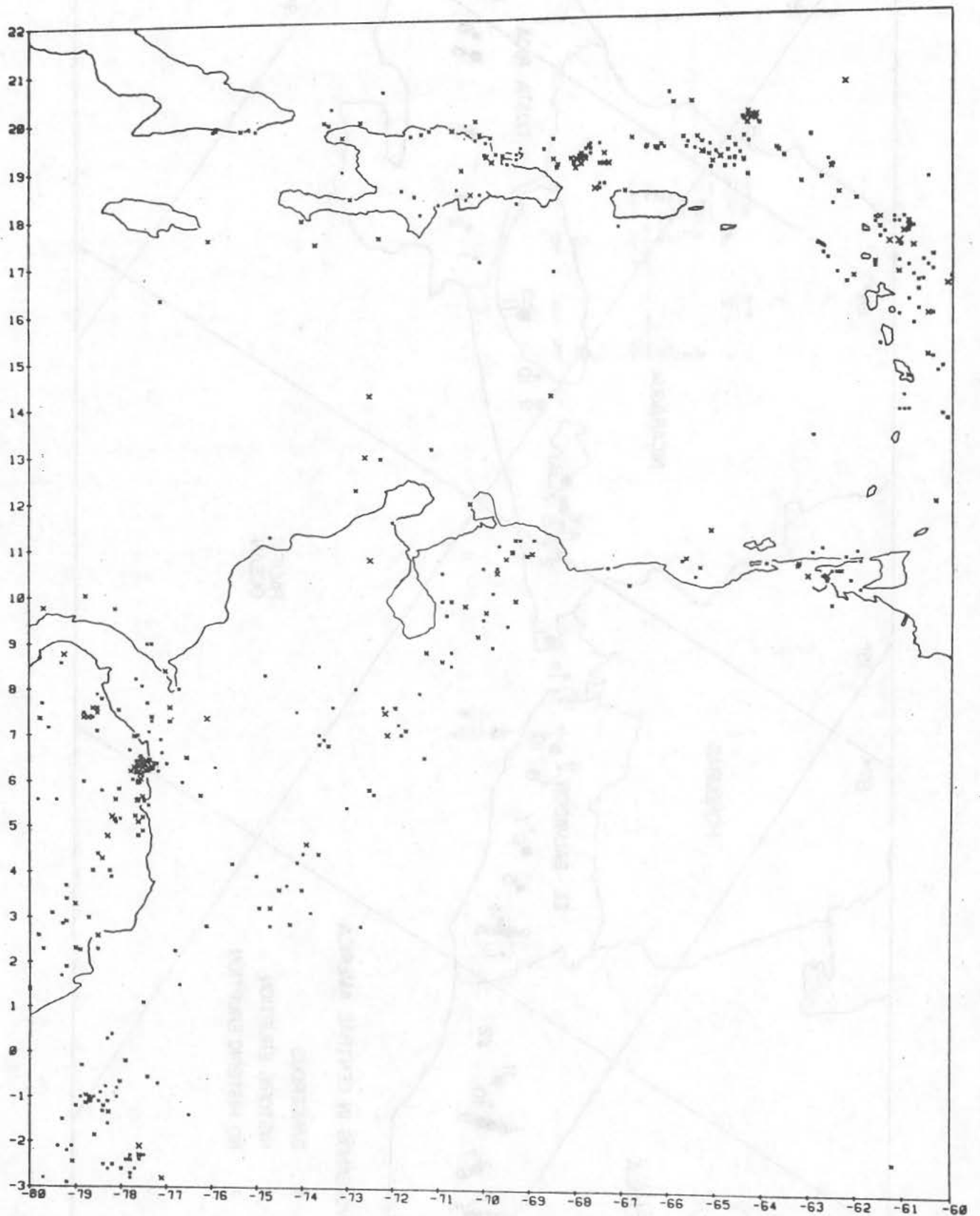
PROPOSED
OFFICE OF SPACE AND
TERRESTRIAL APPLICATIONS

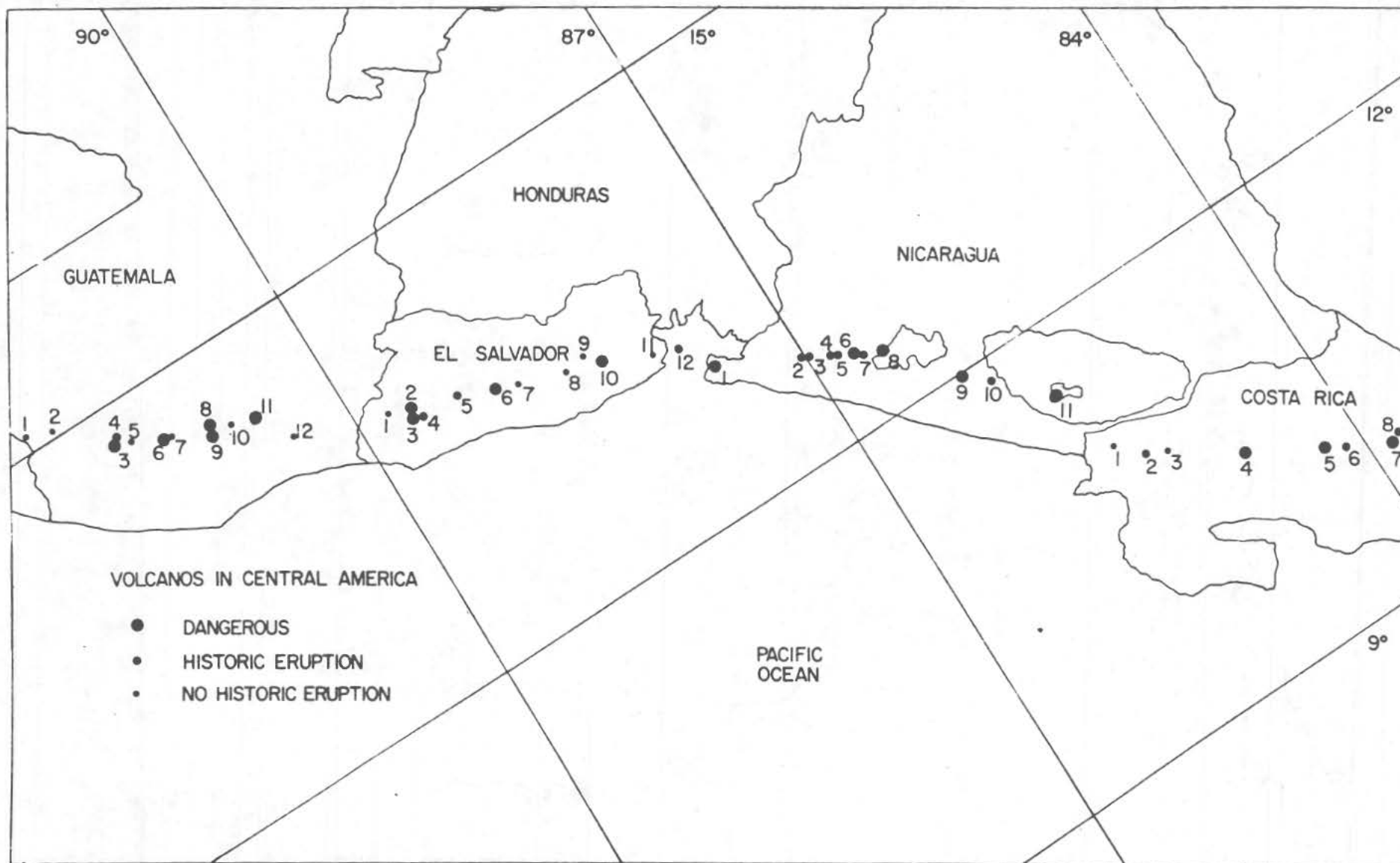




Relative movements of plates influencing the seismicity and volcanism of Central America. (Adapted from Jordan, 1972).







Volcanoes in Central America

GUATEMALA

| <u>No.</u> | <u>Name</u> | <u>North</u> | <u>West</u> | <u>Dangerous</u> | <u>Historic Eruption</u> | <u>No Historic Eruption</u> |
|------------|---------------|--------------|-------------|------------------|------------------------------|---------------------------------|
| 1 | Tacana | 15°08' | 92°06' | | | X |
| 2 | Tajumulco | 15°02.6' | 91°53.9' | | | X |
| 3 | Santa Maria | 14°45.5' | 91°32.9' | X | | |
| 4 | Cerro Quemado | 14°47.9' | 91°31.0' | | X | |
| 5 | Zunil | 14°42.8' | 91°28.5' | | | X |
| 6 | Atitlan | 14°35.3' | 91°10.9' | X | | |
| 7 | Toliman | 14°36.85' | 91°10.6' | | | X |
| 8 | Acatenango | 14°30.2' | 90°52.4' | X | | |
| 9 | Fuego | 14°28.9' | 90°52.9' | X | | |
| 10 | Agua | 14°28.0' | 90°44.5' | | | X |
| 11 | Pacaya | 14°23.0' | 90°36.2' | X | | |
| 12 | Tecuamburro | 14°09.0' | 90°26.1' | | | X |

EL SALVADOR

| | | | | | | |
|----|----------------|----------|----------|---|---|---|
| 1 | Ahuachapan | 13°55' | 89°47.5' | | | X |
| 2 | Santa Ana | 13°51.2' | 89°37.8' | X | | |
| 3 | Izalco | 13°48.9' | 89°38.1' | X | | |
| 4 | San Marcellino | 13°48.4' | 89°34.6' | | X | |
| 5 | San Salvador | 13°44.3' | 89°17.3' | | X | |
| 6 | Islas Quemadas | 13°40.3' | 89°03.2' | X | | |
| 7 | San Vicente | 13°37.4' | 88°51.1' | | | X |
| 8 | Tecapa | 13°29.8' | 88°30.2' | | | X |
| 9 | Chinameca | 13°30.6' | 88°21.7' | | | X |
| 10 | San Miguel | 13°26.2' | 88°16.3' | X | | |
| 11 | Conchagua | 13°16.6' | 87°51.2' | | | X |
| 12 | Conchaguita | 13°13.1' | 87°45.9' | | X | |

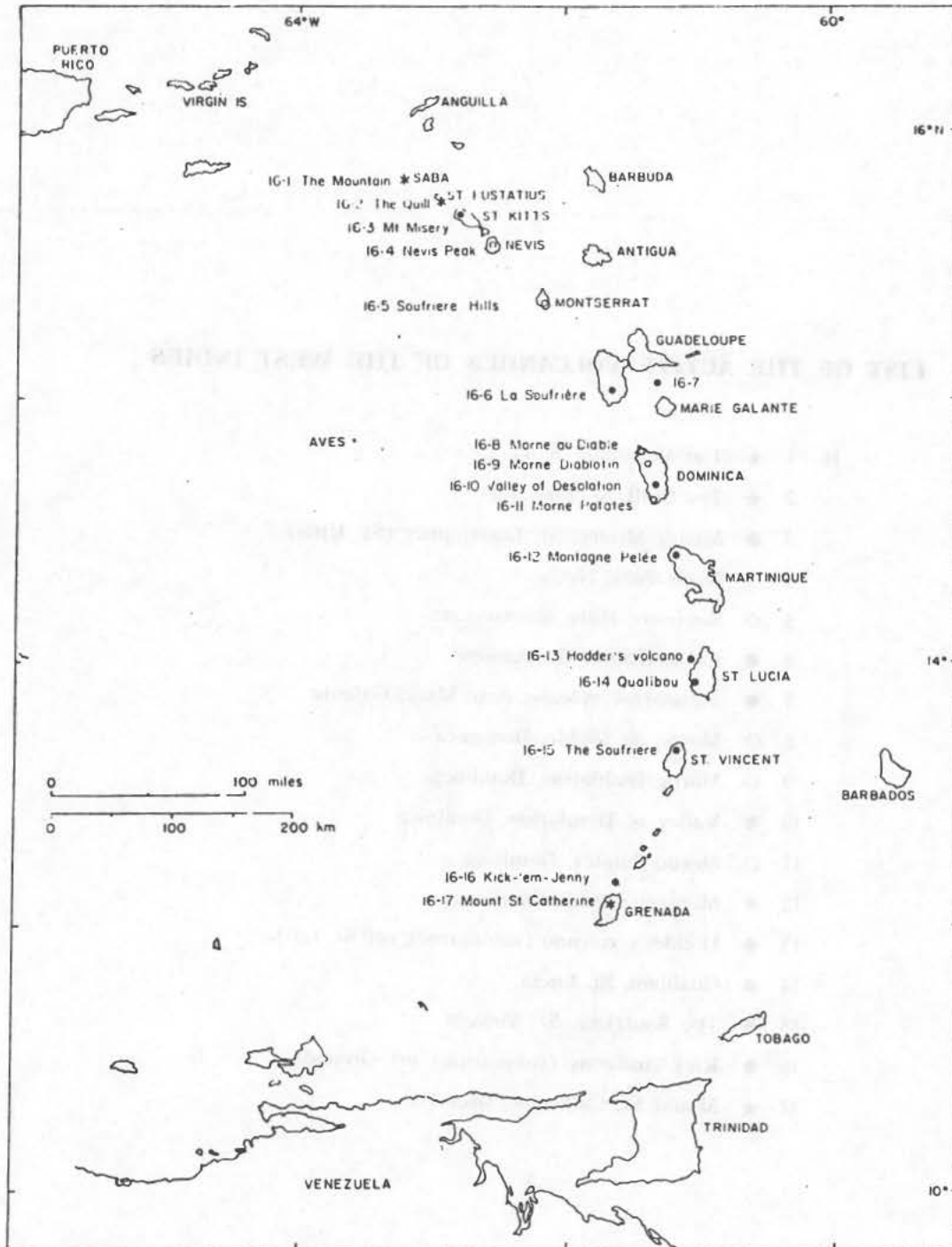
Volcanoes in Central America

NICARAGUA

| <u>No.</u> | <u>Name</u> | <u>North</u> | <u>West</u> | <u>Dangerous</u> | <u>Historic Eruption</u> | <u>No Historic Eruption</u> |
|------------|-------------|--------------|-------------|------------------|------------------------------|---------------------------------|
| 1 | Coseguina | 12°58' | 87°35' | X | | |
| 2 | El Vaiejo | 12°42' | 87°01' | | X | |
| 3 | Chichigalpa | 12°41' | 86°59' | | X | |
| 4 | Telica | 12°36' | 86°52' | | X | |
| 5 | Santa Clara | 12°34' | 86°49' | | X | |
| 6 | Cerro Negro | 12°31' | 86°44' | X | | |
| 7 | Las Pilas | 12°29' | 86°41' | | X | |
| 8 | Momotombo | 12°25' | 86°33' | X | | |
| 9 | Masaya | 11°57' | 86°09' | X | | |
| 10 | Mombacho | 11°50' | 89°59' | | X | |
| 11 | Concepcion | 11°32' | 85°39' | X | | |

COSTA RICA

| | | | | | | |
|----------------------------------|--------------------|----------|----------|----|----|----|
| 1 | Orosi | 10°59' | 85°29' | | | X |
| 2 | Rincon de la Vieja | 10°50' | 85°21' | | X | |
| 3 | Miravalles | 10°47' | 85°10' | | | X |
| 4 | Arenal | 10°27.6' | 84°42.1' | X | | |
| 5 | Poas | 10°11' | 84°13' | X | | |
| 6 | Barba | 10°08' | 84°05' | | X | |
| 7 | Irazu | 9°59' | 83°45' | X | | |
| 8 | Turrialba | 10°02' | 83°45' | | X | |
| TOTAL FOR GUATEMALA - COSTA RICA | | | | 17 | 13 | 13 |



Map of the eastern Caribbean, showing the location of the volcanoes described in the text.

LIST OF THE ACTIVE VOLCANOES OF THE WEST INDIES

- 16- 1 ★ The Mountain, Saba
- 2 ★ The Quill, St. Eustatius
- 3 ● Mount Misery, St. Christopher (St. Kitts)
- 4 ○ Nevis Peak, Nevis
- 5 ○ Soufriere Hills, Montserrat
- 6 ● La Soufrière, Guadeloupe
- 7 ● Submarine volcano near Marie Galante
- 8 ○ Morne au Diable, Dominica
- 9 ○ Morne Diablotins, Dominica
- 10 ● Valley of Desolation, Dominica
- 11 ○ Morne Patates, Dominica
- 12 ● Montagne Pelée, Martinique
- 13 ● Hodder's volcano (submarine), off St. Lucia
- 14 ● Qualibou, St. Lucia
- 15 ● The Soufriere, St. Vincent
- 16 ● Kick-'em-Jenny (submarine), off Grenada
- 17 ★ Mount St. Catherine, Grenada.

EARTH OBSERVATIONS DIVISION

- **APPLICATIONS SYSTEMS VERIFICATION TESTS**
 - EMPHASIS ON AGRICULTURE, RANGE, FORESTRY APPLICATIONS
 - LARGE AREA EXPERIMENTS - EG LACIE
 - CO-PARTICIPATION WITH OTHER FEDERAL AGENCIES
 - TRANSFER REMOTE SENSING TECHNOLOGY
- **EXPLORATORY INVESTIGATIONS**
 - WORK WITH FEDERAL, STATE, LOCAL AND COMMERCIAL USERS
 - EVALUATE APPLICATION OF REMOTE SENSING TECHNOLOGY
 - AUTOMATED INFORMATION MANAGEMENT SYSTEMS
- **SUPPORTING RESEARCH AND TECHNOLOGY**
 - DEVELOP ANALYSIS AND INTERPRETIVE TECHNIQUES
 - SPECIFY SENSOR DESIGN/REQUIREMENTS
 - DEFINE PARAMETERS TO BE MEASURED
- **DATA SYSTEMS DESIGN**
 - SUPPORT ONGOING TASKS/PROGRAMS
 - DEFINE ADVANCED OPERATIONAL SYSTEMS

Earth Observations Division



The Landsat.

The major efforts of the Earth Observations Division (EOD) are directed to the support of the Earth Resources Program at JSC. The EOD develops and maintains the technical personnel and facilities to analyze, interpret, improve, and implement applications of Earth Resources Program data. In addition, it demonstrates the usefulness of these applications and coordinates a program for making the acquired technical information available to scientists at JSC, PI's, and the user community.

Specific responsibilities of the EOD include:

- Acquiring, analyzing, correcting, and managing the basic elements of the NASA/JSC remote sensing program
- Handling requests from and delivery of data to authorized PI's through JSC contracts, grants, and working agreements
- Working with cooperating universities and the U.S. Department of Agriculture (USDA) to develop a system for classification of agricultural data

- Mapping various areas to locate resources such as forests, farmland, water reservoirs, wildlife, and mineral deposits and recommending means for effective land use and environmental protection of such resources
- Defining requirements for facilities such as sensors, survey platforms, and ground support and analysis equipment for approved applications development programs at JSC
- Identifying, evaluating, and developing analysis techniques for photointerpretation, feature selection, pattern recognition; and image registration of data
- Analyzing and evaluating techniques using mathematical and statistical methods and integrating them into supporting research programs
- Providing technical advice for the development, acquisition, testing, calibration, and operation of ground and flight sensors and hardware for ground and flight support
- Maintaining a center for the gathering and storage of information from NASA missions, including the Gemini, Apollo, Skylab, the Land Satellites (Landsat-1 and -2), and aircraft.

The efforts of the EOD in developing remote sensing applications systems are an invaluable aid in many scientific fields. Direct applications are made in the fields of agriculture, forestry, geography, geology, hydrology, and oceanography. In addition, remote sensing can be used to detect the probable locations of ancient ruins, petroleum and mineral deposits, and many other resources for the research and enhancement of various scientific endeavors.

The EOD is responsible for four major projects:

- The Large Area Crop Inventory Experiment (LACIE)
- The Forestry Applications Project (FAP)
- The Regional Applications Project (RAP)
- The Earth Resources Experiment Package (EREP).

The primary source of remote sensing data for EOD applications is the multispectral scanner (MSS) onboard the Landsat-1 and -2. The first Earth Resources Technology Satellite, which was launched in June 1972, was renamed Landsat-1 in January 1975, the same month NASA placed the Landsat-2

in orbit. These two satellites orbit the Earth at the same rate of speed, each covering the same area every 18 days at an altitude of 915 kilometers (569 miles). They are opposite each other on the orbital track so that coverage of the same area is obtained every 9 days. Ground coverage by two satellites greatly reduces the effects of cloud cover and other physical factors which impair MSS data.

The Landsat-1 gathers four channels of data, whereas the Landsat-2 gathers three. Data are screened at the Goddard Space Flight Center and forwarded to NASA/JSC for storage and analysis. Landsat MSS data are used extensively in the LACIE, the FAP, and the RAP.

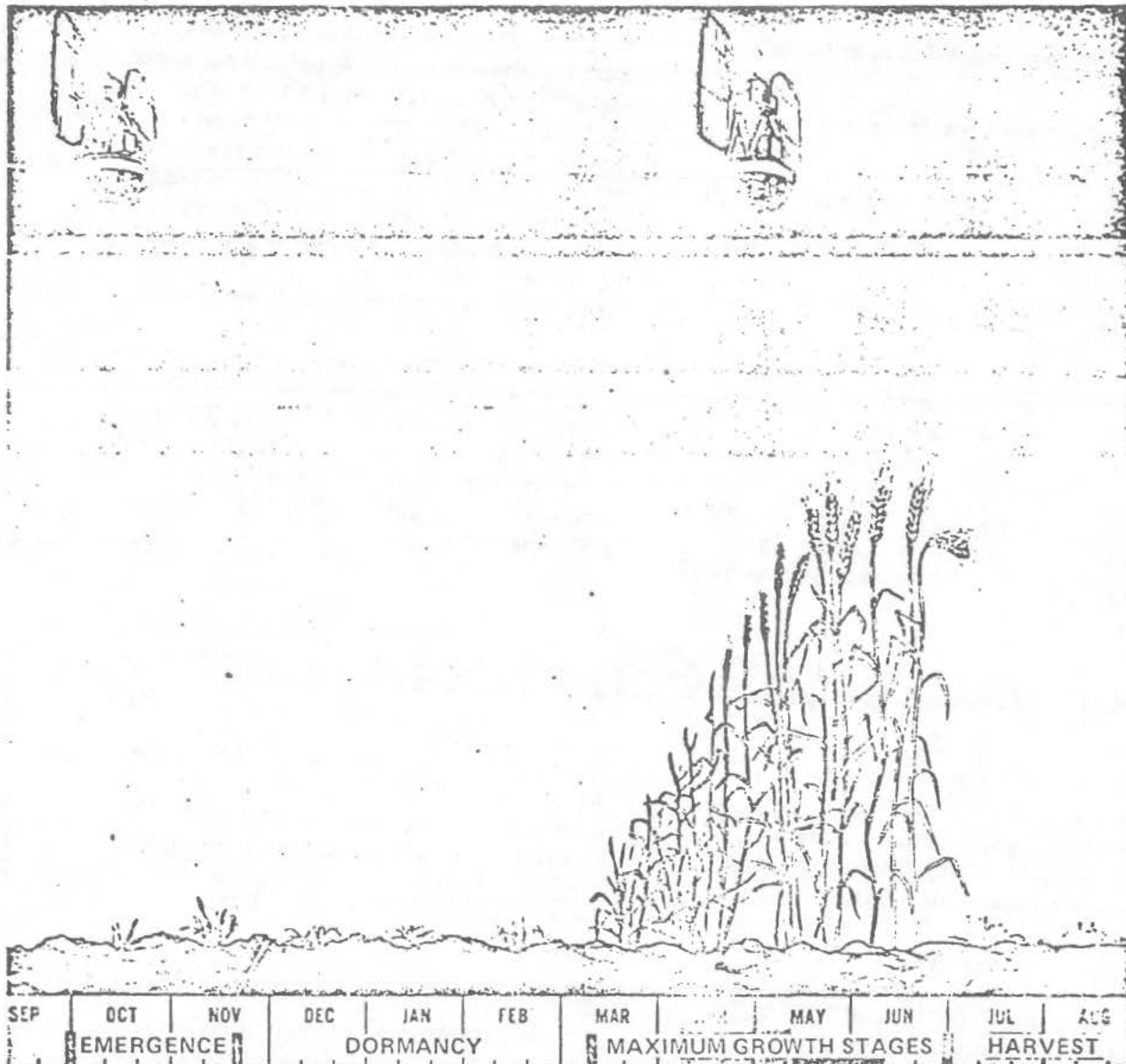
LARGE AREA CROP INVENTORY EXPERIMENT

Increasing population and the fluctuating food supply from year to year have created a demand for accurate forecasting of agricultural production to combat starvation in some areas of the Earth. In response to this need, the LACIE was initiated in 1974 as a joint undertaking of the USDA, the National Oceanic and Atmospheric Administration (NOAA), and NASA/JSC. Its purpose is to develop a means of increasing the accuracy of crop inventories, extending such inventories to cover more widespread areas, and predicting the worldwide food supply.

The LACIE plan to achieve this goal consists of expanding and testing present technology and procedures to develop a cost-effective, computer-aided system capable of combining satellite MSS, climatological, meteorological, and conventional data and making an accurate forecast of the available supply of a major crop prior to harvest. Based on history, planting practices, growth stage of the crop, weather, and other factors, yield assessments and, ultimately, production fore-

casts of crop output are planned prior to the end of the growing season. The intent of the LACIE is to modify and expand existing methods and thereby increase the accuracy of crop predictions over larger areas than are afforded by present technology.

Because of its importance to human nutrition and international trade, wheat was chosen as the major crop at the outset of LACIE. The proposed inventory system will be based on crop area measurements from the Landsat-1 and -2 and meteorological data from NOAA satellites. It will use regression models and meteorological parameters obtained at ground stations in the World Meteorological Organization (WMO) network to estimate crop yield. Training statistics will be developed for the yield model. The experiment is supported by a parallel research, test, and evaluation effort to develop solutions in areas where additional technology is required to determine the impact of specific factors such as planting practices and catastrophic events such as the influx



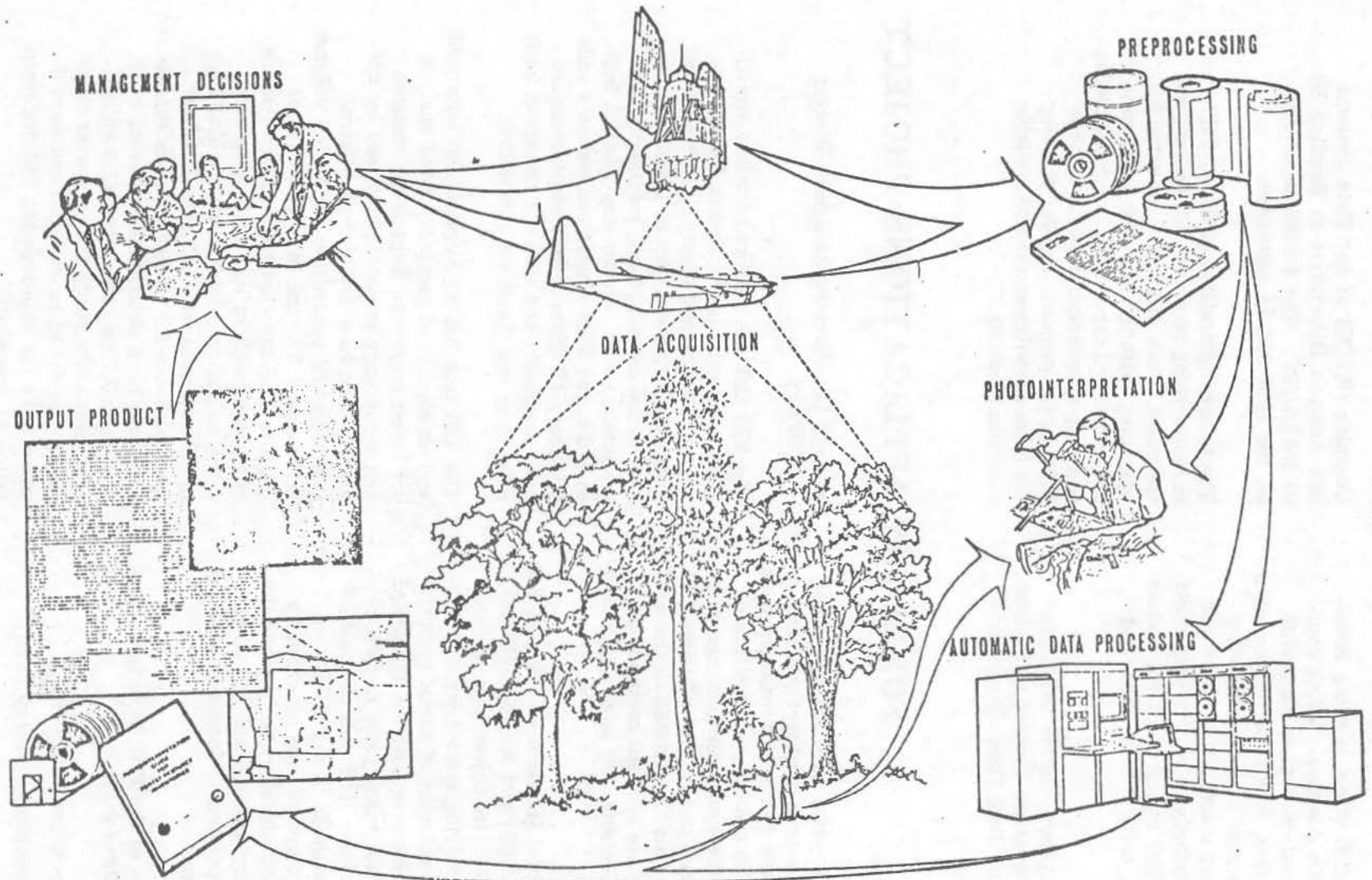
Remote sensing of wheat showing four biological phases.

of insects or the onset of plant disease.

The USDA will study the experimentally derived production estimates for use in its crop reports, which are made public as a routine service to the domestic and international agricultural community.

Basically, the LACIE objectives are

- To demonstrate an economically important application of MSS data from space
- To test the capability of Landsat-1 and -2 to contribute essential data toward estimating the production of a world crop
- To validate the system procedures, subsystem interfaces, and personnel training which could provide accurate and timely estimates of crop production
- To identify key problems to be solved before an operational system can be implemented.



Remote sensing for forestry applications.

The first LACIE effort is being undertaken in North America. When completed and confirmed as a successful operating system, it will be implemented to make estimates of wheat in other grain-producing countries of the world as well. Eventually it will be expanded to include other major crops for human consumption, such as rice, corn, and soybeans.

The LACIE system utilizes the Earth Resources Interactive Processing System (ERIPS) in the Real-Time Computer

Complex (RTCC) of the Data Systems and Analysis Directorate in Building 30 of NASA/JSC. The ERIPS is resident on the IBM 360-75 computer.

The future implications of the LACIE's remote-sensing computerized techniques are many. They offer great potential for upgrading existing information gathering and processing capabilities, for contributing to a long-range solution of the Earth's food supply problem, and for planning the more advantageous use of available food commodities.

FORESTRY APPLICATIONS PROJECT

Because recent years have brought about the onset of resource shortages and environmental problems, forest land managers have been required to assume greater responsibilities and make more decisions regarding the maintenance and control of range and forest lands. This has resulted in the need for quicker, more efficient methods of obtaining, processing, and analyzing forest resource data.

The FAP, a joint endeavor of the U.S. Forest Service (USFS) and NASA/JSC/EOD, started in 1972. Its objective is to devise methods of applying remote-sensing technology to the solution of forest resource problems. Remote sensing has been used by the USFS for many years as a data-gathering medium. The goal of the FAP is to devise methods of using the ever-increasing amounts of data provided by this advancing technology to improve the speed, accuracy, and accessibility of the information required to formulate management decisions.

Recent efforts of the FAP have been concentrated in three areas:

- Soil Resources Inventory (SRI)
- Timber Resources Inventory (TRI)

● Land Use Planning Assistance Process (LUPAP).

The SRI task has performed initial investigations of test sites located in Texas, Tennessee, Florida, and Georgia, within three distinctly different types of terrain delineated as the coastal plains, piedmont, and mountain zones. Preliminary findings indicate that the FAP system can obtain a soils inventory 10 times faster than techniques used previously and that the savings in both manpower and funds are substantial.

The TRI task has investigated and improved various aspects of computer-aided analysis for forest mapping. Supporting research and technology projects performed by universities also have established efficient satellite-based procedures for timber volume inventories. The use of aircraft and/or satellite MSS data has been proven feasible at various levels of detail by using data gathered during different seasons and their multitemporal combinations. The best spectral bands for timber type discrimination have been determined. Present work includes a 0.7-million-hectare (1.5-million-acre) feasibility study for computer classification of broad cover types and several other tasks for improvement and documentation of procedures.

The LUPAP utilizes various types of input that include existing and remotely sensed data to arrive at the various best uses for individual land sites known as environmental management units (EMU's). Using computer processing, the FAP weighs the suitability, needs, demands, inventory ratings, and resource compatibilities and produces, in numerical code, a map of preferred land use for each parcel of land.

After the methods developed in the FAP have been tested and evaluated, they will be transferred to the user agency. To ascertain that the methods developed by the FAP meet the user's expectations and to assure their continued value, a technology transfer program with the user will go into effect after the transfer is made.

REGIONAL APPLICATIONS PROJECT

The goal of the RAP is to transfer NASA technology in remote sensing and information systems to State and Federal resource management agencies. Existing technology is evaluated, modified, and documented in close cooperation with the potential user agency and then transferred to the user. Technology transfer efforts are underway or have been completed with the following agencies:

- Texas Water Development Board
- Texas Water Rights Commission
- Texas General Land Office
- Texas Parks and Wildlife Department
- Texas Natural Resources Information System
- U.S. Army Corps of Engineers
- USDA Statistical Reporting Service
- State of Ohio

The project emphasizes the development and transfer of technology in the fields of machine classification, water detection, coastal zone mapping, and land use.

Machine Classification

In the area of machine classification, the RAP effort has resulted in the development of computer tapes and documentation on existing JSC computer programs and their subsequent transfer to agencies of the State of Texas. In cooperation with the

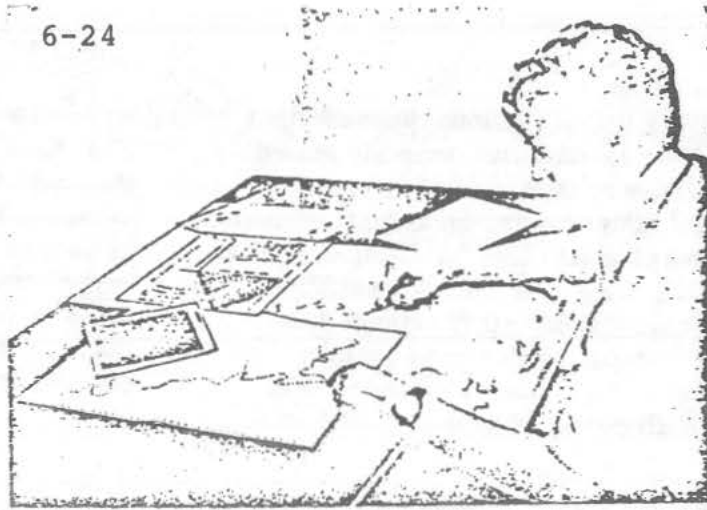
Laboratory for Applications of Remote Sensing of Purdue University (LARS), a series on the theory and use of the LARS online computer classification system (LARSYS) was developed and presented to member agencies of the Texas Inter-agency Council on Natural Resources and the Environment. Under contract with Texas A&M University, the LARSYS will be converted to the university's IBM 370 computer and made accessible to State agencies with remote terminals in Austin, Texas.

Water Detection

In 1973 the U.S. Army Corps of Engineers and the Texas Water Rights Commission requested assistance from NASA/JSC in using satellite data to prepare a complete inventory of dams impounding sufficient water to pose potential danger to life or property. Joint activity by the user agencies and NASA/JSC to solve this problem include the following phases:

- Definition of requirements
- Evaluation of existing technology
- Development and evaluation of a prototype system
- Development of an operational system
- Documentation and transfer of the operational system
- Evaluation and continuing support.

It was learned during the initial phases of this activity that, without the use of ground truth, existing programs did not meet the requirement for 90 percent classification accuracy of water bodies larger than 4 hectares (10 acres) at low computer cost. A new prototype system was developed to meet these requirements. The prototype was then expanded into an operational system which provides flexible output in the form of accurate, precisely framed maps scaled to individual user requirements. These maps may be produced on a computer line printer or a pen plotter, to an absolute positional accuracy of greater than 300 meters. The computer cost for mapping an entire Landsat scene [an area 100 nautical miles (185 kilometers) square, which requires more than 200 standard 7.5-minute quadrangle maps] is several hundred dollars.



The DAM procedure. Analysts use computer printouts and plots, along with conventional maps, to locate water resources.

The documented operational system, which was named the Detection and Mapping (DAM) package, was transferred to user agencies and implemented on computers in Austin, Texas, and Slidell, Louisiana. Preliminary evaluations of areas in the States of Tennessee and Washington indicate that the DAM system is more accurate than conventional techniques for detecting and making inventories of water impoundments.

Additional applications are now being developed for the DAM package.

- The Texas Water Development Board plans to use this tool to monitor the locations and extent of standing water in the playas (shallow, intermittently wet, surface depressions) of the Texas high plains.
- The Statistical Reporting Service of the USDA is testing the precise map registration capability of the DAM package for use with agricultural data from the Landsat-1 and -2.

Because of its precisely registered output, it is possible to interface the DAM procedures

with various computerized information storage and retrieval systems.

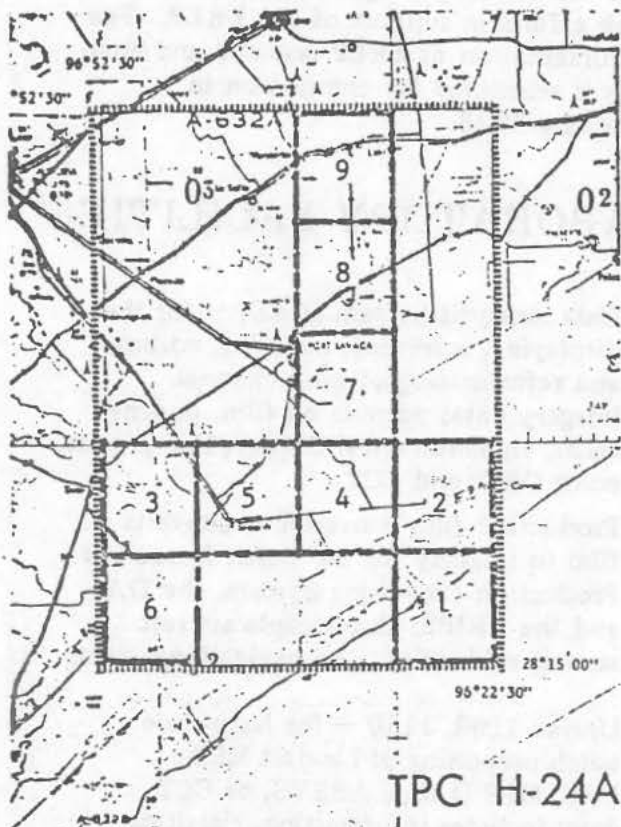
Coastal Zone Mapping

This activity was begun in 1973. Because of the diversity of significant physical and biological features, the Matagorda Bay area was chosen as the study site for the project.

The project consists of four phases:

- I Candidate classification evaluation
- II Design of the Prototype Inventory and Monitoring System
- III Test and evaluation of system performance
- IV Documentation of procedures

During phase I, which is underway, two teams — one from the LARS and one from the RAP — are performing the primary tasks. The RAP team is gathering ground truth by interpreting RB-57F conventional aerial photography and performing supplemental ground surveys. The LARS team is utilizing the LARSYS to process MSS data from the Landsat-1 and -2 for classification of vegetation



Map of Matagorda Bay test site for Coastal Zone Mapping Project. Prioritized test sites are indicated by numbers.

within the prescribed study area. Upon completion of the computer classification, LARS forwards the candidate classification, corresponding magnetic tapes, and procedural documentation to the RAP team for analysis.

Evaluation of the candidate classifications by the RAP team consists of analyzing the

spectral and spatial accuracy of the LARS classifications by comparing them to ground truth overlays (scale of 1:24,000). In performing its evaluation, the RAP team utilizes all necessary and available optical and digital image enhancement techniques as deemed necessary to assess classification accuracy and overall system performance. The evaluation is documented, and a report stating the results of the evaluation is prepared. The results of the investigation will be used to develop the technology and procedures for phase II, Prototype Inventory and Monitoring System.

System performance will be tested and evaluated in phase III, and procedures for user agencies will be documented in phase IV. When completed and validated, the system will be used by the State of Texas to inventory and monitor coastal resources for effective land use programs and for the protection and preservation of plant and wildlife species.

Land Use

The Texas Parks and Wildlife Department, assisted by the RAP and using Landsat MSS data, plans to map vegetative cover for the entire State. The satellite data will be classified using the LARSYS and the Elliptical Table Lookup (ETL) system. The classified vegetation maps will then be used to delineate areas of wildlife habitation. Utilizing this information, the State will develop effective means of preserving game and wildlife species.

EARTH RESOURCES EXPERIMENT PACKAGE

Although the three manned Skylab missions were completed during 1973 and the first 2 months of 1974, the analysis of Skylab data is still in progress. The data acquired by the EREP comprises approximately one-tenth of the Skylab data. The EOD Principal Investigator Management Office (PIMO) is responsible for the management of

approximately 140 PI's who are performing postmission analyses of EREP data from the three manned missions.

The research of EREP data under the PIMO includes: photoanalysis; computer analysis of remotely sensed data; development of techniques for satellite sensing of

atmospheric effects and climatological conditions; mapping projects (primarily in the Western Hemisphere); and the study and documentation of geological formations.

The PI's are preparing written reports of their efforts in support of the EREP. The documentation of EREP research and analyses is scheduled for completion in February 1976.

EOD LABORATORY FACILITIES

Electronic Capabilities

All ongoing projects of the EOD have access to the following items of major electronic equipment at JSC.

- Purdue terminal — provides the user a direct link to the LARSYS for immediate evaluation and continuous access to current LARS techniques; output is on punched cards, and line printer.
- ERIPS — an interactive graphics system which allows the user to analyze and interact with remotely sensed Earth resources data as processing takes place; is connected to the IBM 360/75 computer in the RTCC.
- GE** IMAGE 100 — a computer system to which film transparencies or computer-compatible tapes (CCT's) are input; displays Landsat scenes in color on cathode-ray tube (CRT) and outputs data on a graphics display terminal and printer/plotter.
- Earth Resources Production Processing Facility — allows the input of options to certain programs for limited statistical analysis of Skylab 28-track and aircraft 14-track instrumentation tapes; outputs film images, plots, tabulations, and CCT.
- CDC* Cyber 73 — for batch processing of data input by tape from the ERIPS and the Earth Resources Production Data Processing Facility; outputs CCT and tabulations.

*Control Data Corporation.

**General Electric Company.

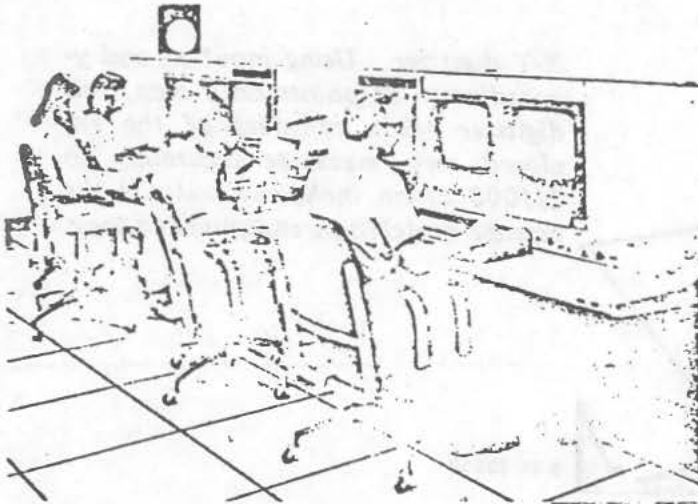
- Data Analysis System (DAS) — for the displaying, screening, indexing, editing, and reformatting of multichannel imagery data; outputs on film, punched cards, alphanumerical display, line printer, color CRT, and CCT.
- Production film converter — converts film to imagery for the Earth Resources Production Processing System, the DAS, and the ERIPS; also accepts aircraft sensor, calibration, and navigational data.
- Univac 1108, 1110 — for large-scale batch processing of Landsat MSS bulk, MSS DAS, LARSYS, or CCT data; includes reformatting, classification, clustering, image data correlation and registration, correction of atmospheric data, and statistical analysis; outputs tapes, punched cards, plots, gray maps, tabulations, and histograms.
- Tape-to-film converters and remote terminals — for access to the above systems.

Photographic and Cartographic Equipment

To support its photointerpretation, photogrammetry, and cartography efforts, the EOD has the following equipment:

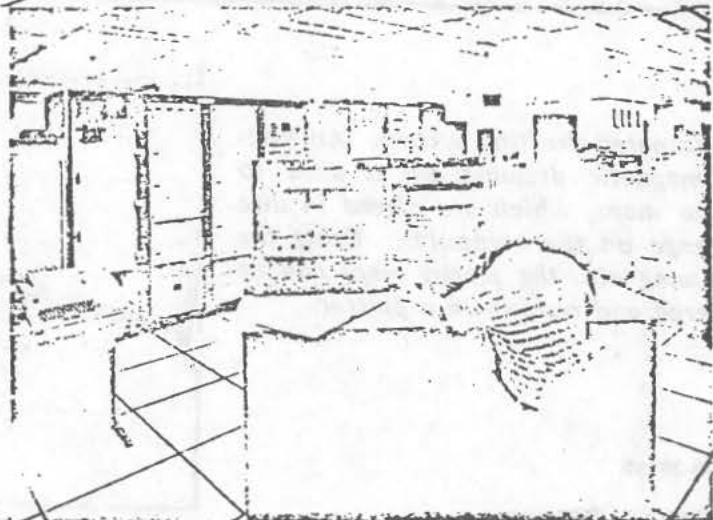
- For geometric analysis — electronic calculators, comparators, an X-Y digitizer, an automated drafting system, a multiscale stereographic point-marker, stereoplotters, stereoscopic point-transfer devices, and an orthoprojector.

S-75-28949



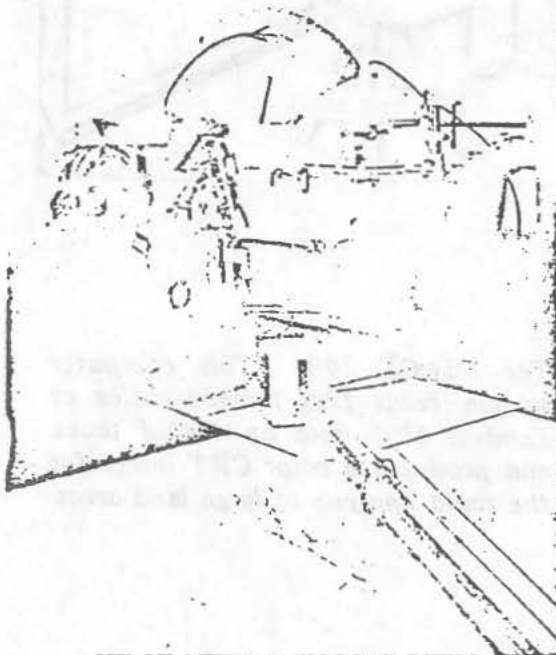
The ERIPS terminal. This interactive graphics system allows the user to analyze and interact with remotely sensed data as it is being processed.

S-75-28955



The EOD computer facility. Digital tapes produce a color image on the CRT to aid in analyzing data.

S-75-28954



Stereoplotter. A pair of transparencies is placed, one on each side of this apparatus, and a map is plotted combining the significant features of each.

EOD

facilities

S-75-28951



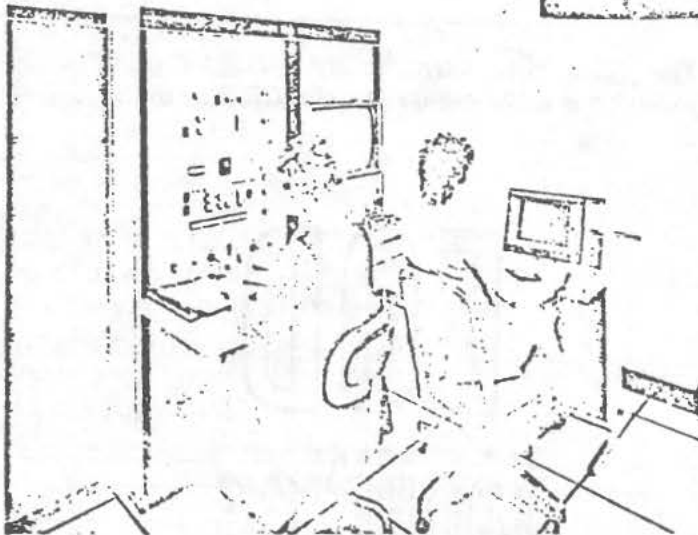
X-Y digitizer. Using input x- and y-coordinates of points on a map, this digitizer reads contours of the enclosed area, measures accurately to 1/1000 of an inch, and outputs the acreage on teletype and punched tape.

S-75-28952

Automated drafting system. An electromagnetic drawing aid is used to draw maps, which are placed in disc storage on the computer. Using the drawing aid, the stored maps can be altered and output on a plotter.



S-75-28950



The IMAGE 100. This computer system reads film transparencies or Landsat MSS data on digital tapes and produces a color CRT image for the rapid analysis of large land areas.

- For photointerpretation — black-and-white and color film viewers, printers, and readers; a multisensor takeup table for viewing separate film tracks; a rear-projection film reader system; a zoom transferscope for superimposing images; a color additive viewer; a closed circuit television system for displaying black-and-white transparencies (with color-additive features); and a multiband camera film viewer for converting image data to a television signal and displaying these data on a 1,000-line color display.

Project Support Office

The Project Support Office (PSO) in Building 17 of NASA/JSC is the repository for all quality-assured, remotely sensed Earth resources data obtained by satellite, aircraft, and manned spacecraft.

The services of the PSO include:

- Storage of data on computers, microfilm, and microfiche
- Indexing and cataloging of written reports on Earth Resources Program missions
- Responding to the requests for information on Earth resources from persons, institutes, and agencies inside and outside JSC.

During a day of operations the PSO may receive more than 100 requests for information, either by letter, telephone, or personal appearance at the Center. Every request is answered by individualized research or, if the PSO cannot supply the information, by referring the requesting party to the appropriate office or agency.

Approved visitors to the PSO who are seeking information are allowed access to the imagery. By examining the natural features on microfilm, microfiche, or CKT and using their scientific training and experience, a geologist may discover a possible area for oil exploration, and an arche-

ologist may uncover the site of ancient ruins.

Letter and telephone requests from all over the world and all fields of scientific study are received and studied by a research assistant. The researcher assesses the individual needs and recommends the appropriate data. The requester may then purchase hard copies of reports or data or aerial photographs from the Earth Resources Observation Systems (EROS) Data Center at Sioux Falls, South Dakota.

Information storage and retrieval facilities at the PSO include an automated historical data base for JSC-acquired aerial photography from Mission 293 and subsequent aircraft missions. These data are stored on a Hewlett-Packard 3300 computer. The retrieval unit consists of a keyboard, a CRT, and a line printer. This equipment will search for and locate aerial photography over a given area.

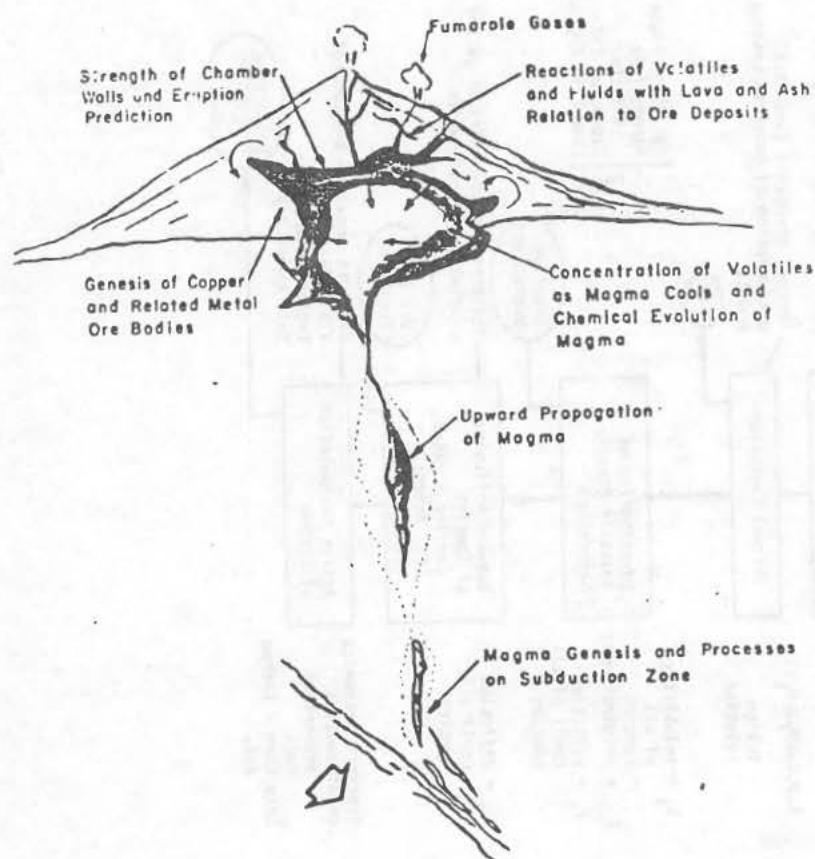


Remote sensing data from Gemini, Apollo, Skylab, and satellite (Landsat-1 and -2) missions are stored on microfilm and microfiche. The PSO has units available for reading these data.

The reference collection of the PSO encompasses most of the documents published regarding remotely sensed data, including symposium papers.

Copies of all data are available to persons and organizations approved by the Earth Resources Program Office (ERPO).

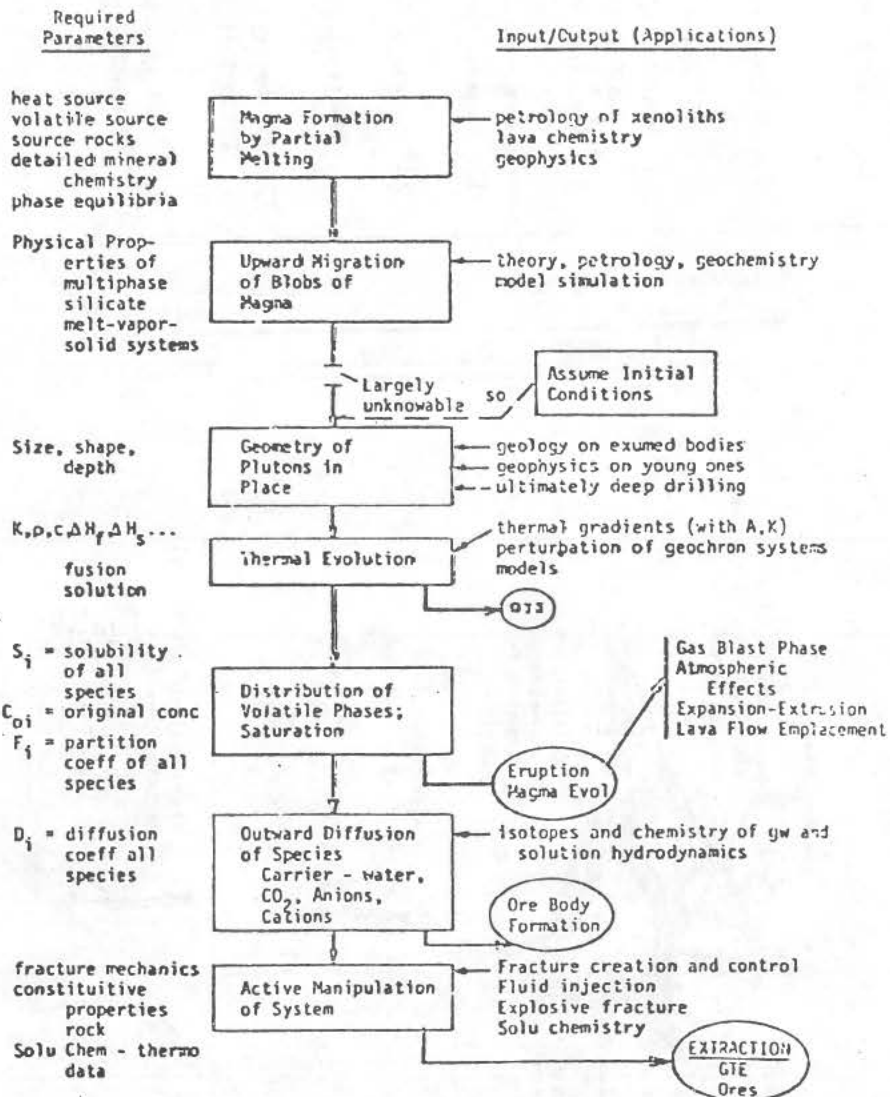
SOME PROBLEMS IN STRATOVOLCANOEES OF THE CIRCUMPACIFIC OR CASCADE TYPE



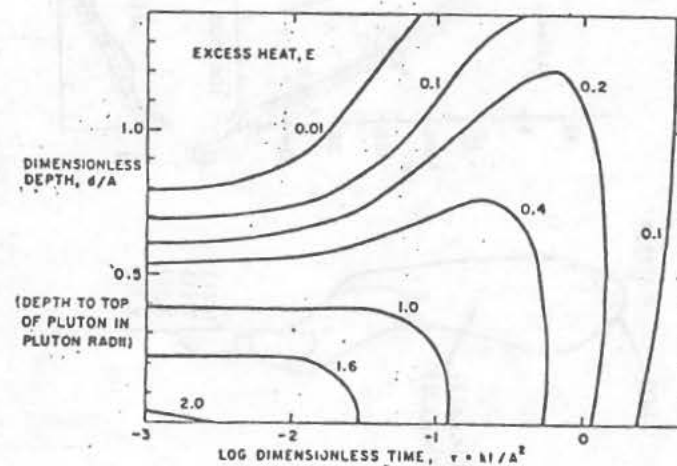
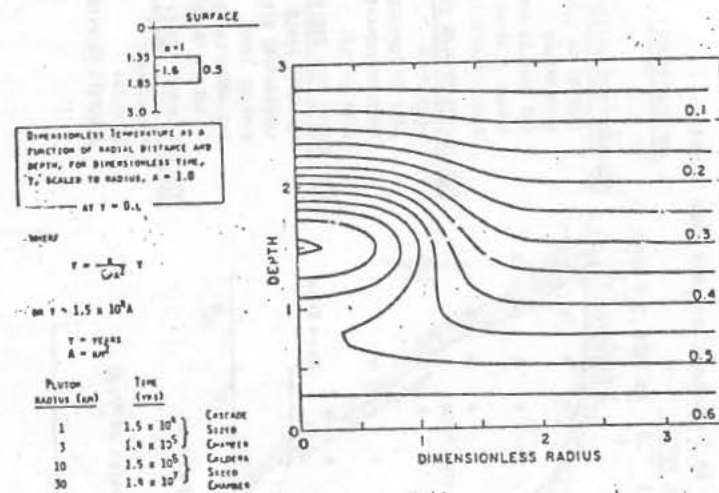
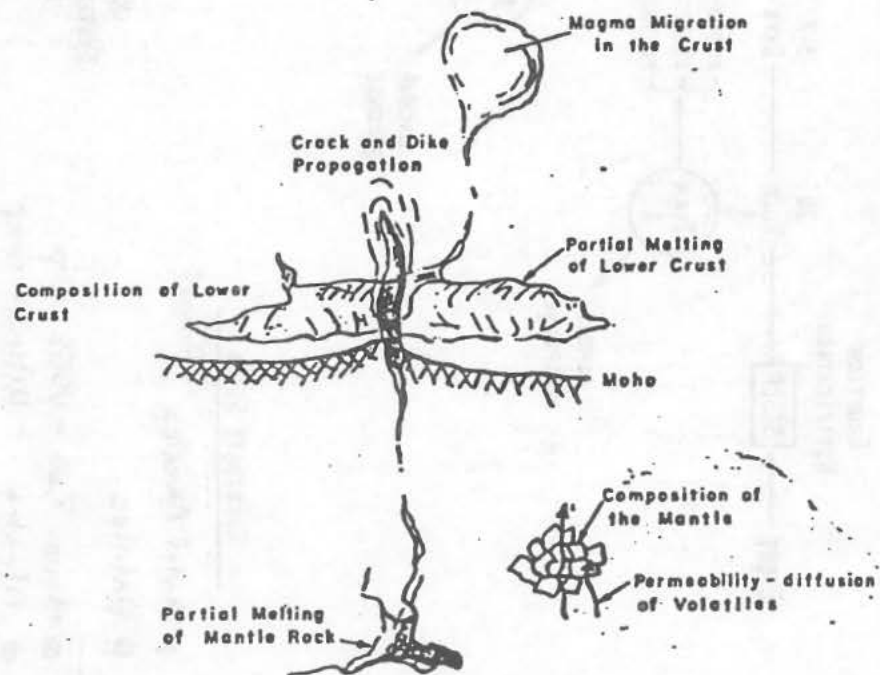
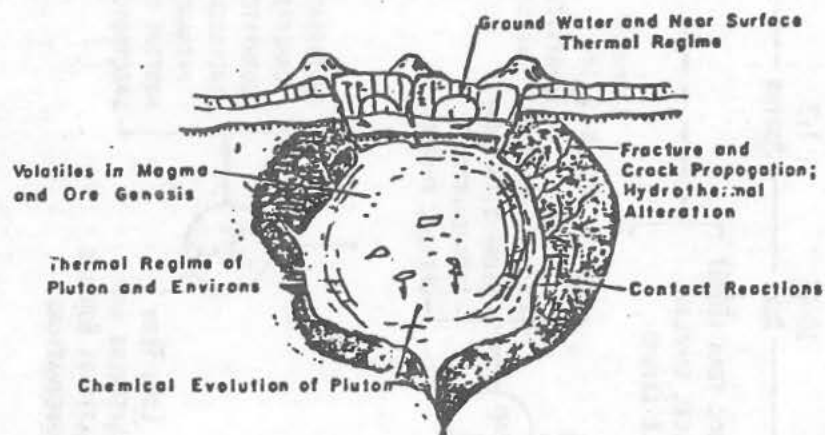
| | | EXPERIMENT | VOLCANO GEOPHYSICS |
|--------------------------|----------|--|--|
| GEOPHYSICAL OBSERVATIONS | AIRCRAFT | 1. PHOTOGRAPHY | SYNOPTIC DOCUMENTATION OF EVENTS + HYDRODYNAMIC OR PHENOMENOLOGICAL MODELING |
| | | 2. OPTICAL PHYSICS IR SPECTROSCOPY | THERMAL HISTORY AND GAS ANALYSIS |
| | | 3. ATMOSPHERIC PARTI- CULATE SAMPLING | ASH CLOUD EVOLUTION; FALL- OUT CHEMISTRY |
| | | 4. ATMOSPHERIC TRANSMISSION | EFFECTS OF ASH ON ALBEDO; CLIMATE AND WEATHER EFFECTS |
| GROUND BASED | | 1. PHOTOGRAPHY | ERUPTION DYNAMICS AND PHENOMENOLOGICAL MODELING |
| | | 2. OPTICAL PHYSICS IR SPECTROSCOPY | TEMPERATURE OF ERUPTION PRODUCTS; MOLECULAR (AND ISOTOPIC) SPECIES IN VAPOR |
| | | 3. SEISMOLOGY GEODSY TILT | DEFORMATION AND GROUND MOTION ASSOCIATED WITH ERUPTIONS |
| | | 4. SAMPLING AND STRUCTURAL GEOLOGY | CHEMICAL EVOLUTION OF MAGMAS; HOW VOLCANOES EVOLVE |

alamos
of the Laboratory
of the University

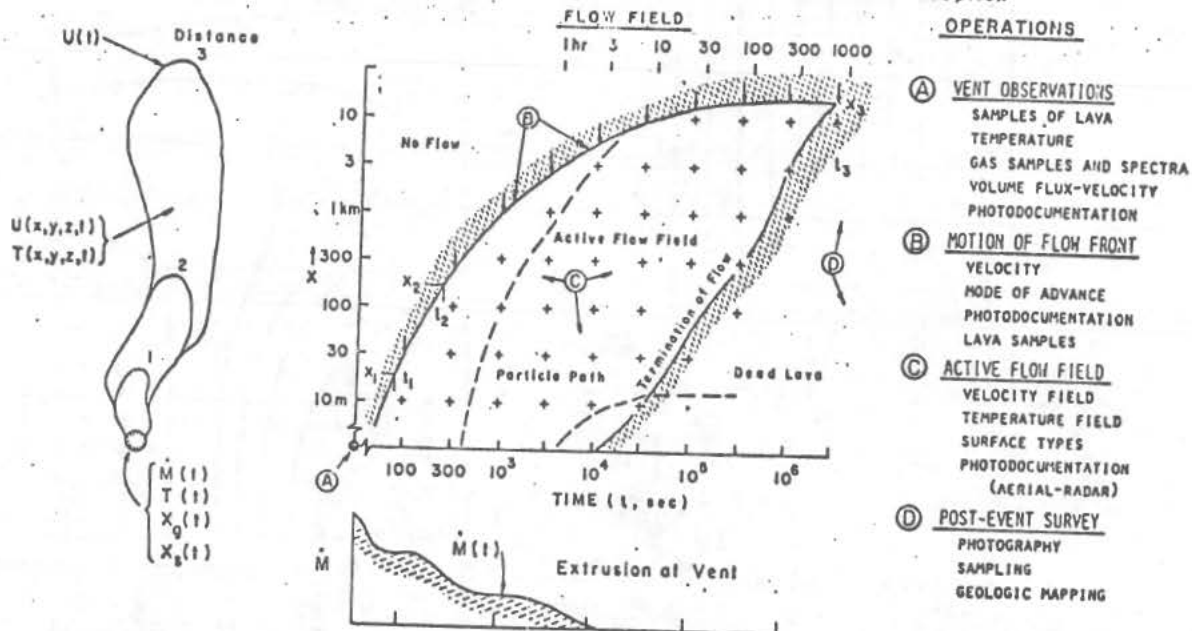
IGNEOUS PROCESS ALGORITHM



SOME FUNDAMENTAL GEOSCIENCE PROBLEMS IN UNDERSTANDING GEOTHERMAL SYSTEMS

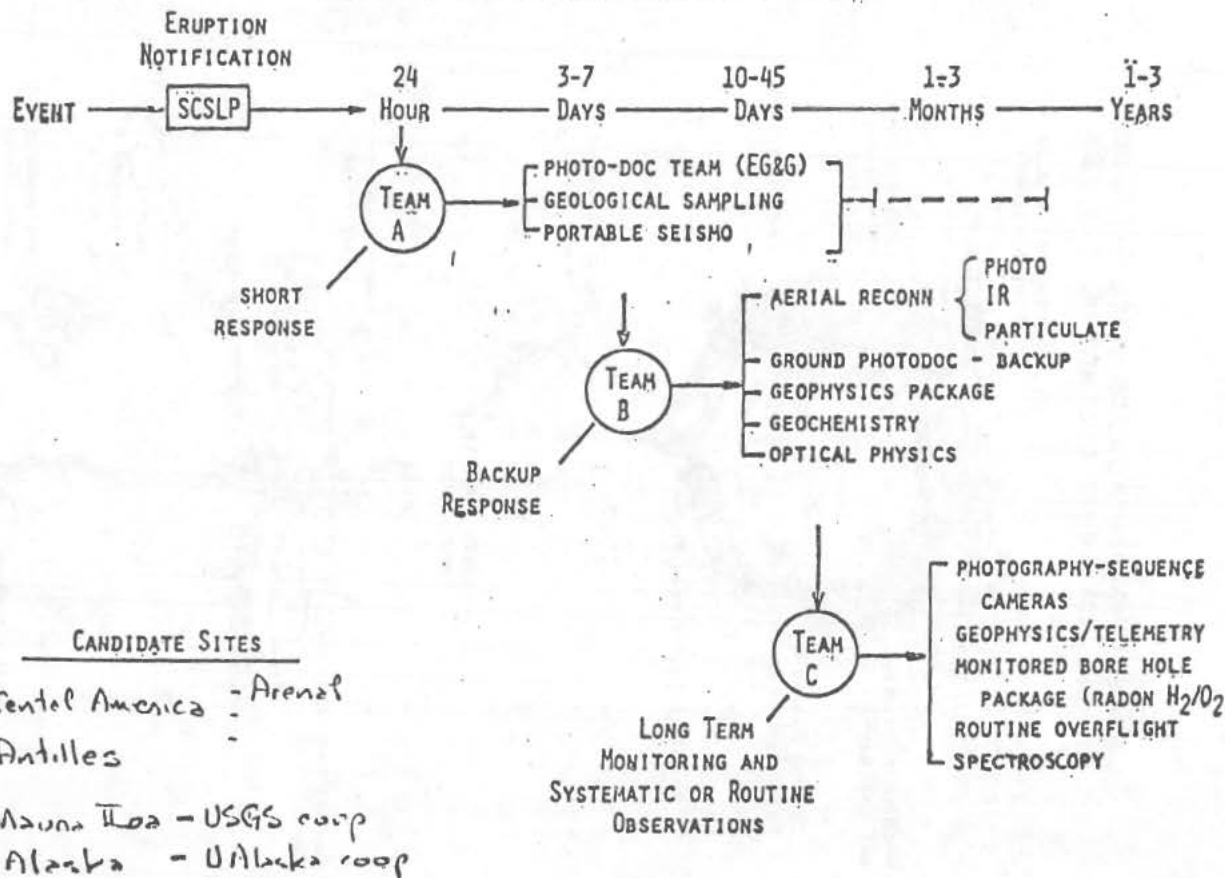


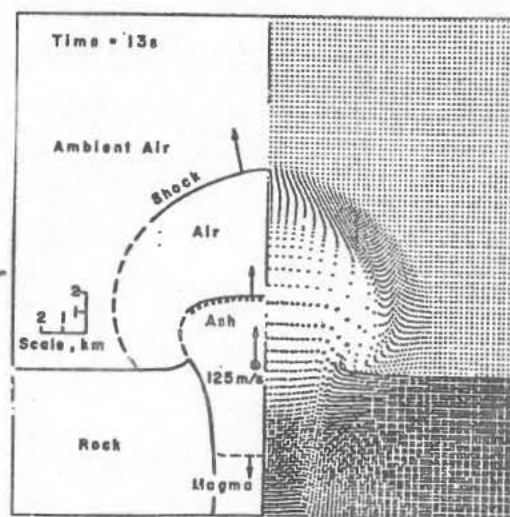
Sampling and Data Acquisition Rationale for Lava Flow Eruption



SWAT-Team Approach

VOLCANIC ERUPTION PHENOMENOLOGY RESEARCH





Computer Simulation of Eruption from Large Silicic Magma Chambers. (The Bandelier Tuff - 13 seconds old.)

TABLE I

Some Unknown Parameters Required for Solution of the Caldera Eruption Problem

| | Data Required | Approach for Acquisition of Data |
|-------------------------------------|--|--|
| Field/Petrochemical Studies of | • P, T and $f_{H_2O}, f_S, f_{O_2}, \dots$ at top of magma chamber | Petrochemical studies on airfall ash |
| | • Identity of vapor species | Detailed descriptive chemical petrology on ash; geochemistry and phase equilibria; fluid inclusions |
| | • Vertical distribution of volatiles | Inversion of volcanic stratigraphy to yield magma chamber layering and chemical petrology and geochemistry |
| | • Geometry of source vents - size, shape and roughness | Detailed mapping, possibly geophysics and drilling |
| | • Timing of roof collapse - pressure history in magma chamber during eruption | Detailed mapping of air and ash flow units |
| Theoretical/Experimental Studies | • Equation of state of volatile rich magmas (equilibrium) | Experimental phase equilibria studies theory - sound speed |
| | • Pressure-density-relations under dynamic unloading conditions | Experimental and theoretical studies of volatile bearing melts - under disequilibrium |
| | • Multiphase hydrodynamics | Experimental simulation; theory; computer experimentation |
| | • Physical properties of magmas | Transport properties of melt-volatile systems - diffusion, viscosity.... |
| Geophysical Studies of Modern Cases | • Magma chamber configuration; contents and environs - chemical and physical state | Geology of exhumed analogs; geophysics of active sites - ultimately, deep drilling (see CDP, E. M. Shoemaker, 1975) |
| | • Eruption phenomenology | Photodocumentation, optical physics-gas chemistry, ash-lava petrology and geochemistry at modern analog eruption sites |

7. PRESENTATIONS OF MEETING #2 - 24 FEBRUARY 1978

- 7.1 McGetchin (LPI) - Greetings, Introduction and Summary
of Meeting #1
- 7.2 Smistad (JSC) - - JSC/Airborne Instrumentation Research
Program Review
- 7.3 Flinn (NASA Headquarters) (Telecommunication) -
Review of NASA Program in Geodynamics
- 7.4 Jordan (UCSD) - - Lateral Heterogeneities in the Earth's
Interior
- 7.5 Srnka (LPI) and Hall (U. Houston) -
Status of Caribbean Area Magnetic
Mapping
- 7.6 Jordan (UCSD) - - Tectonics of Caribbean
- 7.7 Discussion, Summary and Decision to Construct Program Plan

ENCLOSURES

| | |
|---|--------------|
| Smistad/JSC Airborne Instrumentation Research Program | 7-3 to 7-28 |
| Jordan/Map showing depth to Benioff Zone under Central America | 7-29 |
| Srnka-Hall/Caribbean Magnetics | 7-31 to 7-32 |

JOHNSON SPACE CENTER

AIRBORNE INSTRUMENTATION RESEARCH PROGRAM

PRESENTED TO:

CARIBBEAN PLATE WORKSHOP
LUNAR SCIENCE INSTITUTE

FEBRUARY 24, 1978

AIRBORNE INSTRUMENTATION RESEARCH PROGRAM

BASIC OBJECTIVE: DATA ACQUISITION IN SUPPORT OF OSTA RESEARCH, APPLICATIONS, SPACE-CRAFT AND SENSOR DEVELOPMENT PROJECTS

FUNDING: FY79 - BASIC: AIRP OFFICE

DATA ACQUISITION AND PROCESSING: DISCIPLINE OFFICES

FY80 - TOTAL PROJECT: AIRP OFFICE

SUPPORT TO OSTA: EARTH RESOURCES

WEATHER AND CLIMATE

ENVIRONMENTAL

OCEAN PROCESSES

OTHER - REIMBURSABLE

LOCATION: JOHNSON SPACE CENTER/AMES RESEARCH CENTER

NC130B

ENGINE: 4 TURBOPROP

ALTITUDE: 30,000 FEET.

DURATION: 8 HRS; 6 HRS DATA ACQUISITION

PAYLOAD: STANDARD AND EXPERIMENTAL; 20,000 POUNDS MAX

CREW: 3 CREW, PLUS OPERATORS AND PRINCIPAL INVESTIGATORS

REMOTE SENSING EQUIPMENT:

CAMERA: METRIC - 6 INCH

SCANNER: 11 CHANNEL, 0.33 - 13.5 MICROMETERS

8 CHANNEL, 0.45 - 12.4 MICROMETERS (THEMATIC MAPPER)

MICROWAVE: ACTIVE (4)/PASSIVE (2) SYSTEMS

OTHER: INERTIAL NAVIGATION

CENTRAL RECORDING

FEATURES: STANDARD COMPLEMENT

WALK-ON PAYLOAD CAPABILITY

REMOTE INTEGRATION CAPABILITY



WB57E

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

REMOTE SENSING EQUIPMENT

CAMERA: METRIC - 6/12 INCH FOCAL LENGTH

HIGH RESOLUTION - 24 INCH FOCAL LENGTH

SCANNER: 5 CHANNEL, 0.50 - 12.5 MICROMETERS (LANDSAT-C SIMULATOR)

OTHER: INERTIAL NAVIGATION

CENTRAL RECORDING

FEATURES: UNIVERSAL PALLET

STANDARD INTERFACE

REMOTE INTEGRATION CAPABILITY



AIRP 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 METERS AT 20,000 FEET ALTITUDE
APPROXIMATELY 5 METERS AT 60,000 FEET ALTITUDE

6" F.L. METRIC CAMERAS

1 METER FOR HIGH RESOLUTION CAMERAS AT
20,000 FEET ALTITUDE

FILM PRODUCTS: POSITIVE AND NEGATIVE TRANSPARENCIES
CONTINUOUS AND FRAME PAPER PRINTS, COLOR AND BLACK & WHITE
TRANSPARENCY AND PAPER PRINT ENLARGEMENTS
FILM CALIBRATION AND ANALYSIS (DENSITOMETRY AND SENSITOMETRY)
MICRODENSITOMETRY
IMAGE ENHANCEMENT
FILM/FILTER SELECTIONS

AIRCRAFT ELECTRONIC SENSOR PAYLOAD CAPABILITIES

NC130B

- NERDAS (DATA ANNOTATION)
- M²S (11 CHANNEL SCANNER)
- NS001 (THEMATIC MAPPER SIMULATOR)
- PMIS (IMAGING MICROWAVE)
- MFMR (MICROWAVE RADIOMETER)
- PRT-5 (RADIATION THERMOMETER)

WB57E

- NERDAS
- RS-18MS (LANDSAT-C SIMULATOR)
- APQ-102 (SLAR)

GENERAL SENSOR CHARACTERISTICS

● MODULAR MULTISPECTRAL SCANNER (M²S)

●● DESCRIPTION

- AN ELECTRO-OPTICAL SCANNER WHICH SCANS SUCCESSIVE CONTIGUOUS LINES ACROSS THE FLIGHT PATH
- RECORDS 11 DISCRETE SPECTRAL BANDS SIMULTANEOUSLY
- RECORDS VISIBLE AND THERMAL INFRARED ENERGY REFLECTED OR EMITTED FROM EARTH FEATURES

●● SPECTRAL CHARACTERISTICS

| <u>CHANNEL NUMBER</u> | <u>BANDWIDTH (MICROMETERS)</u> |
|-----------------------|--------------------------------|
| 1 | .38 - .44 |
| 2 | .44 - .49 |
| 3 | .49 - .54 |
| 4 | .54 - .58 |
| 5 | .58 - .62 |
| 6 | .62 - .66 |
| 7 | .66 - .70 |
| 8 | .70 - .74 |
| 9 | .76 - .86 |
| 10 | .97 - 1.06 |
| 11 | 8.05 - 13.7 |

●● SPATIAL CHARACTERISTICS

- 100° SCAN ANGLE ($\pm 50^\circ$ FROM NADIR)
- 2.5 MRAD INSTANTANEOUS FIELD-OF-VIEW
 - 12.5 FEET AT 5,000 FEET ALTITUDE
 - 50.0 FEET AT 20,000 FEET ALTITUDE

●● DATA PROCESSING PRODUCTS

- DIGITAL TAPE AND/OR 70-MM. BLACK & WHITE FILM

● NS001MS

●● DESCRIPTION

- AN ELECTRO-OPTICAL SCANNER WHICH SCANS SUCCESSIVE CONTIGUOUS LINES ACROSS THE FLIGHT PATH
- RECORDS EIGHT SPECTRAL BANDS SIMULATING THE THEMATIC MAPPER
- RECORDS ENERGY REFLECTED OR EMITTED FROM THE EARTH'S SURFACE IN THE VISIBLE AND THERMAL INFRARED RANGE

●● SPECTRAL CHARACTERISTICS

| <u>CHANNEL NUMBER</u> | <u>BANDWIDTH (MICROMETERS)</u> |
|-----------------------|--------------------------------|
| 1 | .45 - .52 |
| 2 | .52 - .60 |
| 3 | .63 - .69 |
| 4 | .76 - .90 |
| 5 | 1.00 - 1.30 |
| 6 | 1.55 - 1.75 |
| 7 | 2.08 - 2.35 |
| 8 | 10.4 - 12.5 |

●● SPATIAL CHARACTERISTICS

- 100° SCAN ANGLE ($\pm 50^\circ$ FROM NADIR)
- 2.5 MILLIRADIAN INSTANTANEOUS FIELD-OF-VIEW
 - 12.5 FEET AT 5,000 FEET ALTITUDE
 - 50 FEET AT 20,000 FEET ALTITUDE

●● DATA PROCESSING PRODUCTS

- DIGITAL TAPE AND/OR 70-MM. BLACK & WHITE FILM

● PASSIVE MICROWAVE IMAGING SYSTEM (PMIS)

●● DESCRIPTION

- A PASSIVE DUAL-POLARIZED CONSTANT ANGLE-OF-INCIDENCE MICROWAVE IMAGER
- RECORDS MICROWAVE RADIATION EMITTED OR REFLECTED FROM THE EARTH'S FEATURES

●● SPECTRAL CHARACTERISTICS

- 10.69 GHZ FREQUENCY
- 200 MHZ BANDWIDTH

●● SPATIAL CHARACTERISTICS

- APPROXIMATELY 3° BY 1.8° HALF-POWER BEAM DIMENSIONS
- 70° SCAN ($\pm 35^{\circ}$ FROM NADIR)
- RESOLUTION
 - 490 FEET WITH 13,000 FOOT SWATH FROM 10,000 FEET ALTITUDE
 - 50° CONSTANT ANGLE-OF-INCIDENCE

●● DATA PROCESSING PRODUCTS

- DIGITAL TAPE, HARDCOPY TAB, BLACK & WHITE 70-MM. FILM

● MULTIFREQUENCY MICROWAVE RADIOMETER (MFMR)

●● DESCRIPTION

- THE MFMR IS A FIVE FREQUENCY PASSIVE MICROWAVE RADIOMETER WHICH MEASURES EMITTED MICROWAVE ENERGY FROM THE EARTH'S FEATURES
- THE SENSOR IS DUAL POLARIZED, RECORDING BOTH VERTICAL AND HORIZONTAL POLARIZATION FOR EACH BAND

●● SPECTRAL CHARACTERISTICS

| <u>BAND</u> | <u>FREQUENCY</u> | <u>WAVELENGTH</u> |
|-------------|------------------|-------------------|
| L | 1.42 GHZ | 21 CM |
| C | 4.99 GHZ | 6 CM |
| Ku | 18.0 GHZ | 1.65 CM |
| K | 22.05 GHZ | 1.40 CM |
| Ka | 37.0 GHZ | .8 CM |

●● SPATIAL CHARACTERISTICS

| <u>BAND</u> | <u>BEAM WIDTH</u> |
|-------------|-------------------|
| L | 16° |
| C | 6° |
| Ku | 5° |
| K | 5° |
| Ka | 5° |

●● DATA PROCESSING PRODUCTS

- DIGITAL TAPE AND HARDCOPY TAB CONTAINING CORRECTED ANTENNA TEMPERATURES

● PRECISION RADIATION THERMOMETER (PRT-5)

●● DESCRIPTION

- LIGHTWEIGHT, PORTABLE, BATTERY-POWERED THERMAL INFRARED RADIOMETER
- RECORDS THERMAL INFRARED RADIATIONS EMITTED FROM THE EARTH'S FEATURES

●● SPECTRAL CHARACTERISTICS

- SINGLE BANDPASS FILTER (8 - 14 μ m)

●● SPATIAL CHARACTERISTICS

- 2° FIELD-OF-VIEW
 - 35 FEET AT 1,000 FEET ALTITUDE
 - 350 FEET AT 10,000 FEET ALTITUDE

●● DATA PROCESSING PRODUCTS

- DIGITAL TAPE, HARDCOPY TAB, AND STRIPCHART

● RS-18MS

●● DESCRIPTION

- AN ELECTRO-OPTICAL SCANNER SYSTEM FOR HIGH-ALTITUDE FLIGHT WHICH SCANS SUCCESSIVE CONTIGUOUS LINES ACROSS THE FLIGHT PATH
- SIMULTANEOUSLY RECORDS FIVE DISCRETE SPECTRAL BANDS
- RECORDS REFLECTED AND EMITTED ENERGY IN THE VISIBLE AND THERMAL INFRARED RANGE

●● SPECTRAL CHARACTERISTICS

| <u>CHANNEL NUMBER</u> | <u>BANDWIDTH (MICROMETERS)</u> |
|-----------------------|--------------------------------|
| 1 | .5 - .6 |
| 2 | .6 - .7 |
| 3 | .7 - .8 |
| 4 | .8 - 1.1 |
| 5 | 10.4 - 12.5 |

●● SPATIAL CHARACTERISTICS

- 80° SCAN ANGLE ($\pm 40^\circ$ FROM NADIR)
- 1.0 MILLIRADIAN INSTANTANEOUS FIELD-OF-VIEW
-- 60.0 FEET AT 60,000 FEET ALTITUDE

●● DATA PROCESSING PRODUCTS

- DIGITAL TAPE AND/OR 70-MM. BLACK & WHITE FILM

● APQ-102 SIDE-LOOKING RADAR

●● DESCRIPTION

- ACTIVE DUAL-POLARIZED SYNTHETIC APERTURE RADAR IMAGING SYSTEM USING FILM RECORDING AND A DATA CORRELATOR/PROCESSOR

●● SPECTRAL CHARACTERISTICS

| <u>BAND</u> | <u>FREQUENCY</u> | <u>WAVELENGTH</u> |
|-------------|------------------|-------------------|
| X | 9600 MHZ. | 3 CM |

●● SPATIAL CHARACTERISTICS

- 15M BY 15M

●● DATA PROCESSING COSTS AND PRODUCTS

- 5-INCH BLACK & WHITE FILM
- \$250 PER 200-FOOT ROLL (OPTICAL CORRELATION PHASE ONLY)

(SENSOR NOT RELEASED FOR OPERATIONS)

● NASA EARTH RESOURCES DATA ANNOTATION SYSTEM (NERDAS)

●● DESCRIPTION

- THE NERDAS SYSTEM ACCEPTS AUXILIARY DATA FROM VARIOUS SYSTEMS ONBOARD THE AIRCRAFT, ANNOTATES THEM IN BINARY CODE FORMAT ON FILM AND MAGNETIC TAPE, AND PROVIDES REAL TIME DISPLAY OF SELECTED PARAMETERS
- THE NERDAS RECORDS MISSION IDENTIFICATION INFORMATION SUCH AS MISSION NUMBER, DATE, TIME, AND AIRCRAFT FLIGHT PARAMETERS SUCH AS GROUND SPEED, RADAR ALTITUDE, PITCH ANGLE, ROLL ANGLE, LATITUDE, LONGITUDE, AND SYSTEM STATUS

●● DATA PROCESSING PRODUCTS

- HARDCOPY TABULATIONS OF GUIDANCE AND NAVIGATION DATA, AS WELL AS CAMERA CORRELATION INFORMATION

STANDARD DATA PRODUCTS

ELECTRONIC

CCT'S

COMPUTER TABS

FILM (FROM SCANNER DATA)

CAMERA CORRELATION TAB

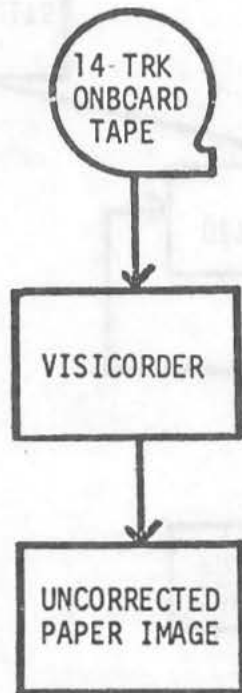
PHOTOGRAPHIC

ORIGINAL FILM

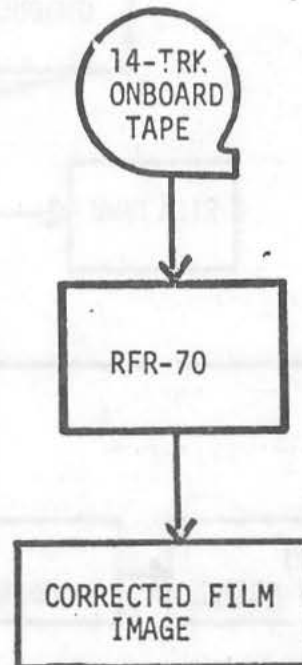
DUPLICATE POSITIVE TRANSPARENCIES (TWO)

GENERAL ELECTRONIC DATA PROCESSING FLOW

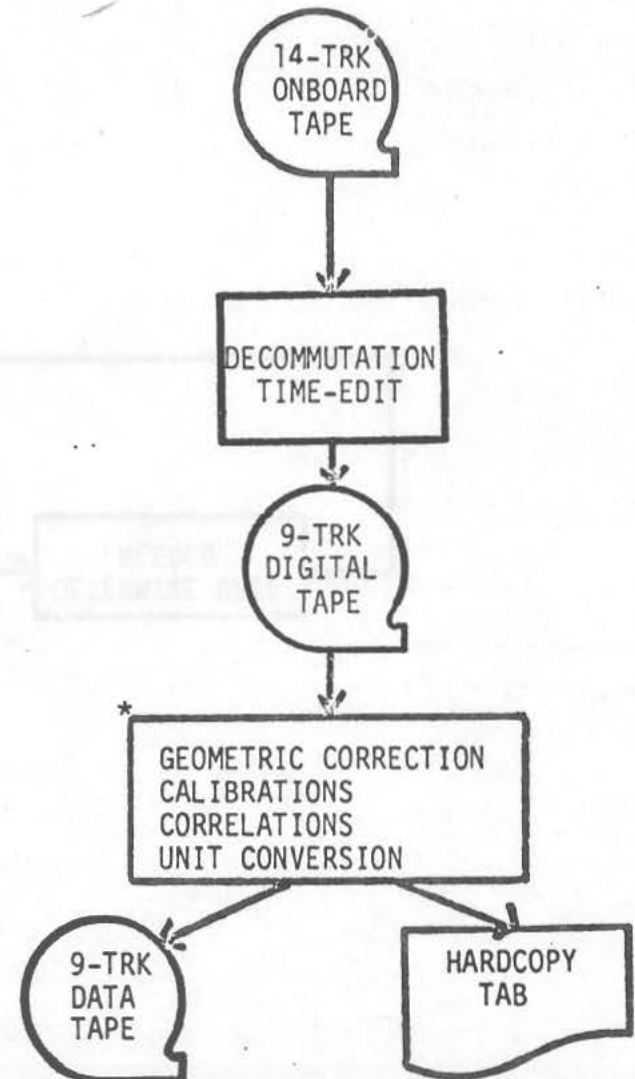
SCREENING IMAGE FLOW (SCANNERS)



FINAL IMAGE FLOW (SCANNERS)

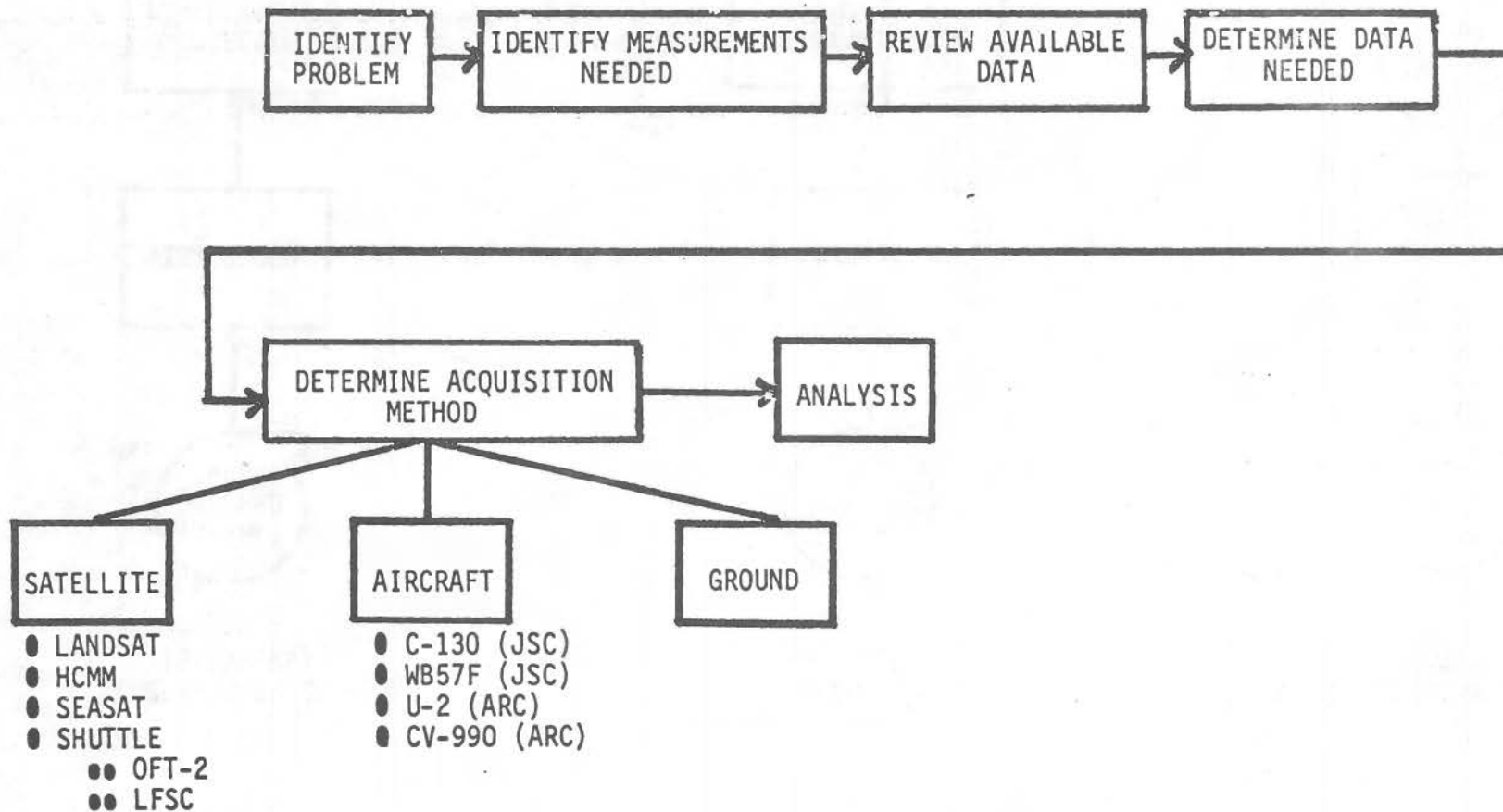


DIGITAL DATA PRODUCTS FLOW (ALL ELECTRONIC SENSORS)

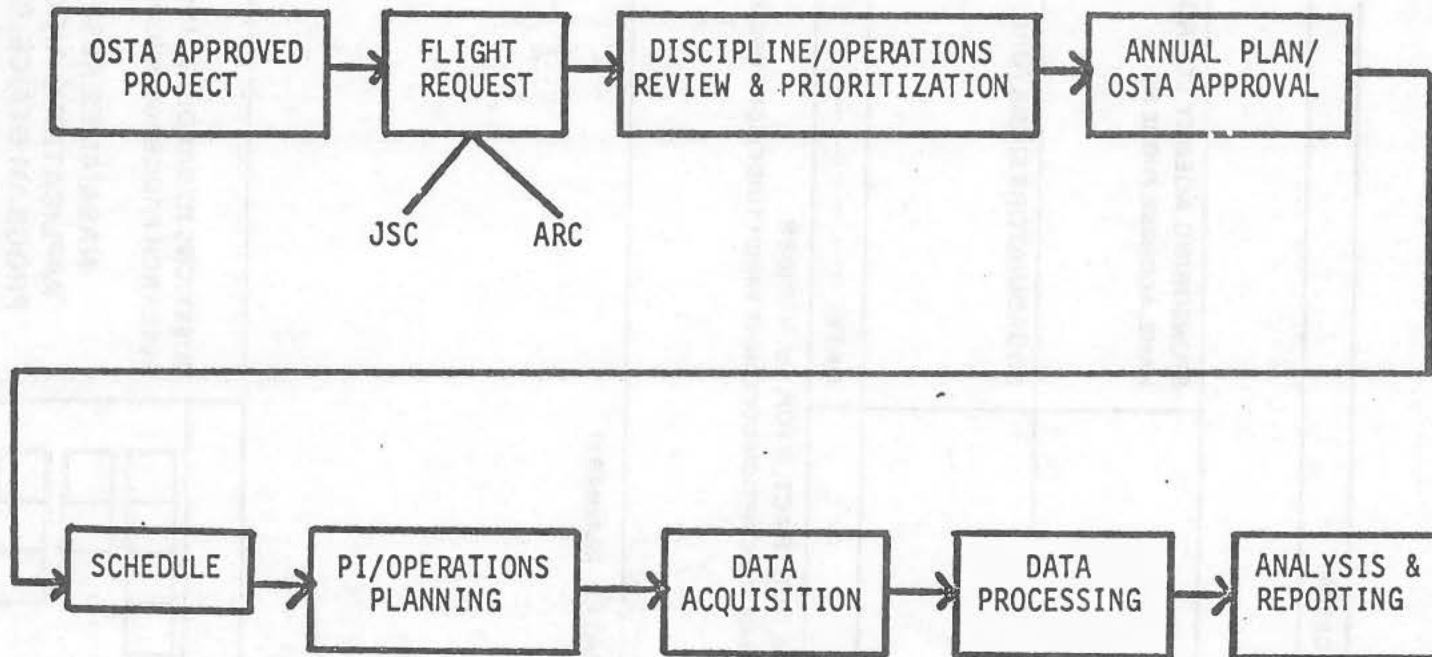


* PDP 11/70 PROCESSOR

INVESTIGATIVE APPROACH



THE SYSTEM



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION OFFICE OF APPLICATIONS

FLIGHT REQUIREMENTS FOR AIRBORNE INSTRUMENTATION RESEARCH PROGRAM AIRCRAFT

PART I (TO BE COMPLETED BY INVESTIGATOR)**INVESTIGATION TITLE**

PRINCIPAL INVESTIGATOR
NAME, ADDRESS, PHONE NO.

SPONSORING AGENCY COORDINATOR
NAME, ADDRESS, PHONE NO.

PRINCIPAL INVESTIGATORS SIGNATURE**COORDINATORS SIGNATURE****DATE****DATE****APPROVED INVESTIGATION, PROGRAM, CONTRACT, RTOP, etc. NUMBER**

A COPY OF THE RTOP, PROPOSAL OR PROGRAM DESCRIPTION DOCUMENT WHICH THIS FLIGHT REQUEST WILL
SUPPORT MUST BE ATTACHED.

TEST SITES AND REQUIRED FLIGHT DATES (SUMMARY)**TO BE COMPLETED BY NASA****DISCIPLINE CODE**

| | | | |
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PROGRAMMATIC AREA

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PROJECT CENTER

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PLANNING YEAR

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APPROVAL CODE

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QUESTIONS REGARDING AIRCRAFT SUPPORT OF
RESEARCH PROGRAMS SHOULD BE DIRECTED TO:

**NASA/AMES RESEARCH CENTER
APPLICATIONS AIRCRAFT SUPPORT
PROGRAM OFFICE, CODE SEP - 240-5
MOFFETT FIELD, CALIFORNIA 94035**

TELEPHONE (415) 965-6611

PART II SPONSORING AGENCY REVIEW

7-25

THESE REQUIREMENTS HAVE BEEN REVIEWED AND IMPLEMENTATION IS RECOMMENDED AS REQUESTED**TYPED NAME AND TITLE****SIGNATURE AND DATE****THE REMAINDER OF THIS FORM TO BE COMPLETED BY REQUESTER****(TO AVOID DELAYS, PLEASE PROVIDE COMPLETE INFORMATION)****PART III OBJECTIVES****INVESTIGATION OBJECTIVES (DESCRIBE THE OVERALL OBJECTIVES OF THE INVESTIGATION AND GIVE RATIONALE FOR REQUIRED AIRCRAFT SUPPORT)****PART IV RELATIONSHIP TO OTHER INVESTIGATIONS****HISTORY AND RELATIONSHIP TO OTHER INVESTIGATIONS (IF THE REQUESTED FLIGHTS ARE PART OF A BROADER EARTH OBSERVATIONS PROGRAM, DESCRIBE THAT PROGRAM INDICATING THE INTERRELATIONSHIP WITH THIS INVESTIGATION. IS THIS A CONTINUATION, UPDATE OR REVISION OF A PREVIOUSLY SUBMITTED REQUEST?)**

PART V SITE DESCRIPTION AND FLIGHT TIMING

GEOGRAPHIC LOCATION (STATE THE LOCATION OF EACH TEST SITE SPECIFYING ITS LOCATION AND BOUNDARY COORDINATES BY LONGITUDE AND LATITUDE TO THE NEAREST MINUTE. IN THOSE SITUATIONS WHERE PARTICULAR TEST SITES CANNOT BE SPECIFIED i.e., SEA-STATE CONDITIONS, WEATHER PHENOMENA, etc. IDENTIFY THE MOST DESIRABLE AREA. GIVE ALTERNATES IF APPROPRIATE. SPECIFY THE DATE OR DATES OF EACH TEST SITE OVER-FLIGHT, INDICATE ITS PRIORITY TO MEET YOUR INVESTIGATION OBJECTIVES. INDICATE TIMING TOLERANCE AND SUPPORTING RATIONALE.)

NOTE: ATTACH A MAP OF THE TEST SITES, ANNOTATED TO INDICATE THE AREAS TO BE OVERFLOWN BY AIRCRAFT. IDENTIFY THE LOCATION OF GROUND TEAMS, SPECIFIC FLIGHT LINES DESIRED, PROMINENT FEATURES AND FLIGHT LINE MARKERS. THESE MAPS WILL BE USED FOR PLANNING PURPOSES. MORE DETAILED MAPS MAY BE REQUIRED AT A LATER DATE.

PART VI OPERATIONAL REQUIREMENTS

AIRCRAFT OPERATIONS AND FLIGHT PLANNING CONSTRAINTS (DESCRIBE AIRCRAFT OPERATIONAL CONSTRAINTS AND REQUIREMENTS WHICH MUST BE CONSIDERED FOR THIS INVESTIGATION, e.g., MAXIMUM/ MINIMUM ALTITUDES, FLIGHT LINE MARKERS, FLIGHT PROFILES, etc. DESCRIBE THE PHYSICAL CONSTRAINTS WHICH MUST BE CONSIDERED FOR THIS INVESTIGATION, e.g., CLOUD COVER, SUN ANGLE, TIDAL CYCLES, DIURNAL CYCLES, AND SURFACE CONDITIONS, SNOW COVER, SEA-STATE, SOIL MOISTURE, etc.)

PHYSICAL PHENOMENA AND SENSOR REQUIREMENTS (DESCRIBE THE PHYSICAL PHENOMENA TO BE MEASURED OR DETECTED. SPECIFY THE SPECTRAL REGIONS OF INTEREST, AND SPATIAL AND SPECTRAL RESOLUTIONS. DESCRIBE THE GENERAL TYPE OF SENSORS REQUIRED FOR THIS INVESTIGATION AS WELL AS SPECIFIC SENSOR OPERATION REQUIREMENTS, e.g., POLARIZATIONS FOR RADAR AND MICROWAVES, FILMS, FILTERS, LOOK ANGLES, OVERLAP FOR CAMERAS, etc. IF THIS IS A SENSOR DEVELOPMENT INVESTIGATION, WHAT, IF ANY, ARE ITS UNIQUE OPERATIONAL/INTEGRATION CHARACTERISTICS?)

PART VIII DATA REQUIREMENTS

DATA PRODUCTS REQUIREMENTS AND DATA ANALYSIS PLAN (DESCRIBE ANY SPECIAL DATA PROCESSING REQUIREMENTS, AND PLANS FOR ANALYSIS AND UTILIZATION OF DATA)

| TEST SITE | 7-28 | FLIGHT DATE AND TOLERANCES (FROM PART VI) | | | | | | | |
|---|-----------------|---|-------------------------------|---|--|--|--|--|--|
| WHAT IS THE MEAN ALTITUDE OF THE TEST SITE ABOVE SEA LEVEL? | | | | | | | | | |
| FLIGHT LINE NUMBER | FLIGHT ALTITUDE | FLIGHT LINE LENGTH IN NAUTICAL MILES | TIME OF DAY OF FLIGHT (LOCAL) | SENSORS (IDENTIFY EACH SENSOR AND THE SPECTRAL BANDS REQUIRED.) | | | | | |
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| NOTE: COMPLETE A SEPARATE SHEET FOR EACH DIFFERENT TEST SITE OVERFLIGHT | | | | | | | | | |



T. Jordan (1978-unpublished)
Map showing depth to Benioff Zone under Central America

CARIBBEAN MAGNETICS

A brief survey of the existing work on the total field magnetic data from the Caribbean reveals the following generalizations :-

- (i) Interpretative studies of detailed magnetic surveys close to the land areas bordering the Caribbean have been made. A majority of such studies, however, have concentrated on other geophysical measurements, especially seismic reflection records, and interpretation of the magnetics has been of secondary concern.
- (ii) Detailed surveys over the centre of the basins, viz. Colombian, Venezuelan and Yucatan Basins, have not been made but widely spaced tracks are available. No detailed analyses of these tracks have been made.
- (iii) A regional compilation of the data existing up until 1975 has been made by Jim Matthews of the U S Naval Oceanographic Office who has prepared a total intensity map of the entire region. No residual anomaly map was produced owing to the sparsity of data over the deep water areas. Interpretation of the total field data has not been made in any regional context. As noted above all interpretative work has emphasized local rather than 'entire plate' problems.
- (iv) Magnetic lineations are claimed for at least two areas, viz. Colombia Basin (E. Christofferson, G.S.A. Bull., v.84, 1973) and Cayman Trench (McDonald and Holcombe, 1978, in press) although the evidence is only convincing for the latter. The absence of lineations elsewhere is not surprising as a) such features are anticipated over the deep water areas where the coverage is poor, and b) the amplitudes of the anomalies observed over the deeper water are much smaller than those associated with the islands bordering the Caribbean.

The above generalizations suggest a three part attack on the problem:-

- (1) Compilation of existing information.
- (2) Detailed study of existing data over the deep water areas.
- (3) Airborne surveys over target areas resulting from 1 and 2.

- (1) New data from the various Galveston cruises and elsewhere need to be added to the compilation of Matthews and an attempt made to produce residual anomaly maps. These maps could take the form of several sheets each with its own measure of reliability to compensate for the poor coverage in certain areas. Of especial importance would be the delineation of "interesting areas" for which additional data could be gathered later.
- (2) Although sparse the deep water magnetic measurements appear the best possibility for obtaining evidence (if any) of seafloor spreading and hence the tectonic evolution of the area. A careful study of the available data should therefore be made in order to provide a more regional setting in which to place the detailed "local" interpretations. Although the data may be too widely spaced to obtain any direct answers or permit a thorough interpretation(e.g. modelling or the recognition of anomaly patterns), the data should be sufficient to pinpoint critical areas for further study.
- (3) Airborne surveys should be planned to answer specific questions arising from 1 and 2. Coverage of critical areas should be viewed in the light of all available data not solely magnetic and be amenable to interpretation using magnetic data. For example, what happens to lineations north and south of the Cayman Trench? or the location of structural features found in the basins by 2, etc.

8. ENCLOSURES AND ATTACHMENTS

| | | |
|-----|---|----------------|
| 8.1 | ICG Report 8 | 8-3 to 8-19 |
| 8.2 | Geodynamics Project - U.S. Progress Report - 1977 | 8-21 to 8-25 |
| 8.3 | Heiken - Catalogue of Satellite Photo- graphy of the Active Volcanoes of the World | 8-27 to 8-36 |
| 8.4 | Ward et al. - Development and Evaluation of a Prototype Global Volcano Sur- veillance System Utilizing the ERTS-1 Satellite Data Collection System | 8-37 to 8-63 |
| 8.5 | Calio - Testimony before House Subcommittee NASA/OSTA | 8-65 to 8-99 |
| 8.6 | Shuttle OFT-2 (Orbital Flight Test) Experiments | 9-101 to 8-111 |
| 8.7 | Skylab (February, 1973 Publication) - Excerpts | 8-113 to 8-139 |
| 8.8 | Additional References | 8-141 |

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COMMISSION INTER-UNIONS
DE GÉODYNAMIQUE

ICG REPORT 8

MID-TERM ACTIVITY (1975)

Secretariat of the Inter-Union Commission on Geodynamics

1

January 1976

MID-TERM REPORT OF WORKING GROUP 2"Geodynamics of the Eastern Pacific Region, Caribbean and Scotia Arcs"

Reporter: R. Cabré

Constitution

WG-2 was constituted by 16 geoscientists with a view to balanced representation of geologists and geophysicists - both continental and marine specialists (see Appendix I).

This composition has been maintained to date with the exception of the replacement of A. Fiedler by A. Bellizzia and of C. Lomnitz by L. del Castillo. C.R. Allen and R. Ritsema resigned and L. Kulm has replaced Tj. van Andel.

Activities: Organization and Communication

Originally a regional division, North and South, was proposed, to facilitate communication between members with similar problems. This was unsuccessful and in 1973, in Lima, the creation of Study Groups was proposed and has provided a workable framework. The Study Groups are:

- Juan de Fuca Plate
- Caribbean and Coco's Plate
- Nazca Plate
- Scotia Arc

Communications between WG members have been a problem and despite precautions taken, it has really been defective, with the exception of international meetings. Response to letters from the Chairman, despatched at irregular intervals has been poor and WG meetings few. This difficulty is an indication of the systematic isolation of geoscientists throughout nearly all the region.

Two meetings have been organized by WG-2:

1. WG-2 meeting and Conference on Geodynamics, in association with the IASPEI Assembly, Lima, 1973. The Conference was well attended and valuable scientific contributions were made. The WG thus promoted renewed activity and international projects. Much remains to be done, however, to stimulate these projects and to respond fully to the needs of regional problems.
2. The second meeting was joint with that of WG-1 and a Symposium on Geodynamics, during the 15th Pacific Science Congress, Vancouver, 1975. A report on this meeting appears on p.85 of this volume.

Other meetings have provided an occasion for promoting the goals of WG-2. That of Chairmen of National Committees for the Americas Plate (Rio de Janeiro, March, 1973) was especially important in that it prepared the conference and meetings in Lima by proposing seven subjects of particular concern.

During the Mexico AAAS (1973) meeting, several papers on the geodynamics of South America were presented, mainly relating to the Coco's Plate.

Caribbean studies were presented in subsequent meetings (Caracas, September 1975; Tegucigalpa, June 1974; Guadeloupe, June-July 1974); reviewing and planning further studies went on in Kingston, Jamaica during the IDOE Workshop (February 1975).

A large part of the Lima Conference on Geodynamics was devoted to the Nazca Plate.

Several meetings of informal nature gave real substance to the existence of the Study Groups on the Scotia Arc in Santiago, Chile, September 1974, during the IAVCEI General Assembly.

The list could be protracted with the mention of other important events such as A.G.U. meetings, etc.

Activities and Research

Marine research of great interest for the region is carried out mainly by USA institutions and, to a lesser extent, by Canada, Colombia, Argentina, UK, etc. South American countries, in several instances, have collaborated with foreign institution.

Geological and geophysical cruises of higher importance have been carried out to the north of the Juan de Fuca Plate, in the Caribbean, over the Nazca Plate and in the Scotia Arc.

The marine investigations have tended to describe ocean crust and its fractures and in some instances to measure the ocean floor expansion, for instance at the end of the East Pacific Rise, and plate movements, by using relative position determination, as, for instance, between Hawaii and North America, by means of artificial satellites.

Crustal thickness found in the Colombian and Venezuelan basins, of 12 to 15 km. contrasts to the 6 to 8 km. found in larger ocean basins.

On land, conventional geophysical and geological work has resulted in most countries in greatly improved tectonic maps. Tectonics of the Scotia Arc, and the Central Andes are much better understood than heretofore. Some countries have interpreted intensively ERTS imagery.

The Narino project, promoted by the Carnegie Institute of Washington, in southern Colombia and northern Ecuador, has led to the cooperation of several countries and institutions. It was coordinated on land by a member of WG-2, J. Ramirez; the results are being compiled for publication.

In Argentina, the tectonics of the Cordillera Oriental has been especially studied. Further geochronological methods, supervised by E. Linares, are confirming that the NNW-SSE oriented orogenic belts decrease in age from E to W. In Colombia, on the contrary, oldest ages are found in the Central Cordillera, younger in the Western and the youngest in the Eastern Cordillera. Orogenic study of the Western Cordillera is being intensified. Colombians, together with Venezuelan scientists are focusing their work on the Bucaramanga 'triple point' and its seismic activity.

In the central part of South America, the geometry of the subducted Nazca Plate with its fractures and folding has claimed special interest;

clear relations have been found with metallogenesis. Simultaneously, electrical conductivity anomalies have been described, in particular by Ing. M. Casaverde: the anomalies are doubtless related to the subducted plate. Studies of the Coastal Batholith in Peru and that of the Cordillera Real in Bolivia, continue.

Present State of Knowledge

In some areas a systematic study has been made of present-day knowledge: a review of the Caribbean area was prepared for the IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, held in Kingston, Jamaica, February 17-22 1975, and was notably complete. Six papers reviewed singly the following topics:

- bathymetry and sediments
- stratigraphy
- structural geology
- hydrocarbon resources
- tectonic models.

In addition, papers presented to the Tectonophysics Symposium of the G.S.A. in Miami, November 1974, by A. Bellizzia (see report of SG-1 below).

J. Weaver and his colleagues have published a list of researchers active in the Caribbean area, with their addresses and field of interest, under the title: "Status of Geological Research in the Caribbean".

Occasionally geodynamic research is a by-product of economic investigations: such is the work on prediction of volcanic eruptions and evaluation of seismic risk in Trinidad-Tobago under the direction of J. Tomblin. Work includes determination of seismic focal mechanisms, volcanic activity evolution, etc. Geothermal studies in Colombia and Chile give similarly results of interest to geodynamics.

Investigations on the Mexican 'volcanic axis' are being intensified

The Rio de Janeiro meeting of Geodynamics National Committee Chairmen for the Americas Plate, recommended seven major lines of research. With the exception of the first, all points are pertinent to WG-2. Comments on each point are made below:

Point 2: South American Geotraverses, Plate Tectonics and Mountain Building

Little progress has been made on this subject.

Point 3: Geology and Dynamics of Major Shear Zones

Attention has not yet been focused directly on this problem.

Point 4: Comparative Study of Tectonism and Magmatism of Orogenic Belts and associated Platforms

This subject has been studied to a greater extent than Points 2 and 3, but investigations should be intensified.

Point 5: Tectonic Correlations

Considerable progress has been made in some areas.

Point 6: Magmatism and Tectonics

The relationship between magmatism and tectonics, in the light of the plate tectonic theory, has made considerable progress in some areas. Results of the IGCP Circum-Pacific Project contribute to this point.

Point 7: Metallogenesis and Plate Tectonics

Some promising leaders for future previsionsal metallogenesis have been found.

In general, investigations continue slowly and seldom are only geodynamic problems involved. The basic problem of the forces involved in major tectonic processes is seldom broached; one of the few cases when it was attacked was the WG Chairman's introduction to the Lima Conference on Geodynamics. Apparently scientists are as yet unwilling to commit themselves.

The major problem, after lack of funds and resulting lack of organization, is lack of communications throughout most of the WG-2 area.

The field in which most progress has been made is that of tectonics where geological analysis is being assisted by conventional geophysical methods such as seismic refraction, gravity measurements and geomagnetism with happy results.

Problems of Special Interest

Researchers in the eastern Pacific region are faced with a long list of problems which are of either a special nature (a), or more general nature (b).

(a) Structure of an Internal Sea, such as the Caribbean

Facets requiring attention include:

- compilation of a geological-geophysical atlas
- collation of geochemical and geochronological data concerning volcanoes and plutonic rocks in the Caribbean
- the nature of the active zone in Panama: is it a contact between three blocks: Cocos, Caribbean, Panama. Subduction certainly occurs - but in what sense?
- Scotia Arc history and evolution - knowledge would assist in the reconstruction of Gondwanaland (see Appendix I). Subduction in the South Shetland region and its relation to the geochemistry of the lavas, and to the opening of the Bransfield Straights
- Liaison between WG-2 and the IGCP Project: Circum-Pacific Magmatism would be advantageous to both
- Palaeomagnetic studies should be intensified and likewise seismic reflection and refraction work
- etc., etc.

(b) General Problems

- Mineralization as related to tectonic processes
- Tectonic maps

- Increased interest in the subjects outlined in the Rio de Janeiro meeting
- Continental margins and particularly continental platforms
- A method of improving communications between researchers must be found

Report of Study Group 1 of WG-2 on Coco's and Caribbean Plates

Organization

SG-1 on Coco's and Caribbean Plates was appointed by the ICG Bureau during the Lima meetings of the ICG (August 1973). The WG strongly supported and recommended the resolutions made by the Rio de Janeiro 1973 meeting of Chairmen of the Americas Plate.

Following a suggestion from the WG Chairman, R. Cabré, and the ICG President, C.L. Drake, a round-table discussion was chaired in Lima by L. del Castillo G. (Coco's Plate), and A. Bellizzia (Caribbean Plate). The solid earth background of both plates, with specific lines of research in general geology and geophysics, was reviewed. Participants agreed on a seismically and volcanically active area through Mexico and Central America which represents an ideal laboratory for studying various geodynamic phenomena connected to plates. Considering the significance of earthquake phenomena and geothermal energy, mineral deposits and petroleum in the region, scientific and economic studies were recommended. Particular items of the preliminary programmes were as follows:

- (a) improve the seismograph network on the margins of both plates
- (b) integrate geological, geophysical and geochemical studies to determine island arc evolution pertaining to the problems
- (c) establish an exchange visitor programme among Central American and Caribbean researchers.

During the 2nd Latin-American Geological Congress, Caracas, November 1973, it was recommended that a practical means of communication among ICG Committees of the area be established. Later, during the 4th Meeting of Central American Geologists, Tegucigalpa, Honduras, June 1974, a regional Central American Geodynamics Committee was created with the participation of Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama.

Summary of Activities

AAAS-CONACYT Meeting, Mexico City, June 20th - July 4th, 1973

C.L. Drake and C. Lomnitz convened a Geodynamics Symposium on this occasion. Thirty papers on different topics were read in three sessions, chaired by F.F.M. de Almeida, D.C. Tozer and G.P. Woollard. Interesting contributions on the interaction of the Coco's Plate and the Neovolcanic Belt were as follows:

- TOCHER, D.: Tectonic Setting for the 1972 Managua Earthquake
 MATTHIESEN, R.B.: Strong Motion Instrument Data from the Managua Earthquake
 FIEDLER, F.: Some Aspects of the 1972 Managua Earthquake
 DEL VALLE, E.C.: Case Studies of the Managua Earthquake

- HUSID, R.: Collapse of Two-Storey Structures
- ROSENBLUETH, E.: Earthquake Engineering Research in Mexico
- VAIL, P.: Seismic Expressions of Subduction Zones - Eastern Pacific Margin
- BELLIZZIA, C.: Tectonic Interpretation of the Southern Region of the Andes and the Caribbean in the Plate Concept
- NEGENDANK, J.: Some Aspects of the Volcanics of the Valley of Mexico
- SAENZ, R.: Volcano Forecasting in Costa Rica
- WARD, P.: Earth Satellite Volcano Warning Stations in Central America
- STOIBER, R.: Volcanic Gases from Central American Volcanoes
- ROSE, W., Jr.: Volcanic Ash from Central American Volcanoes
- MELSON, W.: The Eruption of Arenal Volcano, Costa Rica
- McBIRNEY, A.: What We Don't Know about Explosive Volcanic Eruptions
- ROBJON, G.: Geothermal Power
- ESPINOZA, H.A.: Geothermal Power in Mexico
- REX, R.: Geothermal Power in the Imperial Valley of California
- BONIS, S.: Explosive Volcanism in Guatemala
- BRUNE, J.N.: Seismology of Tectonics in the Gulf of California Region
- LOPEZ RAMOS, E.: The Paleogeography of Mexico from the Paleozoic to the Quaternary and its Relation with Tectonics
- LOPEZ RAMOS, E.: A Study of the Aftershocks and Intensity of the Managua Earthquake of December 23, 1972
- RODRIGUEZ, R. and MARQUEZ, R.: Quaternary Volcanism, Continental Blocks and Plate Tectonics in Mexico
- LLIBOUTRY, L.: Theoretical Calculation of the 'Absolute' Velocities of Plates
- ESTEVA, L.: Commentary on Seismic Risk Estimation
- GRASES, J.: Historical Seismicity of the Caribbean
- ARTYUSHKOV, F.V., LOMNITZ, C. and MOOSER, F.: Causes of Tensional Tectonics in Continental Margins bordering on Subduction Zones
- FUKAO, Y.: Mechanism of Lithospheric Earthquake and its Tectonic Implications
- SHOR, G.G., RAITH, R.W. and HENRY, M.: Crustal Structure under the Coco's Plate
- DEL CASTILLO, L., MONGES, J. and MENA, M.: Gravity Anomalies under the Mexican Neovolcanic Belts
- WOOLLARD, G.P.: Crust-Mantle Relationships as a Function of Geological Age and Heat Flow from the East Pacific Rise into the Pacific Basin
- HALPERN, M.: Ages of Plutonic Rocks of Southern Chile related to Geochronological Provinces of Southern South America and Plate Tectonics
- Twentieth Annual Meeting of the Pacific Northwest Region, Montana, October 18-19, 1973
- McCAULEY, W.J., HOLMES, M.L. and LEWIS, B.T.R.: Detailed East Pacific Rise Spreading Rates obtained by Stacking Magnetic Anomalies

55th Annual Meeting of the A.G.U., Washington, D.C., April 8-12, 1974

HEEZEN, B.C. and FOX, P.J.: A Proposal for the Evolution of the Caribbean Crust

Penrose Conference on Geological Interpretation of Magnetic Data, Washington D.C., April 14-18, 1974 & First Panamerican Congress of Photogrammetry, Photo-interpretation and Geodesy, Mexico City, 7-12 July, 1974

DEL CASTILLO, L., G.: Relationship between Spectral Analyses in Remote Sensing and Tectonic Pattern on the Western part of the Neo-volcanic Belt

VIIème Conférence Géologique des Caraïbes, Antilles Françaises, 30 Juin - 12 Juillet, 1974

BUTTERLIN, J.: Les Problèmes Soulevés par l'Application de la Tectonique Globale à la Région des Caraïbes

CASE, J.E.: Caribbean Geologic-Tectonic Map

MARTIN, R G.: Gulf of Mexico, Geologic-Tectonic Map

MATTHEWS, J.E. and HOLCOMBE, T.L.: Possible Caribbean Underthrusting of the Greater Antilles along the Muertos Trough

PYLE, T.E. and KRIVOV, H.L.: Structural Studies in the Northwest Caribbean and a Preliminary Bouguer Gravity Map

1974 Annual Meeting of the Mexican Geophysical Union, 4-8 November, 1974

L. del Castillo, G., F. Mooser, M. Halpern, J. Martínez, B. and C. Lomnitz chaired sessions on geodynamics, volcanism, seismicity, exploration and paleomagnetism and geochronology respectively. Papers presented were:

DEL CASTILLO, L., G., et al.: Algunos Aspectos de Geodinamica en la Republica Mexicana

SANDOVAL, H., O., et al.: Tectonofisica en al E.y S. del Continente Mexicano: Interpretacion Preliminar

URRUTIA, J., F., et al.: Resultados Preliminares en la Placa de Cocos: Proyecto Acapulco

LOMNITZ, J. and LOMNITZ, C.: Velocidades sismicas en una Placa Litoférica sometida a esfuerzos Unidireccionales de Larga Duracion

MONGES, J., C. and HANSEN, F., A.,: Gravimetria Submarina en al Golfo de Fonseca, Centroamerica

RODRIGUEZ, R., T.: El Modelo Geodinamico de Mexico aplicado a los Nuevos Conceptos Metalogeneticos del Uranio y su Prospeccion

RODRIGUEZ, R., T., MARQUEZ R. and DIAS, L.: Control Tectonico del Volcanismo Cuaternario Basico del Bloque Continental boreal de Mexico

MAUPOME, L., TAPIA, M., CANTO, J. and ROSADO, M.: Origen de los Jalapascos del Estado de Puebla: Impacto o Volcanismo

ALVAREZ, R.: Un Nuevo Mecanismo de Magnetizacion Lunar

DEL RIO, L., L. and ALVAREZ, R.: Radiacion Solar y Conduccion Eletrica en la Luna

DE LA CRUZ, S. and ACOSTA, J.L.: Conveccion Generada en Capas Fluidas Horizontales por Calentamiento Interno Inhomogeneo

- TOZER, D.C.: A New Interpretation of Low Q, Low Velocity Layers in the Planet
- HAMMER, S.: The Energy Crisis and Geophysics: a Challenge
- VALDEZ-MENDOZA, F.: Elementos Radioactivos Naturales: Observaciones Acerca del Uso de la Gamametría como Metodo de Exploración Geofísica
- RODRIGUEZ, R., T., MARQUEZ, R., C., DIAZ, R., L. and BARCENA, R., y L.: Inferencia de Unidades Litológicas a partir de Aereo-Radiometría Numérica en el Área de 'La Laguna', Edo de Coahuila
- TEJERA, A., R., et al.: Metodo de Exploración Uranífera Mediante Radon
- TEJERA, A., R., et al.: Correcciones y Procesado de Datos Radiométricos
- RUIZ, J.A., et al.: La Magnetometría en la Exploración del Uranio
- ALVAREZ, R., B., et al.: Aeromagnetometría como Discriminador de Cráteres de Impacto, Maars y Conos Volcánicos
- GALVAN DE DEL RIO, N. and ALVAREZ, R., B.: Resistividad Eléctrica en Carbon y Grafito
- CARRILLO, R., C., et al.: Experimentos con el Nuevo Desmagnetizador de Corriente Alterna
- HERRERO, E., B. and PAL, S.: Algunos Estudios Paleomagnéticos en el Estado de Zacatecas, Zac. Mexico
- HALPERN, M., GUERRERO, J., G. and RUIZ, M., C.: Rb-Sr Dates of Igneous and Metamorphic Rocks from Southeastern and Central Mexico: a Progress Report
- PAYO, G.: Magnitude of Iberian Region Earthquakes from Lg Phase
- REYES, A., BRUNE, J.N. and LOMNITZ, C.: Aftershocks and Source Mechanism of the Colima Earthquake
- REYES, A. et al.: A Microearthquake Survey of the San Miguel Fault, Baja California, Mexico
- LOMNITZ, C.: El Experimento Oaxaca: Resultados Preliminares
- MOOSER, F.: Presentación del Nuevo Mapa Geológico del Valle de México
- FIGUEROA, J.A.: La Sismicidad en la Cuenca del Valle de México
- ESTEVA, L.: Geología y probabilidades en la Evaluación de Riesgo Sísmico
- SABINA, F.J. and WILLIS, J.R.: Difracción de Ondas Sh por Irregularidades Topográficas de Pendiente Arbitraria en un Semiespacio
- KRISHNA, S.S. and SABINA, F.J.: Deformación de la Región Epicentral Basada en un Modelo de 'Dilatancia' y Difusión de Fluidos
-
- Symposium on the Caribbean Geology and its Tectonic Evolution, G.S.A., Miami, 18-20 November, 1974
-
- TERENCE, E.N.: Caribbean Geological and Geophysical Framework
- CARL, B.: Gravity Field of Caribbean Region
- BANKS, P.O.: Pre-Mesozoic Rocks of the Caribbean Region
- FOX P.: The Geology of the Caribbean Crust - Review of Drilling and Dredging Results
- HOLCOMBE, T.L.: Late Cretaceous and Cenozoic Sedimentary Strata of the Caribbean
- HAY, W.W.: Stratigraphy and Biostratigraphy of Deep Caribbean Basins
- DONNELLY, T.W.: Mesozoic and Cenozoic Volcanic History of the Caribbean

GUILD, Ph. W.: Mineral Resources of the Caribbean Region
 MEYERHOFF, A.A.: Petroleum Resources of the Caribbean Area
 TOMBLIN, J.F.: Seismicity of the Caribbean Region
 MATTHEWS, J.E.: The Geomagnetic Field of the Caribbean Sea
 CARR, M.J.: Tectonics of the Western Margin of the Caribbean Plate
 PETER, G.: Tectonic Evolution of the Eastern Margin of the Caribbean Region
 BALL, M.M.: The Caribbean - a Zone of Extension and Shear
 BLOOMER, G.: Paleogeographic Evolution of the Caribbean
 SILVER, E.A.: Late Cenozoic Plate Tectonics of the Caribbean Region
 MEYERHOFF, A.A.: The Caribbean Plate
 ITURRAL DE VINENT, M.A.: Problems of Application of Modern Tectonic Hypotheses to the Cuban-Caribbean Region
 KHUDOLEY, K.M.: Origin of the Caribbean Region and Adjoining Areas

Fall Annual Meeting, A.G.U., San Francisco, 12-17 December, 1974

GUERRERO, J. and HELSLEY, C.E.: Palaeomagnetic Evidence for Post-Jurassic Tectonic Stability of Southeastern Mexico
 ORCUTT, J. et al.: A Seismic Refraction Survey of the East Pacific Rise, using Ocean Bottom Seismographs
 WADE, U.S. et al.: Structure near Malpelo Ridge from Seismic Refraction Results
 DORMAN, L.M.: Fracture Zones: the Gravitational Edge Effect and the Inverse Potential Problem
 IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February, 1975

Three *ad hoc* groups discussed: geophysics and tectonics, stratigraphy and sediments, petrology and metallogenesis. Representatives from twenty Caribbean countries attended.

Studies on the Coco's Plate in progress are as follows:

SNYDSMAN, W.E. and LEWIS, B.T.R.: 1975 - Upper Mantle Velocities on the Northern Coco's Plate, in revision
 LEWIS, B.T.R., LYM, W.S. and SNYDSMAN, W.E.: 1975: Magnetic Anomaly fanning on the Northern Coco's Plate, in revision

Research

Study Group 1 considered three main lines of research:

1. Volcanic Belt and its relationship to a triple junction in the Pacific
2. Interaction between the Gulf of Mexico and the Caribbean Plate
3. Coco's Plate: its influence on the Mexican Continent and the coastal Pacific area.

No annual grants are made specifically for the scientific research funds come from those granted by Universities. Cooperative efforts were made

between the Universidad Nacional Autonoma de Mexico (Instituto de Geofisica, Dept. de Exploracion y Sismologia) and the Universities of Washington at Seattle, California at San Diego, Wisconsin at Madison, Texas at Dallas and Hawaii at Honolulu. Three projects were carried out:

- Volcanic Belt Project,
- Oaxaca Project
- Acapulco Project

which involved deep crustal seismic studies along the subduction zone of the Coco's Plate, geophysical marine tracks along the Pacific Mexican coastal area, and heat flow, ground gravity, magnetic, tectonic and petrological studies along the Mexican Neovolcanic Belt. Also paleomagnetic and geochronological studies were emphasized in Southern and Central Mexico.

The Study Group has concluded that research carried out in 1974 would probably be the most important part of the proposed research. The plate tectonic and other crustal models will be tested in a geodynamic approach and a solution will be sought. The work now in progress for two years has given some results and papers have been read to topical international meetings and will be published in current journals after the third year of collection, reduction and analysis of data.

The Coco's Plate offers an excellent opportunity to study trench and subduction zones. Also, the project is aimed at investigations of the structural relations to geothermal mechanisms and ore deposits, on land and off-shore in a triple junction problem. Theoretical work consists of a direct approach to the time-term approach to the interpretation of refraction and potential field data. Sea floor spreading rates and modelling has been done on the basis of bathymetry, gravity and magnetic data. Heat flow measurements were obtained along a line between the Neovolcanic Belt and Acapulco zone in collaboration with the Methodist University of Southern Texas and the Comision Federal de Electricidad.

Extensive seminars and discussions on several topics were carried out at the Instituto de Geofisica in Mexico City with the participation of: R. Mayer, L. del Castillo G., C. Helsley, C. Lomnitz, J. Brune, V. Arana, J. Monges, P. Blackwell, F. Mooser, R. Dietz, E. Artyushkov, I. Yokoyama, D. Husson, S.K. Singh, R. Dominguez, A. Reyes Z., F. Sabina, G.T. Nixon, R. Alvarez, D.C. Tozer, J.H. Sandoval, R. Gay, C. Diaz, E. Berg, A. Cominguez, F. Morrison, R. Carrillo, C. Savit, R. Rodriguez, S. Treitel, E. Lopez R., L. Kunar, S. de la Cruz, R. Bilham, J. Guerrero, M. Bottacini, M. Halpern, J. de Mooyer, S. Pal, E. Faccioli, E. Herrero and D. Terrel from the Instituto Geofisico, U.N.A.M., Mexican Institutions and Universities and organizations from the U.S.A., England, Spain, Canada, U.S.S.R., Italy, West Indies, Japan, Central and South American countries.

The Mexican telemetric seismic network, called RESMAC, is under development with the active collaboration of several Mexican agencies and the Instituto de Geofisica and CIMAS, both at the U.N.A.M. Other Latin-American countries and the U.S.A. have shown great interest in participating.

L. del Castillo, G. (Chairman SG-1)

Report on the Caribbean Region (J. Weaver)

The fact that it is virtually impossible to formulate a concise and coherent report on the geological and geophysical investigations in the Caribbean Region (which are very numerous), during the first half of the Geodynamics Project underlines the almost complete lack of coordination between the projects that have been and are being conducted in the region and particularly lack of coordination with the various countries involved. The Institute of Caribbean Science of the University of Puerto Rico has attempted at least to keep interested institutions and individuals informed as to what is being done by publishing the 'Status of Geological Research in the Caribbean'. The information is not by any means exhaustive since undoubtedly many individual workers have not been approached for information on their work, and a number who have been approached have not responded.

In an endeavour to improve coordination of effort, the Institute has organized a series of working groups based on the broad spectrum of problems of Caribbean geology and attempted to involve all workers concerned with the problems. Funds are being sought to enable these groups to meet and to formulate programmes which would then be submitted to appropriate funding agencies. The workers are enthusiastic - funds are needed.

As regards specific work in the Institution:

A.L. Smith and J. Roobol have been making a stratigraphic and petrologic study of Mt. Pelée and B. Gunn made geochemical investigations of rocks from several West Indian volcanoes. Six papers are published or in press and others are pending.

Smith, Weaver, Pannella and Seiglie are involved in studies of the Mona Passage and the neighbouring areas in Puerto Rico and Dominican Republic. Preliminary papers are in preparation. Seiglie and Moussa are continuing studies of mid-Tertiary biostratigraphy and paleoecology in Puerto Rico.

Information from Study Group 'Scotia Arc'

The Scotia Arc S.G. offered to organize a Symposium on the evolution of the Arc at the SCAR meeting in Madison, 1977. The steering committee has welcomed the proposal. The topic is an ideal inter-face for the interests of SCAR and ICG. Further intense field work on land and marine programmes planned into 1976 make the summer of 1977 an ideal time for a review of the evolution of the Arc. Tentatively, a one-day's programme is proposed, to integrate rather than separate different approaches. Thus, rather than separating presentations on marine geophysics, geochemistry and structural geology, a format is proposed based on the evolution of the Arc through time: this might begin with a geologic analysis of the Paleozoic basement of the Arc, continue with the petrology and geochemistry of the Mesozoic volcanic rocks and ophiolites, proceed to marine geophysical studies bearing on the Cenozoic spreading history of the Scotia Sea and finish with seismicity and volcanology relating to Recent and present-day plate motions.

Contributions from workers in Argentina, Australia, Chile, France, New Zealand, U.K. and the U.S.S.R. and other will be solicited, as many countries have researchers in the region.

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Geodynamics Project

U.S. Progress Report-1977



U. S. Geodynamics Committee

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Washington, D.C.

1977

11

GEODYNAMIC ACTIVITIES IN THE CARIBBEAN AREA

JOHN D. WEAVER

The tectonic and bathymetric maps of the Caribbean at 1:2,500,000 by J. Case (USGS) and T. Holcombe (U.S. Naval Oceanographic Office) are now completed and in course of publication.

The Puerto Rico seismic network has continued operation. Some interesting results are a possible southward-dipping Benioff zone under the Puerto Rico Trench and Puerto Rico. The Mona Canyon continues to be the most active, though anomalously high activity is found in the southwest of the island. A line of events heading NE from the NE corner of Puerto Rico suggests a hitherto unnoted fault.

In volcanology, Smith and Roobol (University of Puerto Rico) continued their studies of alternating sequences of eruptive styles in Mt. Pelee and Statia and hope to carry out similar studies on other West Indian volcanoes. This work should be of considerable value in prediction of volcanic hazards. The continued eruption of the Soufriere in Guadeloupe gave a team from Los Alamos Scientific Laboratory an opportunity to study various aspects of its eruptive activity. H. Sigurdson (University of Rhode Island) is studying tephrochronology in cores taken close to volcanic islands.

A Department of Geology and Mining has been started at the Universidad Catolica Madre y Maestra in Santiago, Dominican Republic, with substantial aid from the United Kingdom. J. Lewis (George Washington University) has spent his sabbatical year there and continues study of the structure and plutonic rocks of the western part of the Republic.

J. Watkins (University of Texas), A. Bellizzia (Venezuela), J. Galavis (Venezuela), J. Saunders (Natural History Museum, Basel), and J. Weaver (University of Puerto Rico) are compiling three N-S geological and geophysical profiles from the Outer Ridge of the Puerto Rico Trench, through eastern Dominican Republic, western Puerto Rico, and the Virgin Islands, across the Venezuela Basin and into the Venezuela mainland (Figure 11.1). A preliminary draft was displayed at the Caribbean Geological Conference in Curacao in July 1977 (see below).

In July 1976, the Caribbean Study Group of Working Group 2 met in Mayaguez, Puerto Rico. Six critical problems and/or areas were agreed upon as foci of future coordinated efforts. These were:

- (a) The four corners or "hinge" areas of the region, beginning with the SE (Barbados)
- (b) Hispaniola

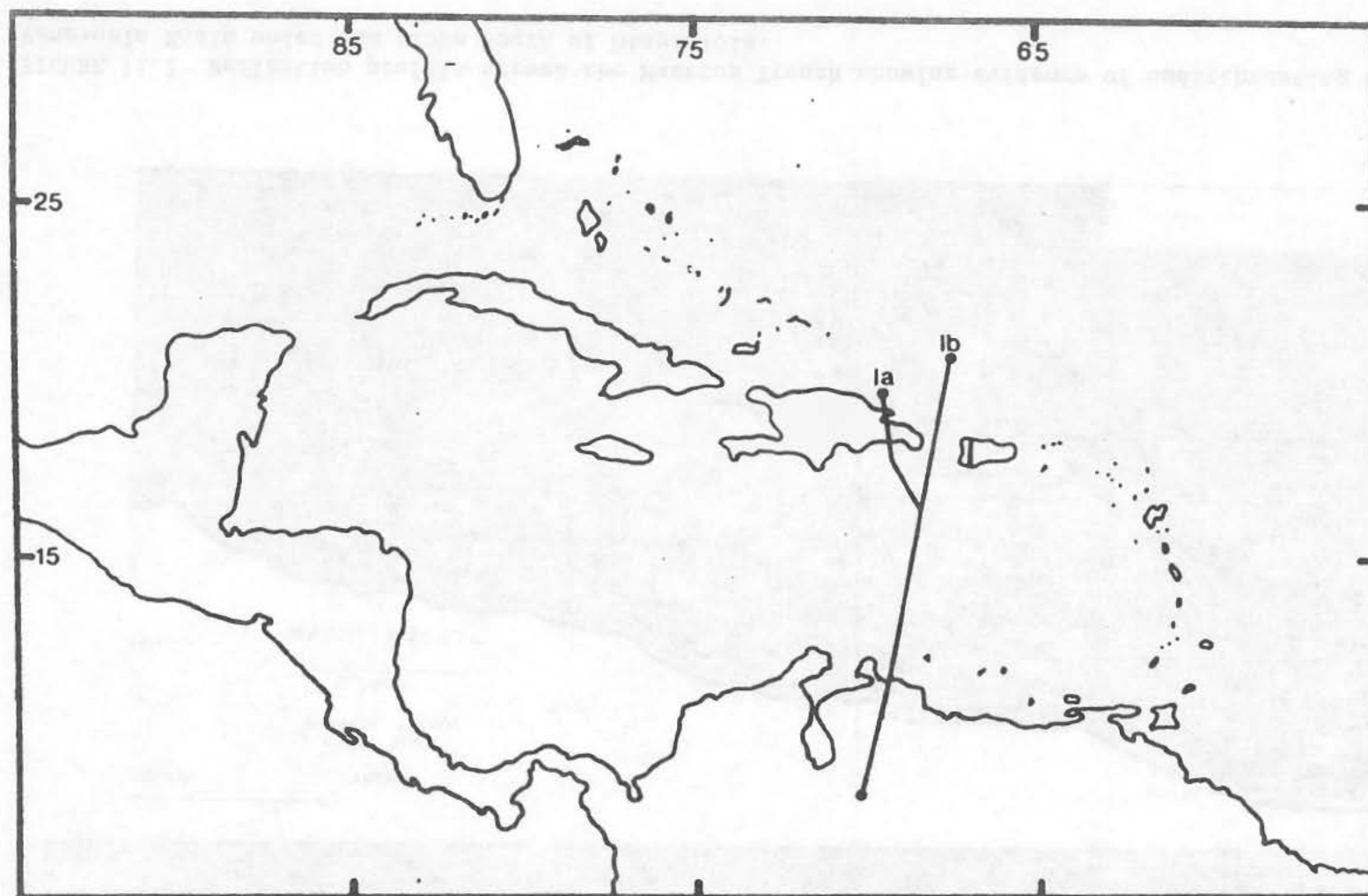


FIGURE 11.1 Location of preliminary cross section presented at the 8th Caribbean Geological Congress, July 1977.

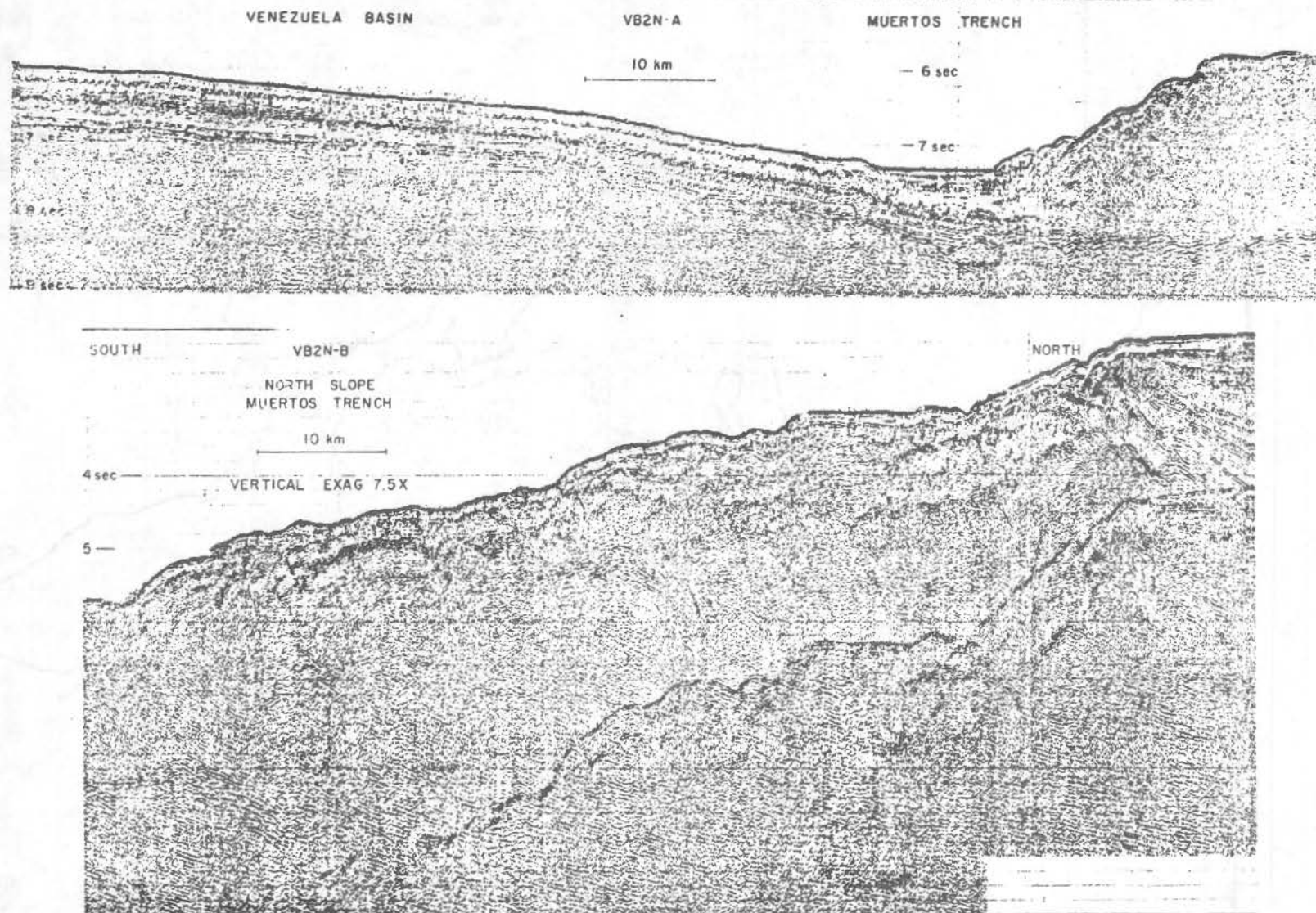


FIGURE 11.2 Reflection profile across the Muertos Trench showing evidence of underthrusting of the Venezuela Basin under the slope south of Hispaniola.

- (c) Exposed "basement" areas
- (d) Recent crustal movements and seismicity
- (e) Metallogenesis related to tectonics and petrology
- (f) Volcanic activity

In April 1977, a Caribbean Workshop was held at SUNY, Albany, organized by K. Burke and P.J. Fox and funded by the National Science Foundation. Its recommendations followed quite closely those of the Caribbean Study Group, though emphasis was placed more strongly on land studies. It was noted that there is a serious lack of workers interested in carrying out studies on land involving mapping.

The suggested possibility of oil in the northern shelf of Puerto Rico and imminent drilling by Venezuelans in eastern Dominican Republic may encourage interest in geology and geophysics locally.

The following report on the Caribbean cross section was provided by Joel Watkins.

Geological-Geophysical Section across the Caribbean

At the 8th Caribbean Geological Conference in Curacao, 9-24 July 1977, the Caribbean Study Group (of ICG Working Group 2) presented a preliminary version of Section 1 from the outer high north of the Puerto Rico Trench to the interior of Venezuela. The section was drawn on a scale of 1:250,000 with no vertical exaggeration.

John Weaver of the University of Puerto Rico contributed sections through Puerto Rico and Hispaniola based on published geology and geophysics of the region. John Saunders of the Natural History Museum in Basel, Switzerland, contributed a section across the coastal ranges and continental margin of Venezuela northward to Curacao. Dirk Beets of the Geology Institute in Amsterdam, the Netherlands, contributed a section across Curacao incorporating the results of his latest mapping. John Ladd of the University of Texas Marine Science Institute (MSI) contributed a section from the outer high north of the Puerto Rico Trench to the island of Curacao using published geophysical information and multichannel data collected by MSI. The display at the Caribbean conference included examples of multichannel data along the line of section (Figure 11.2) as well as data connecting the section to John Weaver's Hispaniola section.

The contributors at the Caribbean Conference felt that the display was only a preliminary attempt since it is hoped that scientists from Venezuela will contribute more detailed information to a Venezuela section and that Lamont will contribute data from their Caribbean work. The contributors plan to display their sections again at the Latin American Geological Congress in Caracas in November 1977.

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Catalogue of Satellite Photography of the Active Volcanoes of the World

by

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CATALOGUE OF SATELLITE PHOTOGRAPHY OF THE ACTIVE VOLCANOES OF THE WORLD

by

Grant Heiken

I. INTRODUCTION

Satellite photography has proven to be useful in volcanology for purposes of geologic mapping and observation of eruptions. With an ever increasing number of earth resources and weather satellites being placed into earth orbit, there is a possibility that continual monitoring of volcanic eruptions may be possible within the next few decades. At present, there is photography of nearly every volcano in the world. This imagery is particularly useful for the regional study of volcanic fields or reconnaissance mapping of inaccessible areas.

This catalogue is of photographs, which have been screened for quality, selected from the earth resources technology satellite (ERTS, recently renamed LANDSAT), Skylab imagery systems and hand-held photography from Gemini and Apollo missions. All of the photography and imagery, collected by the National Aeronautics and Space Administration (NASA), is within the public domain; anyone may purchase the imagery listed here.

II. ANNOTATION AND FORMAT

The catalogue is arranged geographically. The descriptions include the image number, comments on quality of the image and the type of film.

A. ERTS (Landsat)

The ERTS-1 Spacecraft was launched on July 23, 1972. During the first seven months of operation, scenes of 75 percent of the world land areas were acquired. The ERTS-1 spacecraft was renamed Landsat-1 and the Landsat-2 was launched on January 22, 1975. Like its meteorological predecessors it was placed into a Sun-synchronous

orbit. This orbit is such that the spacecraft passes over each point of the earth at the same local time each day and the ground tracks repeat every 18 days. The Landsat spacecraft have two imagery sensors, the RBV (return beam vidicon) and the MSS (multispectral scanner). Most of the imagery is from the MSSs; the RBVs were turned off due to electrical problems (David Pitts, NASA-Johnson Space Center, personal communication, July 1975). ERTS images cover an area approximately 185 x 185 km. The resolution for the MSS is a function of contrast and was found to vary from 60 m for high contrast to greater than 100 m for low contrast targets.

The bands from the RBV include the following.

| Spectral Bands | Wavelength (μ m) |
|-------------------|--------------------------|
| 1 | 0.475-0.575 |
| 2 | 0.580-0.680 |
| 3 | 0.690-0.830 |

The bands from the MSS include

| Spectral Bands | Wavelength (μ m) | Color |
|-------------------|--------------------------|------------|
| 4 | 0.5-0.6 | green |
| 5 | 0.6-0.7 | red (dark) |
| 6 | 0.7-0.8 | infrared |
| 7 | 0.8-1.1 | infrared |

The most common bands used for geologic purposes are MSS-5 and -6. All bands are available as black and white images or combined as false-color composites at a very reasonable price. Magnetic tape is available at considerable cost, for each image, for computer image processing.

ERTS photograph numbers (observation identification) begin with a four-digit number referring to the days since launch and satellite number of the spacecraft, a five-digit number referring to the time of day, and a single-digit number referring to the spectral band. An example of an ERTS identification number would be 1210-15503-6. It should be used when ordering an image.

Black and white transparencies of each band are available with image sizes of 5.58 cm (2.2 in.) (film positive or negative), 18.54 cm (7.3 in.) (film positive, negative, or paper print) and as 37-cm (14.6-in) or 74-cm (29.2-in) paper prints. I have found that 18.54-cm x 18.54-cm film negatives are the most versatile form of imagery for geologic purposes. If you have access to a photographic laboratory, you are free to make prints of any size or contrast. Prints of excellent quality are available if you have no means of printing your own photographs.

False-color composites are available as 18.54-cm x 18.4-cm positive transparencies and paper prints and as 74-cm x 74-cm paper prints.

B. Apollo Missions

A number of handheld 35-mm and 70-mm photographs were taken from earth orbit by Apollo crews. Photograph numbers consist of a mission prefix and number. An example of Apollo 9 photography would be: AS9-19-3019.

C. Gemini Missions

Some photographs were taken of the earth's surface by Gemini crews. The photograph numbers have an "S" prefix, an example being S-65-63150.

D. Skylab

Among the experiments carried out in the first manned earth-orbiting laboratory were several imagery systems in addition to handheld 70-mm and 35-mm cameras. The Skylab sensors include the following.

1. S-190A - Multispectral Camera with six 15.24 cm lenses and 70 mm film format. All

shutters operate simultaneously to provide individual images of the same scene in different spectral bands. The field of view is 21.2° with a surface coverage of 162 x 162 km.

| Station | Band Width(μm) | Spectrum Range | Film |
|---------|----------------|-----------------|--------------------|
| 1 | 0.7-0.8 | infrared | B&W IR-EK2424 |
| 2 | 0.8-0.9 | infrared | B&W IR-EK2424 |
| 3 | 0.5-0.88 | green,red, | IR-127 |
| 4 | 0.4-0.7 | blue,green, red | Color-S0356 |
| 5 | 0.6-0.7 | red | B&W Pan X S0022 |
| 6 | 0.5-0.6 | green | B&W Pan X S0022 |

2. S-190B - Earth Terrain Camera with one 45.7-cm focal length lens and 12.7-cm film format. The surface coverage is 190 x 190 km. This system generally duplicates a portion of the imagery from the 190A system.

| Band Width(μm) | Spectrum Range | Film |
|----------------|----------------|-----------------|
| 0.4-0.7 | blue,green,red | Color S0242 |
| 0.5-0.7 | green,red | B&W ED3414 |
| 0.5-0.88 | green,red,IR | Color IR-EK3443 |

Skylab photography is designated by an "SL" prefix. The first number (for example, SL-4-) designates the particular mission. An example of this would be SL-4-8004.

III. HOW TO ORDER IMAGERY

All NASA imagery such as that collected by ERTS, Skylab, Gemini, and Apollo may be purchased at the following location.

EROS Data Center
Sioux Falls, South Dakota
57198 (U.S.A.)

Some of this imagery for the Southwestern United States and collection of 35-mm transparencies are available at

The Technology Application Center
University of New Mexico
Code 3
Albuquerque, NM 87106 (U.S.A.).

Many of the world's volcanoes are not in this listing (Appendix) due to nearly constant cloud cover. If what you need is not here, please contact user services at the EROS Data Center. As spacecraft continue to collect data, your area of interest may be imaged eventually. If you send the latitude and longitude of the area to the EROS Data Center, with a request for an updated listing, they will send you the most recent computer listing of images for that area.

IV. ACKNOWLEDGMENTS

This compilation was made both at the NASA-Johnson Space Center, Houston, Texas, and at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico. I wish to thank the photographic laboratories at both places for processing all of the prints used for evaluation of image quality.

APPENDIX
CATALOGUE LISTING

| <u>VOLCANO IDENTIFICATION</u> | <u>IMAGE NUMBER</u> | <u>COMMENTS</u> |
|--------------------------------|---------------------|-----------------|
| INDONESIA | | |
| Sumatra | | |
| Belirang-Balak Caldera | ERTS 1108-02433 | |
| | ERTS 1325-02484 | |
| | ERTS 1054-02425 | |
| Bukit Daun | ERTS 1325-02984 | |
| Bukit Lumut Balai | ERTS 1108-02433 | |
| | ERTS 1451-02465 | good |
| Bur ni Geureudong | ERTS 1114-03153 | |
| Bur ni Telong | ERTS 1114-03153 | |
| Dempo | ERTS 1451-02465 | |
| | ERTS 1325-02491 | best |
| Gajolestan (Solfatara field) | ERTS 1168-03151 | cloudy |
| | ERTS 1114-03153 | |
| Hulubelo Caldera | ERTS 1054-02431 | |
| | ERTS 1449-02355 | |
| Kaba | ERTS 1451-02465 | |
| | ERTS 1325-02491 | good |
| | ERTS 1325-02484 | good |
| Kerentji | ERTS 1057-02591 | |
| Krakatau, Sunda Straits | ERTS 1449-02355 | |
| Kunjit | ERTS 1326-02543 | cloudy |
| Marga Bajur, (Solfatara field) | ERTS 1108-02433 | |
| Merapi | ERTS 1094-03050 | cloudy |
| Pematang Batu, Sumatra | ERTS 1054-02425 | |
| Radjabassa | ERTS 1449-02355 | |
| Sorikmarapi | ERTS 1094-03050 | cloudy |
| | ERTS 1418-03032 | cloudy |
| Sumbing | ERTS 1326-02543 | cloudy |
| Talakmau | ERTS 1094-03050 | cloudy |

| <u>VOLCANO IDENTIFICATION</u> | <u>IMAGE NUMBER</u> | <u>COMMENTS</u> |
|---------------------------------------|---------------------|---------------------------------|
| Vsevidof Volcano | SL 4-140-4112 | 70-mm, color, oblique |
| | SL 4-140-4111 | 70-mm, color, oblique |
| British Columbia | | |
| Mt. Edziza | ERTS 1591-19160 | |
| | ERTS 1789-19100 | |
| Cascade Range | | |
| Mt. Adams, WA | SL 3-124-2727 | Sl. oblique, 35-mm, color |
| | SL 4-192-7081 | 35-mm, color, oblique |
| | ERTS 1005-18260 | |
| Mt. Baker, WA | ERTS 1204-18321 | |
| | ERTS 5139-17590 | best |
| Crater of the Moon, ID | ERTS 1053-17524 | |
| Mt. Hood | SL 3-124-2726 | 35-mm, sl. oblique, color |
| | SL 3-19-309 | S 190A, B&W, superb |
| Mt. Jefferson | SL 3-19-309 | S190A, excellent |
| | SL 3-19-310 | S190A, excellent |
| Mt. Lassen, CA | SL 3-25-053 | S190A |
| | SL 3-25-054 | S190A |
| | SL 2-5-465 | 70-mm, color, slight oblique |
| | ERTS 1130-18230 | |
| | ERTS 1291-18173 | |
| Lava Beds National Monument, CA | ERTS 1184-18222 | |
| Medicine Lake Highlands, CA | ERTS 1184-18222 | |
| Newberry Caldera | SL 3-19-310 | S190A, excellent |
| | SL 3-19-311 | S190A, excellent |
| Mt. Rainier, WA | SL 3-124-2726 | oblique, 35-mm, color |
| | ERTS 1005-18260 | |
| Mt. St. Helens, WA | SL 4-192-7081 | 35-mm, color |
| | ERTS 1003-18260 | |
| Mt. Shasta, CA | SL 3-25-053 | B&W, S190A, vertical, excellent |
| | SL 2-5-465 | 70-mm, color |
| | ERTS 1184-18222 | |
| Three Sisters | SL 3-19-309 | excellent, S190A |
| | SL 3-19-310 | excellent, S190A |
| CENTRAL AMERICA AND MEXICO | | |
| Northern Mexico | | |
| Pinacates, Sonora | SL 65-34675 | Gemini, color, 70-mm |
| Volcan de las Tres Virgenes (Baja CA) | ERTS 1264-17295 | |
| Central Mexico | | |
| Volcan Ceboruco | ERTS 1078-16560 | |

| <u>VOLCANO IDENTIFICATION</u> | <u>IMAGE NUMBER</u> | <u>COMMENTS</u> |
|----------------------------------|---|--|
| Colima, Est. de Jalisco | ERTS 1203-16513 SL 4-199-7574 | color, 35-mm, near vertical, cloudless |
| Ixtaccihuatl | ERTS 1203-16512 SL 4-200-7619 SL 4-200-7620 SL 4-207-8056 SL 4-139-4062 | color, 35-mm color, 35-mm 35-mm, excellent 70-mm, color, stereo |
| Jorullo | ERTS 1181-16284 ERTS 1163-16284 ERTS 1255-16404 | |
| La Malinche | SL 4-200-7621 ERTS 1163-16284 | 35-mm, color (out of focus) |
| Nauchampapetl (N. of Orizaba) | ERTS 1180-16225 | |
| Paricutin, Est. de Michoacan | SL 4-199-7574 ERTS 1184-16452 | color, 35-mm, tentative identification |
| Pico de Orizaba | SL 4-200-7622 SL 4-139-4064 ERTS 1180-16225 | 35-mm, color 70-mm, color |
| Popocatepetl | SL 4-200-7619 SL 4-200-7620 SL 4-207-8056 SL 4-139-4062 to 4064 ERTS 1181-16284 AS-9-19-3012 | partial stereo, color, 35-mm, whole ridge partial stereo, color, 35-mm, whole ridge 35-mm, excellent, slight oblique stereo, vert., 70-mm, color Apollo 9, excellent |
| Volcan de San Martin Xitli | ERTS 1197-16172 ERTS 1074-16332 | |
| Guatemala | | |
| Agua | SL 3-25-078 SL 3-25-079 ERTS 1247-15560 SL 4-202-7746 SL 4-201-7667 SL 4-89-290 to 292 SL 4-4B-111 | stereo, S190A stereo, S190A color, 35-mm color, 35-mm stereo pair color, S190, excellent |

VOLCANO IDENTIFICATIONIMAGE NUMBERCOMMENTS

Acatenango

SL 3-25-078

B&W, S190A, partly cloudy

SL 3-25-079

B&W, S190A, partly cloudy

ERTS 1247-15560

SL 4-202-7746

35-mm, oblique

SL 4-201-7667

35-mm, vert.

SL 4-290-292

excellent, stereo

SL 4-4B-111

color, S190, excellent

Atitlan

SL 3-25-077

stereo, S190A, excellent

SL 3-25-078

stereo, S190A, excellent

ERTS 1274-15560

SL 4-202-7746

35-mm, oblique

SL 4-201-7667

35-mm, oblique

SL 4-4B-111

S190, color, oblique

Fuego

SL 3-25-078

B&W, S190A, partly cloudy
stereo

SL 3-25-079

B&W, S190A, partly cloudy,
stereo

ERTS 1247-15560

SL 4-202-7746

35-mm, oblique

SL 4-201-7667

35-mm, oblique

SL 4-89-290 to
292

S190, stereo

SL 4-4B-111

color, S190, excellent

Pacaya

SL 3-25-078 to
079B&W, S190A, partly
cloudy, stereoSL 4-89-290 to
292

S190, stereo

SL 4-4B-111

color, S190, excellent

Cerro Quemado

SL 3-25-076 to
078S190A, partly cloudy,
stereo

ERTS 1247-15560

SL 4-202-7746

35-mm, color, fume

Santa Maria-Santaguito

SL 3-25-076 to
077

good

ERTS 1247-15560

SL 4-202-7746

35-mm, color

Tacana

SL 3-25-075 to
077exact location not
identified, B&W, S190A,
partly cloudy, stereo

SL 4-202-7746

35-mm, oblique

Tajumulco

SL 3-25-075 to
077exact location not
identified, S190A, partly
cloudy, stereo

SL 4-202-7746

35-mm, oblique

Tecuamburro

ERTS 1210-15500

tentative identification

Toliman

ERTS 1247-15560

SL 4-4B-111

color, S190, excellent

| <u>VOLCANO IDENTIFICATION</u> | <u>IMAGE NUMBER</u> | <u>COMMENTS</u> |
|--|---------------------|--------------------------------|
| Zunil | ERTS 1247-15560 | |
| El Salvador | | |
| Coatepeque | ERTS 1210-15503 | |
| | ERTS 1210-15500 | |
| | SL 4-201-7670 | 35-mm |
| Conchagua | ERTS 1209-15444 | |
| Conchaguita | ERTS 1209-15444 | |
| Lake Ilopango and Islas | | |
| Quemadao | ERTS 1120-15502 | |
| | ERTS 1210-15503 | |
| | ERTS 1210-15500 | |
| | SL 4-201-7670 | 35-mm, vert. |
| | ERTS 1209-15444 | |
| Izalco | ERTS 1210-15503 | |
| | ERTS 1210-15500 | |
| San Marcelino | ERTS 1210-15500 | |
| | ERTS 1210-15503 | |
| San Miguel | SL 4-201-7670 | 35-mm, color |
| | ERTS 1209-15444 | |
| San Salvador | ERTS 1210-15500 | |
| | ERTS 1210-15503 | |
| Volcano San Vicente | ERTS 1120-15502 | partly cloudy |
| | ERTS 1210-15503 | |
| | ERTS 1209-15444 | |
| Volcano Santa Ana | ERTS 1210-15503 | |
| | ERTS 1210-15500 | |
| Tecapa | ERTS 1209-15444 | |
| Nicaragua | | |
| Chichigalpa | ERTS 1190-15384 | cloudy |
| | ERTS 1154-15385 | excellent |
| | SL 4-201-7671 | 35-mm, oblique |
| Concepcion | SL 3-121-2430 | 70-mm color (partly cloudy) |
| | ERTS-1243-15335 | |
| Coseguina | ERTS 1190-15384 | |
| | ERTS 1154-15385 | excellent |
| | SL 4-201-7671 | 35-mm, oblique |
| | SL 4-200-7627 | 35-mm, oblique |
| | ERTS 1209-15444 | |
| Hervaderos de S. Jacinto and Tisato | ERTS 1154-15385 | excellent |
| Masaya | SL 3-121-2430 | 70-mm, color, hazy |
| | ERTS 1243-15335 | |
| Mombacho | SL 3-121-2430 | 70-mm, color, partly cloudy |
| | ERTS 1243-15335 | |

| <u>VOLCANO IDENTIFICATION</u> | <u>IMAGE NUMBER</u> | <u>COMMENTS</u> |
|-------------------------------|---------------------|---|
| Momotombo | SL 3-121-2430 | 70-mm, color, hazy |
| | ERTS 1154-15385 | excellent |
| | SL 4-201-7671 | 35-mm, oblique |
| | ERTS 1243-15335 | |
| Cerro Negro | ERTS 1154-15385 | excellent |
| Las Pilas | ERTS 1154-15385 | excellent |
| | SL 4-201-7671 | 35-mm, oblique |
| Santa Clara | ERTS 1154-15385 | excellent |
| Telica | ERTS 1154-15385 | excellent |
| | SL 4-201-7671 | 35-mm, oblique |
| El Viejo | ERTS 1190-15384 | cloudy |
| | ERTS 1154-15385 | excellent |
| | SL 4-201-7671 | 35-mm, oblique |
| Costa Rica | | |
| Irazu | ERTS 2021-15105 | |
| Orosi | ERTS 1243-15335 | |
| Poas | ERTS 2021-15105 | |
| Rincon de la Vieja | ERTS 1243-15335 | |
| Turrialba | ERTS 2021-15105 | |
| SOUTH AMERICA | | |
| Peru | | |
| El Misti | NASA S-66-54832 | Gemini, color, 70-mm |
| | NASA S-66-54833 | Gemini, color, 70-mm |
| | ERTS 1246-14155 | |
| Huaynaputina | ERTS 1246-14155 | |
| Tutupaca | ERTS 1191-14100 | |
| Ubinas | ERTS 1246-14155 | |
| Chile, Argentina, Bolivia | | |
| Antofalla | SL 4-137-3676 | color, 70-mm, slightly oblique |
| Guallatiri | ERTS 1244-14051 | |
| Irrupunctu | SL 4-137-3676 | color, 70-mm, tentative identification |
| | ERTS 1243-14001 | |
| Islugu | ERTS 1244-14051 | |
| Lascar | ERTS 1243-14010 | tentative identification |
| Llullaillaco | SL 4-137-3676 | color |
| | ERTS 1243-14010 | |
| Nevados Ojos del Soladu | SL 4-137-3676 | color, 70-mm, slightly oblique |
| Olca | SL 4-137-3676 | color, 70-mm |
| | ERTS 1243-14001 | |
| Oyahue | SL 4-137-3676 | color, 70-mm |
| | ERTS 1243-14001 | |
| San Pablo | ERTS 1243-14001 | |
| San Pedro | ERTS 1243-14001 | |
| Cerro del Tatio | ERTS 1243-14001 | |

DEVELOPMENT AND EVALUATION OF A
PROTOTYPE GLOBAL VOLCANO SURVEILLANCE SYSTEM
UTILIZING THE ERTS-1 SATELLITE DATA COLLECTION SYSTEM

by

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1.0 ABSTRACT

The ERTS Data Collection System makes it feasible for the first time to monitor the level of activity at widely separated volcanoes and to relay these data rapidly to one central office for analysis. This capability opens a new era in volcanology where the hundreds of normally quiescent but potentially dangerous volcanoes near populated regions around the world can be economically and reliably monitored daily to warn when any one volcano is becoming active again. Before ERTS was launched only a few volcanoes in the world were monitored continuously because of the high cost of building and staffing volcano observatories. Yet it is known from data collected in this century, that while visible signs of pending eruptions may occur only minutes to days in advance, invisible but measurable signs may be detected days, weeks, months and even years before a major eruption. While prediction of specific eruptions is still an elusive goal, early warning of a reawakening of activity at quiescent volcanoes is now a distinct possibility.

A prototype volcano surveillance system was established during the latter part of 1972 and early 1973 on 15 volcanoes in Alaska, Hawaii, Washington, California, Iceland, Guatemala, El Salvador, and Nicaragua. Nineteen seismic detectors that count four different sizes of earthquakes and six biaxial borehole tiltmeters that measure ground tilt with a resolution of 1 microradian have been installed. Data from these instruments are relayed through the ERTS satellite and through a teletype link to the U.S. Geological Survey Office in Menlo Park for rapid analysis. Only seismic and tilt data are collected because these have been shown in the past to indicate most reliably the level of volcanic activity and also because they can be measured relatively easily with available instrumentation. Experience

during this project demonstrates the feasibility of building inexpensive, low power, reliable instruments that can be installed in remote locations and can be expected to run unattended for a few years.

Comparison of the data from these new earthquake counters with data from nearby standard seismometers shows that the counters do normally indicate the level of seismic activity. During periods of high seismic background noise there may be a significant number of spurious counts but the existence and duration of such noisy periods are reliably indicated by other data collected by the earthquake counters. An eruption of Volcán Fuego in Guatemala was preceded by an order of magnitude increase in the number of seismic-event counts several days before.

The tiltmeters operated stably in several different environments. A twenty-microradian collapse of the summit of Kilauea Volcano in Hawaii was observed on three tiltmeters.

This initial experiment shows that now with the advent of inexpensive satellite telemetry it is both technologically and economically feasible to build a global volcano surveillance system. Several details in the design and deployment of appropriate low-power, inexpensive, and reliable instruments still need to be worked out. Work continues to evaluate the scientific feasibility of this system by collecting and analyzing data that clearly demonstrate the ability of this system to detect changes in volcanic activity.

2.0 INTRODUCTION AND PROGRAM DESCRIPTION

Eruptions at the more than 500 historically active volcanoes around the world usually occur with virtually no warning to the surrounding populace. Visible signs of increasing restlessness at quiescent volcanoes normally are not observed, or at least are not recognized, before even catastrophic eruptions, whereas measurable changes in a number of geophysical parameters, such as the frequency of occurrence of microearthquakes and the rate of tilting of the ground surface, have been observed days, weeks, months, and even years before large eruptions. Although accurate prediction of the outbreak of specific eruptions is generally not yet possible even for densely instrumented volcanoes, it does appear to be feasible to detect changes associated with revival of a quiescent volcano and to provide an early warning of the activity that might follow. Such warnings can provide time for implementation of precautionary lifesaving measures as well as for focussing research efforts on volcanoes with the highest probability of erupting and thereby contributing rapidly to the understanding of eruptions and to the development of reliable methods for predicting them.

Few permanent volcano observatories have been established because they are costly to maintain and because most volcanoes erupt so infrequently that they must be monitored for decades to record a single eruption. Recent advances in instrumentation technology now permit large temporary networks of instruments to be established in remote areas very rapidly. Thus, a new era in volcanology can be introduced by application of a widespread network of relatively simple and inexpensive instruments to identify areas that merit intensive research with dense portable networks of instruments.

The Earth Resources Technology Satellite (ERTS) launched by the National Aeronautics and Space Administration (NASA) on July 23, 1972,

provides for the first time a practical system for collecting data from hundreds of remote areas of the globe and making these data rapidly available in one or more locations for analysis by specialists. This polar orbiting satellite relays 64 binary bits of data plus a station identification code from scattered remote ground transmitters at least once every 12 hours to a NASA tracking station in Maryland or California.

Beginning in June, 1972, a prototype global volcano surveillance system was established under the ERTS program to explore the technological, economic, and scientific feasibility of monitoring hundreds of potentially hazardous volcanoes. Instruments were installed in close cooperation with local scientists on 15 volcanoes in Alaska, Hawaii, Washington, California, Iceland, Guatemala, El Salvador, and Nicaragua at the sites shown in Figure 2.1. Data from low powered instruments at 22 different sites are relayed through the satellite and ground tracking stations to Goddard Spaceflight Center in Maryland. The data are processed after each satellite pass and relayed within 90 minutes by teletype to the U. S. Geological Survey Office in Menlo Park, California.

The sensors include 19 multilevel seismic event counters that provide separate counts of earthquakes with amplitudes greater than four different reference levels and 6 biaxial borehole tiltmeters that measure ground tilt with a resolution of one microradian. Seismic and tilt data are collected because these have been shown to be closely related to the level of activity at many different volcanoes in the past. Furthermore, these parameters can be measured relatively easily with new instrumentation.

The fourth generation seismic event counters developed for this project (Photos 2, 3, 4) analyze about 20 million digital bits of seismic data monitored during each 12 hour interval and provide the 64 bits that can be relayed through the ERTS satellite. This data compression is



FIGURE 2.1. Map of volcanoes monitored in this study. Event counters were placed at all sites. Tiltmeters were placed on Mt. Lassen, Kilauea, Fuego, and Pacaya.

extreme, and much information is lost. For the purposes of the volcano surveillance network, however, the essential data required are simply the numbers of small earthquakes of different sizes that occur during the 12-hour sampling interval. These numbers typically change by orders of magnitude before eruptions. The criteria adopted for detecting earthquakes are first that 10 peaks of the full-wave rectified seismic signal must be above the detection threshold in 1.2 seconds and second that no peaks may have been above this threshold in the previous 15 seconds. This second criterion effectively inhibits the counter during periods of high ground noise caused, for example, by wind, harmonic tremor, or cultural activities. The time that a channel is inhibited is counted separately. Comparison of data from the event counters with data from standard seismometers located nearby show that these instruments will reliably detect order of magnitude changes in local seismicity under normal conditions. Such a change was detected 6 days prior to a small eruption of Volcán Fuego in Guatemala in February, 1973. A similar swarm of earthquakes was detected in January, 1973, on St. Augustine Volcano in Alaska, but no eruption was reported at this remote and uninhabited volcano. Longer term changes in the level of seismicity are also being sought as the network continues to operate.

The borehole tiltmeters used in this network contain a precisely-made, electronically-monitored level bubble initially developed as part of an inertial guidance system. These meters are only 5 cm in diameter and can be easily installed in a 1 to 2 meter deep hole in rock or more typically in sandy soil or ash. Extensive tests show that with proper care in installation these meters reliably measure tilts on the order of a few microradians (a few millimeters in one kilometer). A collapse of the summit of Kilauea Volcano in Hawaii, by over 20 microradians, associated

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with an eruption of lava from the flank of the volcano, was measured on May 5, 1973, by three tiltmeters located around the summit. The flanks of Volcán Fuego tilted outward about 35 microradians in the 6 months following its eruption in early 1973.

Results to date from this prototype global volcano surveillance system clearly demonstrate that, while further refinement of the instrumentation is desirable, it is technologically and economically feasible:

1) To build hardy, compact, low-powered instruments that can be deployed for unattended operation in remote locations around the world;

2) To collect data rapidly from all these instruments by means of an ERTS-type data relay system; and

3) To provide a measure of the level of activity of hundreds of widely scattered volcanoes. Work is now under way to increase the information that can be derived from the event counter and tiltmeter data and to explore the use of other types of sensors and other methods of compressing data that may be useful for monitoring volcanoes. This semi-automatic monitoring system of potential global application offers a radically new approach to the surveillance of potentially hazardous volcanoes.

3.0 ACKNOWLEDGEMENTS

Establishment of a network of instruments on 15 volcanoes in 5 countries involves the close cooperation and hard work of many people. In addition to the authors, Roland La Forge worked full-time on this project, beginning in October, 1973. Professor Richard Stoiber of Dartmouth College, Hanover, N. H. provided invaluable advice for the field work in Central America. The following is a list of persons and organizations who assisted in the installation and maintenance of equipment in the field. The underlined names are those of scientists who also have assisted in the data analysis.

Alaska

| | |
|--------------------------|---------------------------------------|
| <u>Dr. Jurgen Kienle</u> | University of Alaska, College, Alaska |
| William Feetham | Homer, Alaska |

California

| | |
|--------------------------|--|
| Superintendent and Staff | Mt. Lassen Volcanic National Park Mineral, California |
|--------------------------|--|

El Salvador

| | |
|--------------------------|---|
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| (Director)) | San Salvador, El Salvador |
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| Ing Jose Gonzales G. | Instituto Geografica Nacional San Salvador, El Salvador |
| Albert Holburn | Inter American Geodetic Survey U. S. Defense Mapping Agency San Salvador, El Salvador |

Guatemala

| | |
|---------------------------|-------------------------------|
| <u>Dr. Samuel Bonis</u>) | Instituto Geografico Nacional |
| Dr. Oscar Salazar) | Guatemala City, Guatemala |
| Carlos Estrada Q.) | |

Hawaii

8-48

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)
George Kojima)
)
Kenneth Honma)

Hawaiian Volcano Observatory
Hawaii National Park, Hawaii

IcelandSveinbjörn Björnsson

National Energy Authority
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Mina El Limon, Nicaragua

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Glacier, Washington

Staff, St. Helens National Forest

Cougar, Washington

General Assistance with the equipment preparation

Jim Ellis)
)
John R. VanSchaack)
)
Wayne Jackson)

USGS, Menlo Park, California

The EROS program of the USGS provided a loan of \$65,000 to expedite construction of the event counters prior to launch of ERTS when NASA continued to delay finalization of this contract. NASA provided \$285,000 to carry out this contract. Funds to continue this research after the NASA provided funds ran out as anticipated October 1, 1973, were provided by several small grants from the EROS program totaling \$55,800 to cover the period up to February 28, 1974.

Three tiltmeters, two in Hawaii and one in Guatemala were provided for this study with funds from the USGS Office of Earthquake Research and Crustal Studies.

5.0 A BRIEF HISTORY OF PREVIOUS INSTRUMENTAL OBSERVATIONS PRIOR TO VOLCANIC ERUPTIONS

5.1 Seismic Activity before Volcanic Eruptions

Volcanic eruptions are typically preceded by individual large earthquakes or swarms of earthquakes. Most of the evidence is from felt reports and it is not possible to establish the true relationship of these earthquakes to the eruptions. Several examples are given by Shimozuru (1971). A partial list of such observations is given in Table 5.1 modified from Harlow (1971). Many references to earthquakes prior to eruptions are so widespread that a complete list would be nearly impossible to compile.

At adequately instrumented volcanoes some data has been collected that helps clarify the relationship between earthquakes and subsequent eruptions. Examples are shown from Sakura-jima in Japan (Figure 5.1), Kliuchevskaya in the U.S.S.R. (Figure 5.2), Asama in Japan (Figure 5.2), Raoul Island in the Kermadec Islands (Figure 5.3) and Merapi in Indonesia (Figure 5.3). Similar sequences are well observed on Kilauea and Mauna Loa volcanoes in Hawaii (Hawaiian Volcano Observatory, unpublished data). Care must be used in comparing these data to allow for the large differences in instrument response, in distance from the earthquake hypocenters to the seismometers, in the size of the ensuing eruption, and in what different seismologists choose as the minimum amplitude of earthquakes to be counted from the records. Nevertheless these data show significant increase in seismicity hours to days prior to eruptions. These same sequences recorded on the high-gain multilevel, seismic event counters used in this study would have increases in seismicity generally in excess of 3 or 4 orders of magnitude. Larger eruptions generally seem to be preceded by larger and more numerous earthquakes, although this relationship can not be clearly documented with the few data available.

TABLE 5.1. Volcanic eruptions preceded by a significant increase in earthquake frequency.

| LOCATION | DATE | EARTHQUAKE ACTIVITY | REFERENCE |
|---------------------------|--------------|---|-------------------|
| Mt. Misery West Indies | 1692 | Felt earthquakes followed by eruption. | Perret (1939) |
| Soufrière West Indies | 1694 1798 | | |
| Mt. Pelée West Indies | 1851 | | |
| Fuji, Japan | 1707 | Swarm of felt earthquakes preceded the eruption. | Omori (1911) |
| Usen-dake, Japan | 2/12/1792 | Swarm of felt earthquakes preceded the eruption. | |
| Usu-san, Japan | 8/16/1663 | Numerous felt earthquakes began on 13 August and continued up to the time of the eruption. | |
| | 3/12/1822 | 3, 44, and 75 felt earthquakes on 9, 10, and 11 March respectively. 100 shocks were felt on 12 March prior to eruption at 2:00 P. M. | |
| | 7/25/1910 | 25, 110, 351, and 162 felt earthquakes on 22, 23, 24, and 25 July respectively. 240 events recorded instrumentally during 10 days leading up to the eruption. | |
| Sakura-jima, Japan | 10/8/1476 | Strong earthquakes felt during five days prior to the eruption. | Omori (1914-1916) |
| | 11/9/1779 | Large number of felt earthquakes on the day preceding the eruption. | |
| | 1/12/1914 | Large increase in recorded earthquakes one day prior to eruption (Fig. 5.1). | |
| Santa María, Guatemala | 1902 | Unusually large numbers of felt regional and local earthquakes beginning 10 months prior to the eruption. | Rose (1973) |
| Katmai, Alaska | 1912 | Many strong earthquakes were felt by local inhabitants during five days preceding the eruption. | Fenner, 1928 |

| LOCATION | DATE | EARTHQUAKE ACTIVITY | REFERENCE |
|-----------------------------------|--|---|----------------------------------|
| Merapi, Indonesia | 11/22/1930 | A large increase in seismicity was recorded for a 2 month period 2 months prior to the eruption followed by a decrease in the number of earthquakes. Seismicity then increased slightly one month before and dramatically a few days before the eruption. | Neumann Van Padang 1933 |
| St. Vincent, West Indies | 4/1812 5/1902 | Both eruptions followed a swarm of felt earthquakes. | Robson (1964) |
| Una-Una, Celebes Is. | 5/2/1898 | Felt earthquakes occurred 3 weeks prior to eruption. | Katili <u>et al.</u> (1963) |
| Pelée, West Indies | 9/16/1929 | Felt shocks occurred prior to eruption. | Perret (1935) |
| Usu-san, Japan (Showa Sin-Fan) | 7- 8/1944 | Several large paroxysmal eruptions preceded by large increases in seismicity. | Minakami <u>et al.</u> (1951) |
| Asama, Japan | 12/4/1941 9/3/1949 9/21/1949 11/7/1935 3/25/1938 4/1/1941 | These eruptions were preceded by recorded earthquakes. | Minakami (1959) Pt. 1 |
| Asama, Japan | 10/3/1958 | Large recorded increase in very shallow earthquakes prior to eruption (Figure 5.2). | Minakami (1959) |
| Kliuchevskaya, Kamchatka | 1951 1953 1954 1956 | Magnitude of recorded swarm proportional to violence of the following eruption. Number of shocks decreased just prior to the 1951 eruption (Figure 5.2). | Gorshkov (1960) |
| Sakura-zima Japan | 10/13/1955 | Anomalous increase in seismicity was recorded during the 5 months preceding the eruption. | Shimozuru, 1971 |
| Bezmianny, Kamchatka | 1955-1956 | 30,000 earthquakes recorded before the first historic eruption. Earthquake frequency was at its maximum at the onset of volcanic activity. | Gorshkov (1959) |

| LOCATION | DATE | EARTHQUAKE ACTIVITY | REFERENCE |
|--|---|---|---|
| Guadelupe, West Indies | 1956 | Eruption followed recorded earthquake swarm. | Robson and Tomblin (1966) |
| Bezymianny, Kamchatka | 2/13/1958 2/27/1958 3/27/1959 11/28/1959 4/13/1960 3/26/1961 | Increasing seismicity beginning 30 - 50 days prior to these eruptions was recorded | Tokarev (1963) |
| Fayal, Azores | 1957-1958 | Earthquakes before the Capelinhos outbreak | Machado (1966) |
| Manam, New Guinea | 3/17/1960 | Few felt and recorded shocks prior to the eruption. Instrument magnification was 10. | Taylor (1963) |
| Tokati, Japan | 6/29/1962 | Daily recorded earthquakes began to rise and fall at the beginning of May. 12 felt shocks were noted during the month preceding eruption. | Yokoyama (1964) |
| Miyake-sima, Japan | 8/24/1962 | Series of felt earthquakes 110 days, 1 week, and 1 hour before the eruption. | Minakami (1964) |
| Shiveluch, Kamchatka | 11/12/1964 | 10 month preliminary seismicity increase and 1 month direct seismic increase prior to volcanic activity. | Gorshkov and Dubik (1970) |
| Raoul Island, Kermadec Is. | 11/21/1964 | Increased seismicity began on 10 November with a maximum of 80 shocks per hour before eruption (Figure 5.3). | Adams and Dibble (1967) |
| Mihara-yama, O-sima, Japan | 12/26/64 | Large increase in recorded seismicity beginning two days before the eruption. | Shimozuru (1971) |
| Piip Crater, Kamchatka (Kliuchevskaya) | 10/6/1966 | Up to 457 shocks per day recorded during 5 days prior to eruption. | Gorshkov and Kirsanov (1968) |
| Deception Island, Antarctic | 12/4/67 | Normal seismicity of 4-30 recorded events per month rose to 300 per month in November. | Smithsonian Institute, Event 1-67, Card 222, 1967 |

| LOCATION | | EARTHQUAKE ACTIVITY | REFERENCE |
|--|------------|--|---|
| Fernandina Caldera, Galapagos Is. | 6/11/1968 | 20 earthquakes with magnitudes between 3.9 and 4.6 located nearby by USCGS during first week of June | Simkin and Howard (1970) |
| Merapi, Indonesia | 1/7/1969 | Greater than 2 orders of magnitude increase in seismicity was recorded beginning approximately 3 weeks prior to the eruption. | Shimozuru <u>et. al.</u> (1969) |
| Deception Island, Antarctic | 2/21/69 | Daily felt tremor began on Feb. 14 and increased up to time of eruption. | Smithsonian Institute, Event 17-69, Card 423, 1969 |
| Bezymianny Volcano, Kamchatka, USSR | 10/11/69 | Recorded earthquakes increased for 2 months leading up to the eruption. | Smithsonian Institute, 1969, Event 135-69, Card 822 |
| Taal, Phillippines | 10/28/1969 | Eruption was preceded by recorded earthquake swarm. | Troncales (1970) |
| La Palma Island, Canaries | 10/26/71 | Eruption started after several days' microseismic activity. | Smithsonian Institute, Event 90-71, Card 1305, 1971 |
| Sakurazima Vol- cano, Japan | 10/27/72 | Swarms of shallow recorded earthquakes occurred after a volcanic explosion on Oct. 6 and before another eruptive period beginning this date. | Smithsonian Institute, Event 60-72, Card 1487, 1972 |
| Asama Volcano, Japan | 2/1/73 | First major activity for 11 years. Minor eruption 8 years ago | Smithsonian Institute, Event 19-73, Card 1565, 1973 |
| Tiatia Volcano, Kuriles | 7/14/73 | Eruption preceded by a series of earthquakes of "considerable magnitude." | Smithsonian Institute, Event 92-73, Card 1684, 1973 |

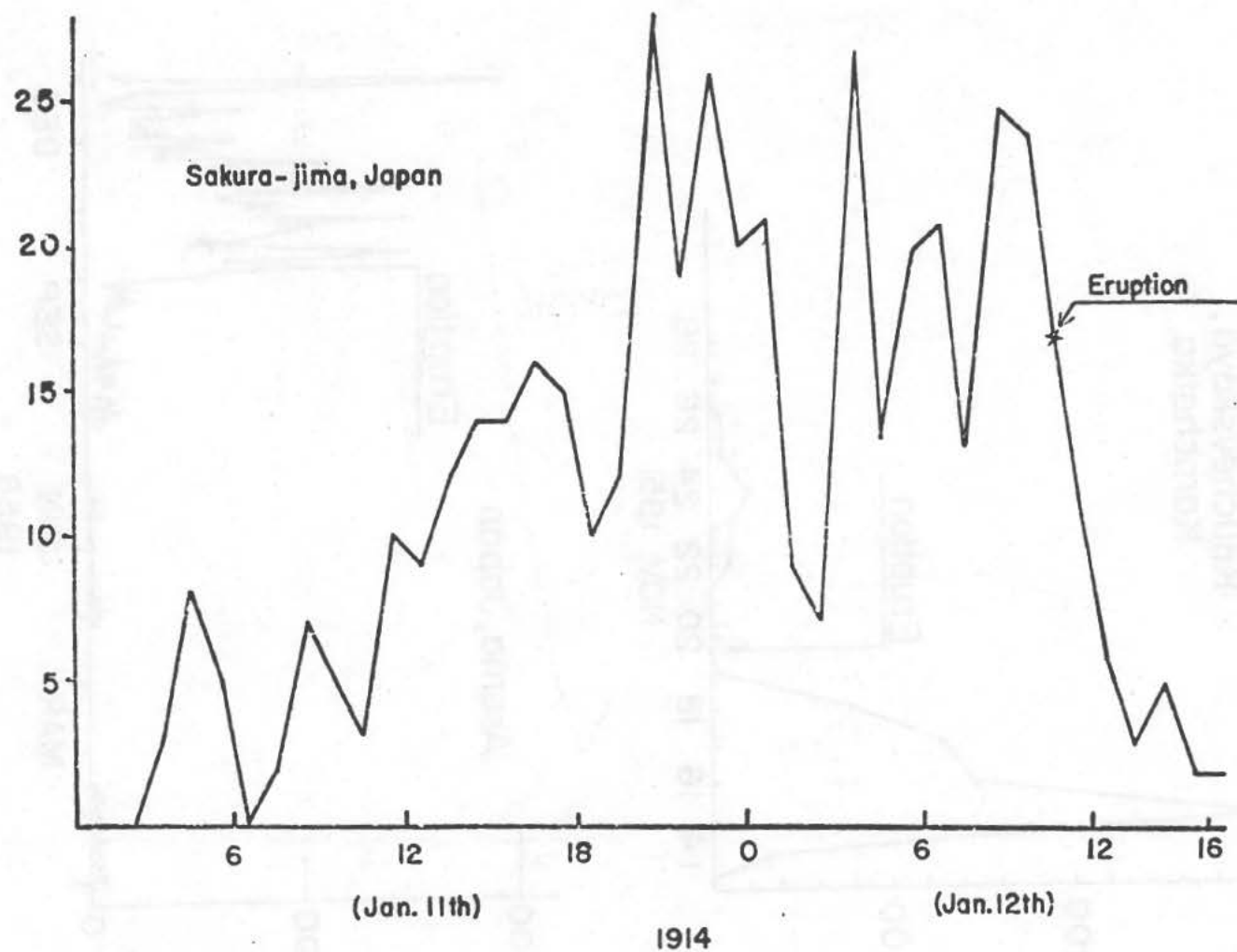


FIGURE 5.1. Number of earthquakes per hour preceding the Sakura-jima eruption of 12 January 1914 in Japan (after Omori, 1914). The instrument had a gain of 10 and was located about 11 km from the volcano.

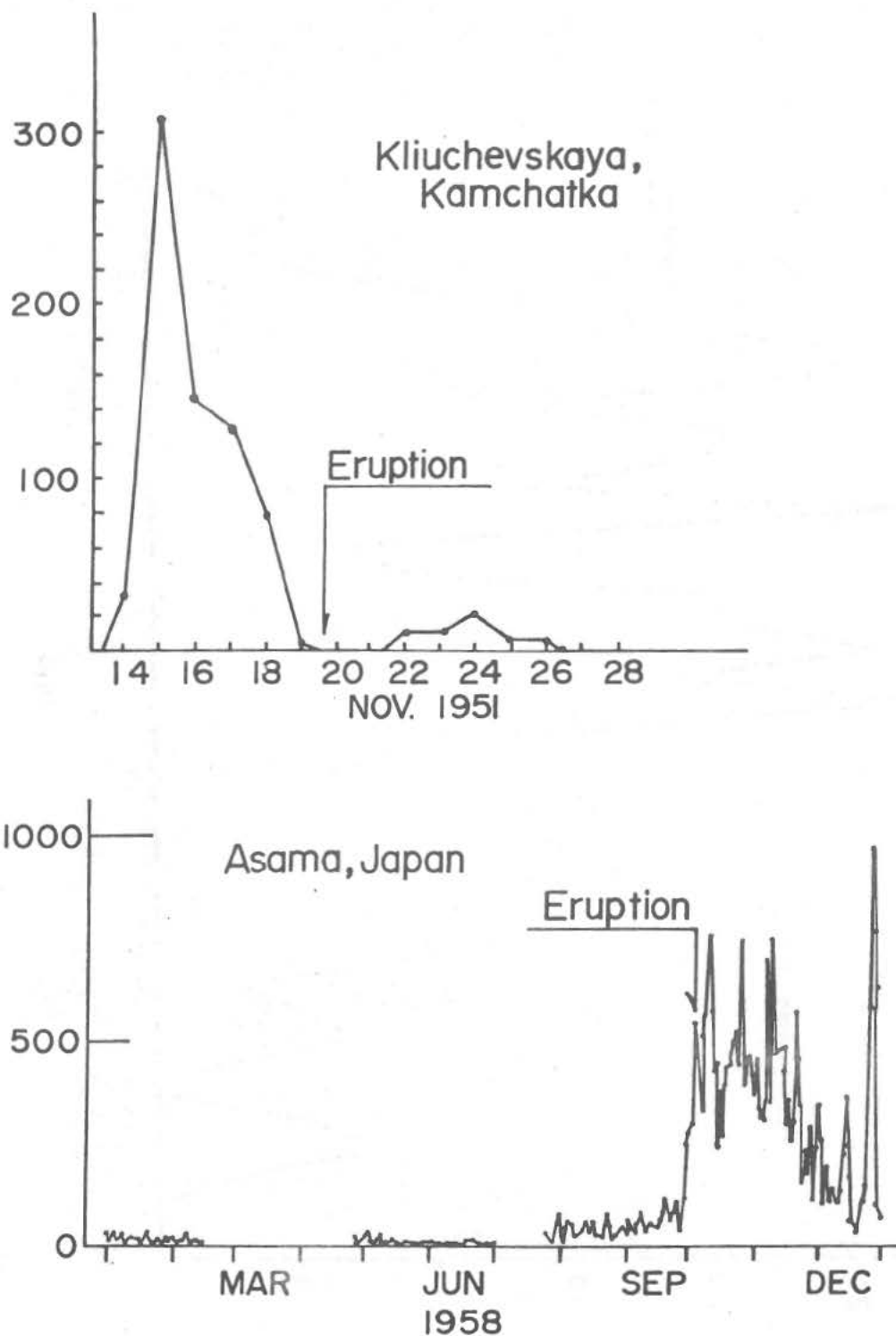


FIGURE 5.2. Number of earthquakes per day prior to the eruptions of Kliuchevskaya on 19 November 1951 (Gorshkov, 1960) and Asama on 3 October 1958 (Minakami, 1960). The instruments had gains of 10,000 and 4,000 and were located 30 km and 2 km respectively from the centers of the volcanoes.

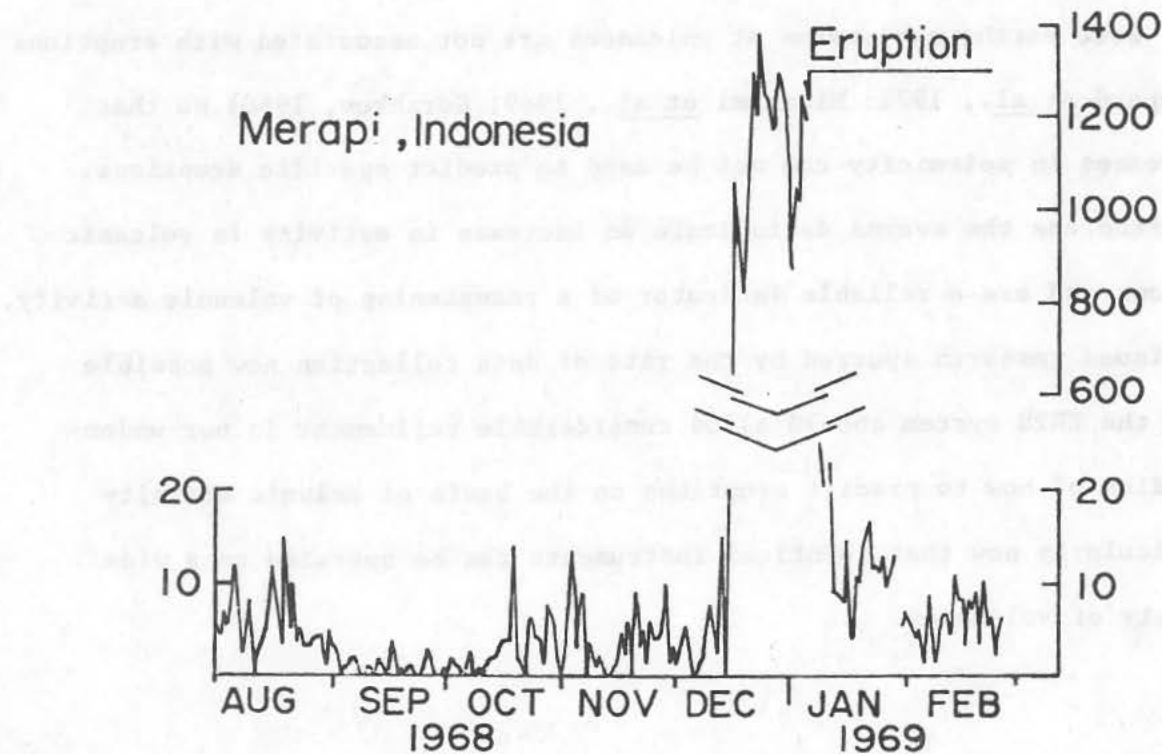
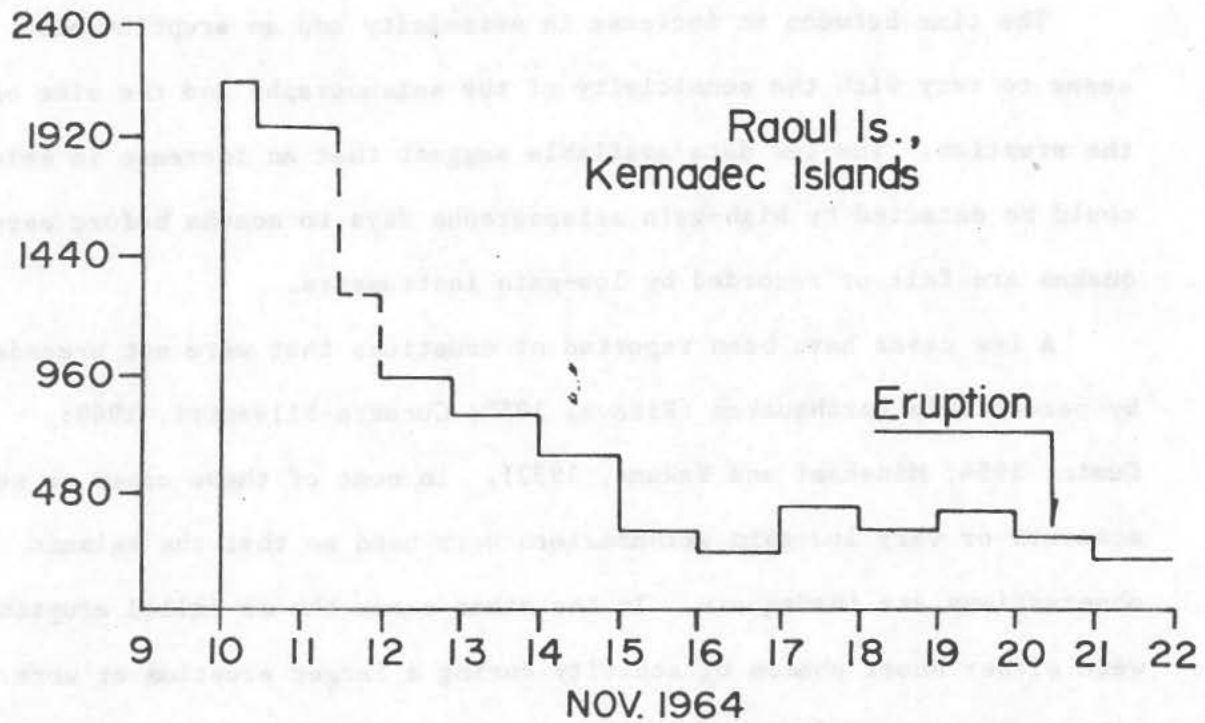


FIGURE 5.3. Number of earthquakes per day prior to the eruptions of Raoul Island on 20 November 1964 (Adams and Dibble, 1967) and Merapi on 7 January 1969 (Shimozuru *et al.*, 1969). The instruments had gains of 4,700 and 15,000 and were located 2 km and 3 km respectively from the centers of the volcanoes.

The time between an increase in seismicity and an eruption also seems to vary with the sensitivity of the seismographs and the size of the eruption. The few data available suggest that an increase in seismicity could be detected by high-gain seismographs days to months before earthquakes are felt or recorded by low-gain instruments.

A few cases have been reported of eruptions that were not preceded by perceptible earthquakes (Kizawa, 1952; Cucozza-Silvestri, 1949; Cumin, 1954; Minakami and Sakuma, 1953). In some of these cases no seismometers or very low-gain seismometers were used so that the seismic observations are inadequate. In the other cases the so-called eruptions were either short phases of activity during a larger eruption or were minor outbreaks of fume or pyroclastics of no danger even to persons living high on the side of the volcanoes.

Some earthquake swarms at volcanoes are not associated with eruptions (Shepard et al., 1971; Minakami et al., 1969; Gorshkov, 1960) so that increases in seismicity can not be used to predict specific eruptions. Nevertheless the swarms do indicate an increase in activity in volcanic regions and are a reliable indicator of a reawakening of volcanic activity. Continued research spurred by the rate of data collection now possible with the ERTS system should allow considerable refinement in our understanding of how to predict eruptions on the basis of seismic activity particularly now that identical instruments can be operated on a wide variety of volcanoes.

5.2 Tilt of the Ground before Volcanic Eruptions

Observations of surface deformation around volcanoes date from about 1904 (Omori, 1907) with the most detailed observations in Japan and Hawaii. Most of the early reports were based on precise geodetic leveling surveys repeated at intervals of years and usually re-run shortly after an eruption. Typical tilts associated with eruptions were up to 1000 microradians for Sakura-jima (Omori, 1914-1922); 300 microradians for Miyake-Sima (Omote, 1950 and Minakami, 1950). One microradian of tilt is 1 mm of elevation change per kilometer of distance. The spacial distribution of surface deformation can be delineated by leveling surveys, but the data can only show that tilt of a certain magnitude was associated with an eruption without showing for sure whether the tilt changes occurred before or during the eruption. Precise geodetic surveys are expensive so that they can normally only be made sporadically. Thus continuous monitoring of ground tilt is necessary before this phenomena can be used to provide an early warning of eruptions.

An excellent example of early continuous tilt measurements is shown in Figure 5.4 from Minakami (1942) who studied the relation of tilt on Asama volcano to explosion swarms. Minakami concludes, ". . . we find that marked variations in tilt appeared associated with every one of these explosion swarms. In comparing the times of occurrence of these two phenomena, we find the very marked fact that the first explosion of an explosion-swarm occurred one or one-and-a-half months after the appearance of abnormal tilt."

Eaton and Murata (1960) demonstrated with detailed tilt records from short based water level tiltmeters at many sites around Kilauea Caldera in Hawaii that tilts of 300 microradians accompanied the 1959 eruption and that the rate of tilt increased very significantly in the weeks preceding the first visible eruptive activity. Similar swelling of the volcano

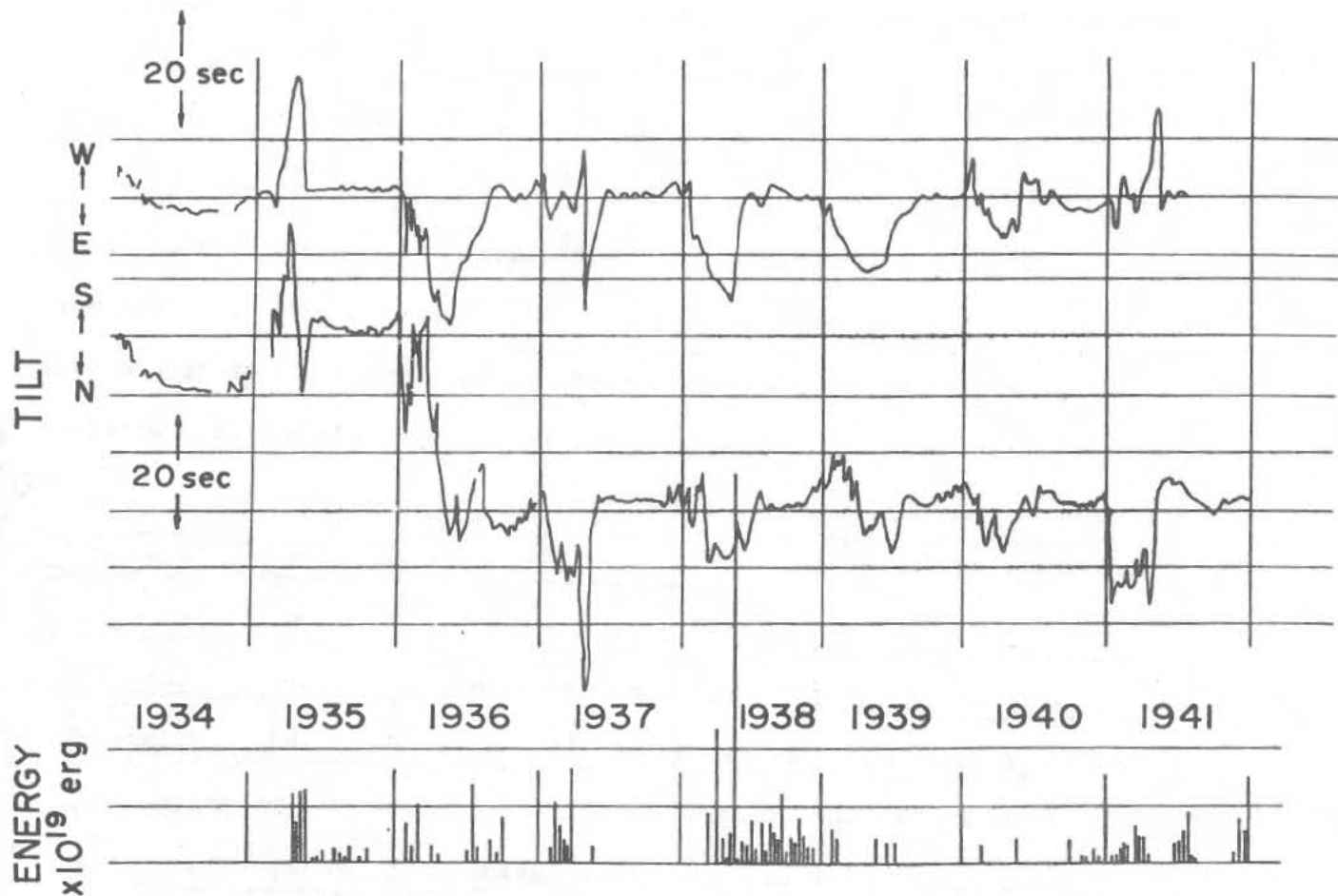


FIGURE 5.4: Tilting of the earth's surface at Nakanosawa, and the sum of the explosion energies for every ten days (after Minakami, 1942).

occurred prior to the 1961 eruption (Figure 5.5) (Richter et al., 1964).

These few examples of the presently available data illustrate how volcanoes have been observed to swell prior to eruptions apparently in response to magma being intruded at comparatively shallow depth under the mountains. An excellent summary of these phenomena is provided by Decker and Kinoshita (1971).

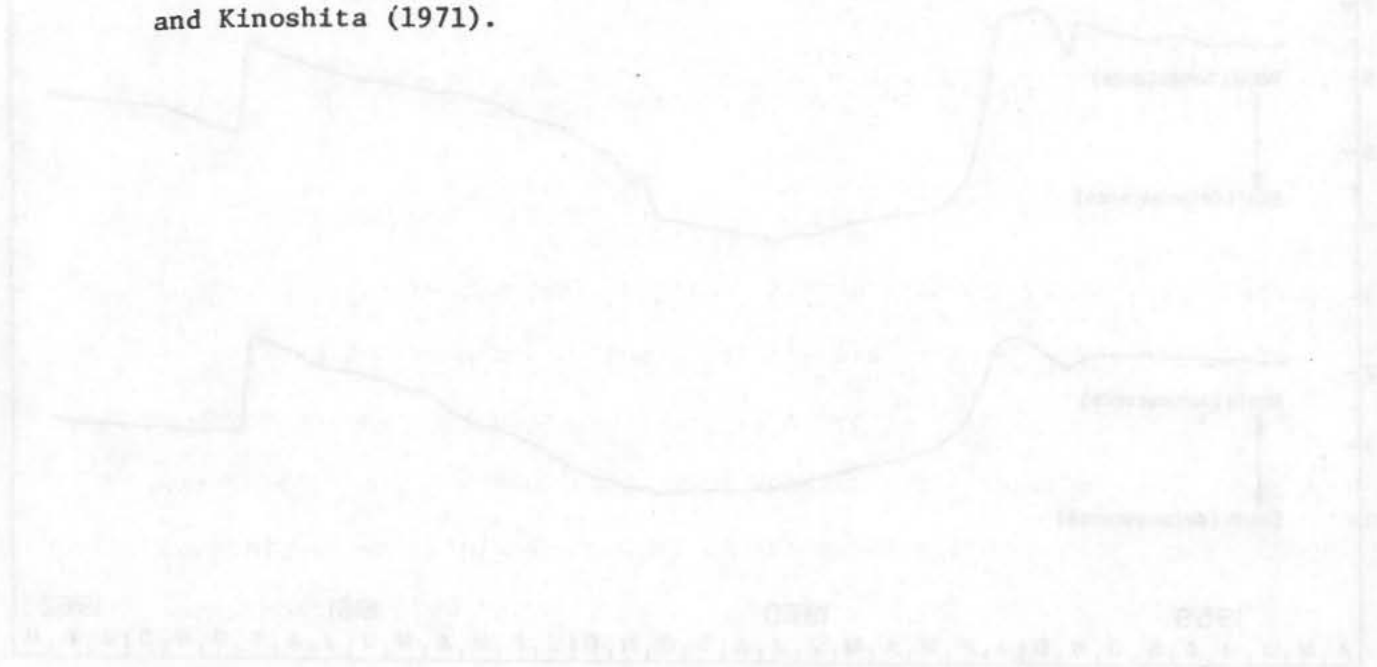


FIGURE 5.5. Elevation of Mount Fuji from 1950 to 1961. The line shows the elevation of the mountain in meters. The vertical axis is labeled 'Elevation (m)' and the horizontal axis is labeled 'Year'. The graph shows a general upward trend with several sharp peaks and troughs, indicating significant swelling and subsidence of the mountain prior to the 1961 eruption.

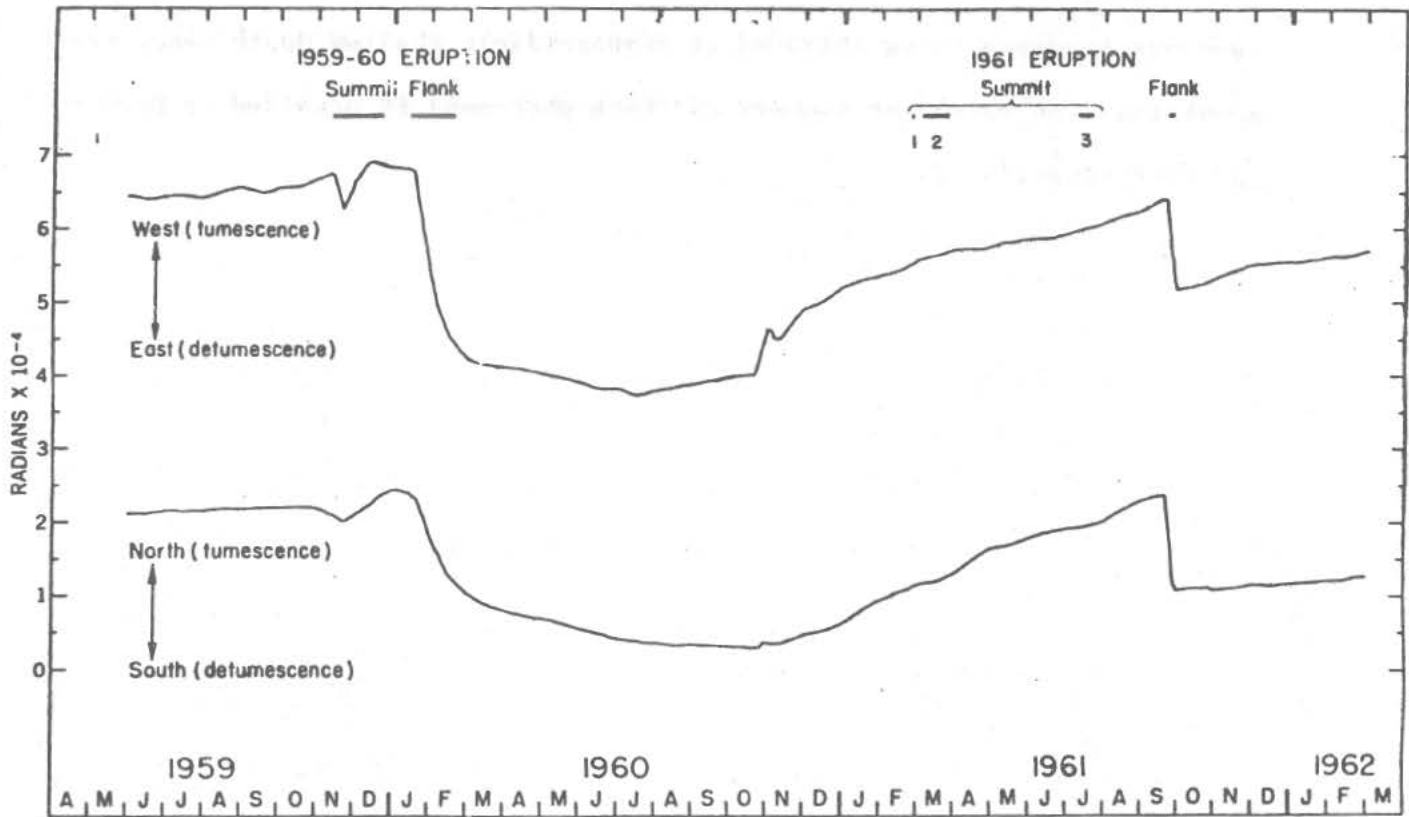


FIGURE 5.5. Ground tilting of the Kilauea summit area as indicated by daily readings of the short base water-level tiltmeter at Uwekahuna from late 1959 to early 1962. Periods of eruption (actual extrusion of liquid lava) are shown by bars at the top.

5.3 Other Types of Instrumental Observations

Measurements of fumarole temperature, pressure, and gas composition have been reported by several authors (e. g. Stoiber and Rose, 1970; Meniaylov and Nikitina, 1967; Noguchi and Kamiya, 1963; Moxham, 1971; Tazieff, 1971; and Tonani, 1971). These techniques have not been extensively developed. Methods for measuring temperature and gas analysis are being developed for use with ERTS by Jules Friedman and Moto Sato respectively of the U. S. Geological Survey.

Yokoyama (1971) summarizes gravimetric, magnetic and electric methods used around volcanoes. None of these methods have proved particularly useful for providing early warning of eruptions. Johnston and Stacey (1969) discuss a volcano-magnetic effect and show that "a magnetic anomaly built up over a period of days before the April 1968 Ruapehu eruptions, but no more than a few hours' notice seems possible from the" record of the 1968 Ngauruhoe eruption.

Thus the most promising and proven methods now available for continuously monitoring the level of activity of volcanoes are recording seismicity and tilt. These two methods are complementary and together seem to provide a reliable indication of the level of activity at a given volcano.

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BY WITNESS

Statement of
Dr. Anthony J. Calio
Associate Administrator for Space & Terrestrial Applications
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the
Subcommittee of Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I am honored to be able to present to you NASA's program of Space and Terrestrial Applications (OSTA). Before we proceed with my testimony, I would like to introduce my associates from the office. With me at the table are Dr. Ichtaque Rasool, our Chief Scientist, and the Directors of our Program Divisions. As a new manager of this program office, I am pleased that my first testimony happens to be before this Subcommittee, which, in the past has shown overall enthusiasm for NASA's activities in the area of Applications. In the next several years, as we implement the program you authorize, I look forward to your continued support and critical evaluations so that we can assure that the nation continues to have the most rewarding and productive program in Space and Terrestrial Applications.

Before I present our budget request of \$283.4M for FY 1979, I would like to spend a few minutes describing to you how I view what we are trying to accomplish, and how we intend to achieve it.

Our nation, and the world at large, is facing many challenging problems today. Among them are a scarcity of energy and mineral resources, alteration of the environment by man, unpredictable natural disasters, and the effect of unanticipated climatic change on agricultural productivity (Chart I). Each of these problems is of primary importance to at least one other agency or department of the Federal Government. The role of NASA and OSTA is to work with these agencies in order to identify and carry out useful space activities which enhance the possibilities and accelerate the process of the eventual solution of these problems (Charts 2, 3, 4, and 5).

Given this supportive role, the objectives of the Office of Space and Terrestrial Applications Programs are varied, complex, and change with the changing National priorities of the problems which we can address. Our current objectives are to contribute to better understanding of weather and climate, world

food production, mineral and energy resource development and control, the growing information and communication requirements of society, and to develop the initial steps whereby our national economy may benefit from the use of the space frontier, while at the same time evaluating national and societal needs which may determine our specific objectives of the future. In order to achieve these objectives, our guiding rationale will reflect problem rather than technique orientation.

All our programs depend on the applications of science, technology, and management skills; and therefore, it is important that we assure scientific integrity, engineering excellence and managerial competence for the conduct of the program. The user involvement in all stages of our program, from conception to conclusion, is of paramount importance. In the next year, emphasizing the aspects I have just mentioned, we hope to implement our charge, "serving humanity," in a most efficient and useful manner.

Let me now discuss the major elements of our program, their basic rationales, utilities and the future directions.

As you know, application programs embrace a broad spectrum of activities that touch our lives each day. I shall explain the primary thrusts of our programs, and then briefly describe some of the many components of each. This morning we shall cover our four major program disciplines; the applications space observations to assess the Earth Resources, and to understand the Earth's Environment, Materials Processing in Space, Communications through space, and our Technology Utilization program which will be discussed later by Mr. Mogavero. Our budget request for FY 1979, broken down by programs, is shown in comparison with the FY 1978 figures in Chart 6. The launch schedule for the next five years is shown in Chart 7.

Earth Resources Detection and Monitoring

Our program in the area of Earth Observations is directly responsive to the current National and worldwide problem of scarcity of both renewable and non-renewable resources. A few years ago, working with the U.S. Geological Survey (USGS) and the U.S. Department of Agriculture (USDA), we asked ourselves some specific questions. Can space observations of the earth reveal the presence of minerals which lie buried in the crust? Can the vantage point of space be used effectively to determine where oil, gas and petroleum resources may be concentrated? Can high resolution multispectral images of the earth produce seasonal inventories of the renewable resources and, more importantly, can we forecast the productivity of farmlands around the globe by monitoring the extent and health of crops from the beginning of the growing season? In order to answer these questions we established a comprehensive program which includes the development of space and supporting ground systems, improved data processing and analysis techniques, high altitude aircraft support for sensor and techniques development, and basic and focused research for monitoring, analyzing, and

managing the Earth's resources. The program is conducted in close cooperation with the public and private user communities to develop practical applications and effective utilization of these capabilities. The use of Landsat 1 and 2 has already demonstrated that satellite data can be helpful both, in the management of renewable resources (for example, agriculture, water and land use) and, at the same time, in the exploration for non renewable resources like minerals, gas, and petroleum.

Renewable Resources

(Agriculture, Water Resources and Land Use)

Since agriculture is a major resource of our country, it is important to be able to forecast the agricultural productivity of both our own and other countries and also to assess the impact of episodic events like floods, droughts, freezes, etc. on these inventories.

The space technology with which to address these objectives has been demonstrated in the USDA/NASA/NOAA Large Area Crop Inventory Experiment (LACIE), a three year joint program being completed in 1978. As we reported to you last October, the results of the experiment indicate that it is technically possible to achieve the goal of a 90% accuracy in wheat estimates by utilizing remote sensing data. In the winter wheat areas of the U.S. Great Plains and in the spring and winter wheat areas of the USSR, the LACIE results are very good. These are the regions where wheat is grown in the large fields that are compatible with the spatial resolution of Landsat 1 and 2. Even though the spring wheat production estimates in the U.S. Great Plains (areas of narrow strip fallow fields) do not yet meet the accuracy goals, the 1977 estimate is better than the 1976 estimate. One of our major activities during 1978 is to complete an in-depth analysis of the three year experiment and to evaluate what we have learned, and to define directions for our future agriculture related efforts (Chart 8).

The USDA, however, is sufficiently pleased with the LACIE experimental single crop results in wheat in the U.S. Great Plains and in the USSR, that USDA and NASA are developing a plan for the extension of a joint experimental effort wherein remote sensing data will be used to augment USDA information and data capabilities. Based on the knowledge gained thus far, during 1979 we propose to initiate production estimates of other agricultural commodities such as soybeans, corn or rice; and extend our studies to other geographic areas that utilize farming practices significantly different from those investigated in LACIE.

Tests have shown that, for improved accuracies in estimating wheat production and extending our capability to assess other crop data, higher spectral and spatial resolution is required, as well as data in additional spectral bands. The first step in getting this new information will be provided through the Landsat-C to be launched in March. Landsat-C represents an improvement on the technology developed for and demonstrated by Landsat-1 and -2. This will be accomplished by an improved Multispectral Scanner (MSS) and an improvement in the spacecraft television camera system referred to as the Return Beam Vidicon (RBV) system.

The MSS on Landsat-C differs from those previously flown in that a spectral band in the thermal range has been added to more clearly interpret effects of temperature changes. This additional capability will allow improved monitoring of agriculture in the preharvest stage and will also improve the capability to monitor dynamic changes in other vital areas such as water pollution, geology, hydrology, and oceanography. The RBV system has been modified to provide a two-fold improvement in resolution (from 80 to 40 meters) over the previously flown RBV systems. This will increase the capability to locate and identify small agricultural fields and improve cartography in poorly mapped areas of the world.

This area of investigation will also benefit from data acquired by Seasat, the Heat Capacity Mapping Mission (HCMM), and other meteorological satellites.

- Water Resources Management

The critical need to manage the nation's water resources wisely has become increasingly apparent in the past few years. In our efforts to apply space technology to the solution of this important national problem, we are conducting a number of joint projects with Federal, regional and state agencies having operational responsibilities for assessment and management of water resources in various parts of the country. In developing appropriate plans and management strategies for control and allocation of water, it is necessary that the agencies have current information on snow pack and associated runoff, stream flow, ground water and reservoir quality and volume, land and water use for agricultural, irrigation and industrial requirements. Experiments and demonstrations have shown that the data acquired by Landsat can be processed to provide important information which can contribute to the knowledge required for wise and timely decisions.

One of our projects dealing with snow melt forecasting involves the Corps of Engineers, the Soil Conservation Service, the Bureau of Reclamation, the Bonneville Power Administration and agencies in the states of Colorado, California and Arizona. A complementary project with the Corps of Engineers, using test sites in Georgia, Pennsylvania, Maryland, Texas and California deals with water runoff and its effect on peak flows, while another project with the California Department of Water Resources is utilizing Landsat data to assess irrigated land areas and the related effects on water requirements (Chart 9). The development of a systematic approach to integration and analysis of these techniques into the water management systems of these agencies is expected to result in more timely, accurate and cost effective operational methods.

- Land Use

Urban expansion in the United States has caused problems in land use, housing, transportation, and waste disposal. Planners, engineers, and managers require current information on population, new construction, and general land use changes in order to deal effectively with these problems. The preparation and acquisition of land use change information through maps, aerial photographs, and surveys is often time-consuming and expensive, and quickly becomes obsolete in areas of rapid growth.

Detecting urbanized area expansion from changes in population has been one of the tasks of the Bureau of the Census. Expansion of U.S. urbanized areas results in a rural to urban change in population and land use, thus creating a need for an updated boundary to accurately delineate the limits of the urbanized area. Urbanized area boundaries are updated from enumerated results and are part of the decision making criteria for Federal funding programs. For the 1980 Census, some 300 metropolitan areas will have to be monitored for changes by Bureau of the Census geographers.

In studying urban expansion, the concept of the fringe zone is used by the Bureau of the Census. The fringe zone is bounded by an inner line indicated as an urbanized area as established in the previous census and an outer line showing anticipated extent of urban growth. In the past, Bureau of the Census geographers have used census returns for a count of the population and have determined the urbanized area boundary by population density. A new approach, being tested in a joint NASA-Census Bureau project, treats expansion as a function of urban land cover. Images obtained by NASA's earth resources satellites, Landsat-1 and Landsat-2, are the sources for the land cover data. The satellite systems provide synoptic, repetitive coverage and the study area scene is analyzed by computer and census tract outlines which are overlaid on the Landsat scene yielding a geographic framework for the categorization of land cover.

A variety of Landsat data products and analysis methods permits the integration of Landsat data with other types of data desired by the user. For Bureau of the Census needs, the categorized image with tract outlines provides Census geographers with spatial representation of land cover data.

Austin, Texas was selected as one of the test cities. Austin was chosen because the Bureau of the Census was evaluating a series of 1980 census procedures there. Images taken in different years can be used for comparison of land cover characteristics to determine areas of change resulting from urban expansion (Chart 10).

Analysis of initial results indicates that the techniques can provide accurate, timely, cost-effective data. The results of tests in a total of 30 urban areas prior to the 1980 census will be evaluated against post 1980 Census Bureau data. If proven, the technique can be expected to be applied for over 300 urban areas.

- Non-Renewable Resources

(Minerals, Oil, Gas, Petroleum)

Use of space observations to assist in the identification of potential non-renewable resource locations in the earth's crust is still in an early stage. Our objective, of course, is to provide that information which is not available conventionally and which would enhance the chances of success and reduce the costs of mineral and oil exploration.

Using Landsat-1 and -2 data, it has been shown that an important feature of these data is that they reveal surface features which seem, at many locations, to be correlated with entrapment of minerals, petroleum and geothermal sources. Such studies have shown not only the viability of the unique data obtainable from space, but also emphasized the need for more geologically dedicated instrumentation and systems.

Last October we reported on the formation of the Geosat Committee Inc., which is supported by many companies dealing with energy resources and represents a unified voice from the industrial exploration geologists. They have made specific recommendations to NASA on how to optimize space instrumentation which would be beneficial for locating resources on the surface of the earth. A substantial portion of our FY 1979 SR&T program and future flight instrumentation in this area is responsive to these recommendations.

We have studied the requirement and the utility of remote sensing in an additional spectral band centered at 2.2u for maximum rock discrimination for mineralogical reasons. A comparison of intensity measured at 1.6u and 2.2u will identify alteration zones based on high ferric iron content of the rock. This concept has been tested in aircraft flights and this extra channel is being considered for incorporation into the Landsat-D system (Charts 11 and 12). Such studies and extensive ground truth comparisons will continue in FY 1979.

In the next several years, we will also be studying in great depth the utility of remote sensing in infrared at a variety of wavelengths for discriminating among various kinds of mineral containing rocks. The program will involve instrument development, testing, comparing the results with ground truth and eventually flying it on one of the early shuttle missions. In this context a Shuttle Multispectral Infrared Radiometer (SMIRR) comprising ten-channels is being developed to obtain earth surface radiance measurements in the 0.6 to 2.5um range. This multi-channel device will provide information for design parameters for future imaging systems directed toward geologic mapping. The SMIRR data will be used to assess the variability in reflectance signature worldwide for at least ten major rock types. The data will be correlated with ground-based reflectance measurements to determine the spectral bands to use for maximum discrimination between such types under all environmental conditions. The instrument is under development at JPL for flight on the second Shuttle Orbital Flight Test (OFT-2) in July 1979. An existing Mariner/Venus/ Mercury mission telescope is being modified for the instrument.

In FY 1979 we will also evaluate the feasibility of radar techniques which may assist in rock discrimination, soil moisture and hydrological studies. A Shuttle Imaging Radar (SIR-A) system is being developed as the first phase of the Spaceborne Imaging Radar Program. It consists of flying the Seasat-A L-band radar residual modules with minor modifications on OFT-2 in July 1979. The major objective of SIR-A is to evaluate the applicability of spaceborne imaging radars for land form analysis and geologic mapping and exploration. During the five-day OFT-2 mission, the SIR-A radar may map as much as 8.4 million square kilometers.

Radar frequencies also have the additional benefit of being able to penetrate the clouds and can, therefore, be specially useful in making geomorphological and geological maps of tropical and polar regions.

In summary, we anticipate further returns from spectral research in the near-IR, thermal IR, and microwave portions of the spectrum. New techniques such as induced fluorescence, as well as other active visible and IR laser systems, are expected to add a new dimension to our search for resources in future years.

Regional anomalies in magnetic and gravity fields have been correlated with concentration of minerals and petroleum (Chart 13). In a joint project with USGS, NASA is developing the Magnetic Field Satellite (Magsat) for launch in 1979. USGS has national commitments to update the global magnetic field maps periodically and Magsat should provide these data at a higher resolution and better accuracy than previous methods. This base map can then be used as a reference point in identifying local variations which are useful in formulating the long range planning of mineral and hydrocarbon exploration programs. Sound knowledge of broad regional geology and geophysics is essential to mineral exploration. Data from this program should aid in selecting the most promising regions. Magsat will carry both a scalar magnetometer for overall measurement of the earth's field and a precise three axis vector magnetometer for the determination of field direction. Work has begun on the spacecraft at the Johns Hopkins University Applied Physics Laboratory using residual hardware available from the Small Astronomy Satellite.

Procurement of the scalar magnetometers has been initiated and design of the vector magnetometer has been completed. In 1979, system tests and launch preparations will be completed and Magsat will be launched into a low earth orbit. The four to eight months of mission duration will allow sufficient repetitive mapping of the global magnetic field to detect and remove noise due to solar activity.

As mentioned before, gravity field anomalies also correlate with regions of mineral and petroleum concentration. Therefore, gravity field altimetric data acquired over ocean areas using GEOS-3, and satellite tracking data acquired with radio frequency and laser ranging are being combined into new gravity field models. As an aid to resource assessment, a geophysical atlas is being prepared by Goddard Space Flight Center for publication in mid 1979. The atlas will include global maps of gravity and magnetic fields, selected Landsat imagery, maps of seismic activity, information on deep mantle velocity anomalies, global tectonic activity, and crustal heat flow. This will allow formulation of crustal models of selected geographic regions. This information will be of significant use in the search for new deposits of mineral and petroleum resources.

Another area in which space observations could be of great benefit is the discipline of Engineering and Environmental Geology. There are regions of earth affected by geological hazards like earthquakes, landslides, volcanoes, subsidence, floods, dam rupture and coastal erosion which could benefit by monitoring from space. In addition, activities such as siting of power plants, other large constructions, mining, etc. could use high resolution Landsat type images with

considerable benefit. In many of these cases one would need stereo images to maximize geological and structural interpretation and we are planning a test on an early Shuttle flight of a Large Format Camera. This high resolution camera will provide stereo capability.

The results discussed above indicate that continued development of space techniques in a number of areas can make space observation even more effective in resolving some of our resources and land use problems here on earth. Identification of rock types containing various kinds of minerals, detection of soil moisture, stereoscopy of structural features of rocks, higher spatial and temporal resolution, measurements at different wavelengths, observations through the clouds, longer lifetime and reliability of the sensors are some of the areas which will be emphasized in our program for the coming years. The program for FY 1979 actually responds to these needs and has been constructed to carry out some of the first tests of these capabilities.

As discussed before, Landsat-C will carry an improved MSS which incorporates a fifth, thermal infrared channel, and a higher resolution RBV system. Launch is scheduled for March (Chart 14). We have terminated the operation of Landsat-1, which is almost five years old.

We will also launch the first of a series of Applications Explorer Missions (AEM's) early this year: the Heat Capacity Mapping Mission (HCMM) which is designed to collect remotely-sensed data for the development of thermal inertia maps of the surface of the earth. The predawn and early afternoon orbit was chosen so that surface temperatures near the maximum and minimum of the diurnal cycle can be measured using a thermal scanner. These data, when combined with ground truth information, should allow comparison of thermal inertia characteristics of various materials, which will help in the identification of surface rock types. Oil and gas exploration rely substantially on identification of reservoir rock and local structures which might provide a trap for petroleum. The routing or location of major civil works, such as highways and canals, are critically dependent upon rock type identification. The feasibility of obtaining soil moisture information will also be tested, which if available, should be a useful input to the agro-meteorological models which are necessary to determine crop yield prediction.

Our major spacecraft activity in FY 1979 will be the continued development of Landsat-D. The major technical focus of the Landsat-D project involves a test of the capabilities of the Thematic Mapper instrument, and an improved ground data handling system. The Thematic Mapper offers higher resolving power and greater spectral coverage than existing instruments. The addition of a seventh spectral channel is being considered specifically to facilitate discrimination among various mineral bearing rocks.

The Multispectral Scanner has recently been proposed by the Administration for flight on the initial Landsat-D spacecraft after a thorough review of the requirements for continuing MSS data. The MSS on Landsat-D will enable users of the MSS data received from the first three Landsat missions to continue with

established applications of multispectral data while obtaining experience with the experimental Thematic Mapper data. Inclusion of the Multispectral Scanner in the Landsat-D payload was authorized by the Congress during consideration of the Agency's FY 1978 budget request.

Landsat-D will provide the user community with the opportunity to test, under realistic conditions, a total information system (Multispectral Scanner, Thematic Mapper, an improved ground data processing system, and data analysis and interpretation) by bringing the satellite-sensed earth resources data to the users in a timely fashion (five to seven days) and on a routine basis over a projected three-year test period. The amount of data transmitted from the spacecraft will be about 10 times more than for Landsat-C. For this reason, an improved data handling system, being developed, is essential.

In FY 1977, a contract for the development of the Thematic Mapper protoflight unit was awarded. In FY 1978, the hardware procurements for the systems modules of the Multimission Modular Spacecraft (MMS) were initiated by exercising options in the basic contracts undertaken in 1977 for the Solar Maximum Mission. The integration and test contractor for the MMS will be selected in early 1978. Proposals for the Landsat-D mission contract are under evaluation. This procurement will provide for the design, fabrication, and integration of the Landsat mission unique systems and the ground data processing system. A contract for the Multispectral Scanner will also be awarded in early 1978.

In late 1979 and the early 80's the Space Transportation System will be used to test, demonstrate, and evaluate earth-viewing, remote-sensing instruments and system. The OFT-2 payload has been selected and development work has been initiated. The instruments are: the Shuttle Imaging Radar (SIR-A) for all weather identification of land features; a Shuttle Multispectral Infrared Radiometer (SMIRR) to conduct research on the optimum spectral bands for geological exploration; and an Ocean Color Scanner to assess the information which can be obtained from improved color sensing techniques in open ocean areas. The SIR-A will be our first use of spaceborne radar for landform analysis. It will be an adaption of the single frequency Seasat-A Synthetic Aperture Radar and will demonstrate the contributions a radar system can make to earth resources information gathering. The Large Format Camera will be flown on an early STS operational flight. It will have direct applications to precision mapping of large geographic areas, and its stereo capability will be especially useful to mineral and petroleum resources exploration and also for environmental and engineering geology.

Geodynamics

Related to the activities in the area of earth resources is our program of Earth Dynamics Monitoring and Forecasting. It applies space observation techniques to studies of the solid Earth. These studies are expected to contribute to the assessment of potential resources areas, and to better understanding of the

physical character and dynamic motions of the Earth, and eventually to the forecasting of catastrophic events such as earthquakes. Our program in this area represents the entire NASA effort in Earth Sciences. The Lunar Laser Ranging program has now been transferred from OSS to OSTA.

Contrary to what is generally assumed, the solid Earth is a very dynamic body. Continents move, crust deforms, volcanoes erupt and as we all know, earthquakes take place all too often. Studies in earth sciences in the last two decades have shown considerable promise in enabling us to relate these various dynamic processes to each other, and perhaps may lead us to some insight into the cause and effect relationship among these phenomena (Chart 15).

It is now well established that the surface of the earth is divided into about a dozen crustal plates, of continental dimensions, that are in motions relative to each other at a rate of a few centimeters per year. There are regions on the earth where these plates are colliding, in shear and sliding against each other, and other regions where they are moving apart. These movements create incredible stresses, deformations, uplifts, etc. which result in phenomena ranging from earthquakes to concentration of minerals, oil and geothermal energy. Precise measurements of these plate motions and mapping regional gravity and magnetic fields seem to be keys to improved understanding of the cause and effect relationships.

Space offers a unique vantage point to carry out these measurements. First, accurate tracking of an orbiting satellite provides critical information on the regional gravity anomalies. From a satellite we can also "remotely sense" the magnetic field of the surface as will be done in the Magsat project already discussed. In addition, satellites can be used as "reflectors" or beacons for accurate measurement of distances between two points on the Earth. It is precisely in these three areas that our program in earth dynamics is concentrating, in close cooperation with other Government agencies such as the U.S. Geological Survey (USGS), the National Geodetic Survey (NGS), Department of Defense (DoD), the National Science Foundation (NSF) and University groups.

Highlights of our accomplishments were presented to you last October. Today, I would like to mention a recent result of our program which is of great interest to seismologists studying the mechanism of earthquakes.

A crustal motion experiment, the San Andreas Fault Experiment (SAFE) was initiated in 1972 in an attempt to demonstrate the practical applications of laser tracking of spacecraft for the determination of the relative motions of the earth's crustal plates. Near certain crustal plate boundaries, regions of concentrated faults tend to be zones of high earthquake probability. The objective of the SAFE experiment was to determine the plate motion along a major fault in a region like the San Andreas Fault in California. In order to do so, two sites were established in 1972 -- one in Quincy on the east and the other in San Diego on the west side of the fault. Tracking operations were conducted in the latter parts of 1972, 1974, and 1976. Additional measurements are planned in 1978 and 1979.

These laser satellite tracking data have been analyzed and the distance between the two sites has been determined to an accuracy approaching a few centimeters. Preliminary results indicate that the distance between the two points 900km apart is decreasing by 9 ± 3 centimeters per year over this four year period. This rate is much higher than the long term average rate of about 2cm/year derived from geological and magnetic records (Chart 16).

In a related experiment, a different technique, Very Long Baseline Interferometry (VLBI) using radio telescopes and quasars as sources of radio signals for accurate interferometric measurements, CalTech scientists have determined that the distance between the Goldstone station in the Mojave desert and a point 180 kilometers away on the grounds of the Jet Propulsion Laboratory in Pasadena, has increased by 13 centimeters in the past three years. The data show that the south side of the San Andreas fault south of the San Gabriel mountains (where the San Andreas takes a bend to the west) has moved westward relative to the north side between 12 and 20 centimeters during those same three years.

These results, if confirmed by subsequent measurements, would lay the foundation for long-term monitoring of plate motions in the earthquake zones around the world and eventually lead the way for the understanding of relationships between such plate motions and large earthquakes.

It is clear that validating these new techniques for measuring separations over large distances to centimeter accuracy is of major significance and utility not only to the earth scientist but the federal agencies responsible for assessing the feasibility of an earthquake prediction system and to our National and personal well being. We are, therefore, implementing this part of our geodynamics program with relatively high priority.

In December 1977, mobile satellite laser tracking systems were deployed to VLBI antenna locations at Haystack, Massachusetts; Owens Valley, California; and Goldstone, California. Measurements of the lengths of the three baselines of this triangle using the two techniques will be compared over a period of several months to test the accuracy of the two approaches and to identify any systematic errors. It is expected that these tests will verify these systems to better than ± 5 centimeters. Later in 1979, similar tests are planned toward the eventual validation of a ± 2 cm capability which, as mentioned before, is supposed to be the average yearly rate of the plate movement.

In the fall of 1978, mobile lasers will be deployed to sites used in the San Andreas Fault Experiment (SAFE) to repeat measurements obtained in 1972, 1974, and 1976 in an attempt to confirm the previously measured nine centimeters relative motion between points on opposite sides of the North American and Pacific plates boundaries.

A mobile VLBI system has been developed to test the feasibility of shorter baseline measurements (of the order of 100-1000km) using a fixed VLBI antenna as the second site. This mobile unit has been used to support USGS requirements for measurement of crustal deformation in California and NGS studies of a discrepancy in the slope of the sea surface along the Pacific coast as determined by conventional land surveying and oceanographic techniques.

In FY 1979, we plan to initiate principal investigator studies of global geodynamics using laser tracking data from Lageos and other satellites. These data will be acquired with NASA mobile units deployed to track Seasat-A and the fixed lunar laser observatories in Texas, Hawaii, Australia, and other countries. These investigators will be selected from proposals submitted in response to an Announcement of Opportunity.

In our long term planning, we are working with the USGS and the NSF to define and coordinate other NASA research appropriate to the Earthquake Alleviation Act of 1977, and with the scientific community to formulate strategies for global plate motion studies in the early 1980's using the laser and VLBI systems now under development.

Environment

Today we are becoming concerned about the state of our environment. The economic impact of unanticipated changes in both short term weather and long term climate is substantial. Last year's winter in the east and drought in the west are only two recent examples. We are also concerned about the possible impact of man's activities on the atmosphere and ocean. The effect of Chlorofluoro Methane (CFM) and various nitrogen compounds on ozone, for example, is an issue of current scientific and public debate. The problems of pollution of our lakes and oceans is of considerable concern, and the exact role of the ocean and its impact on our weather and climate is still unanswered. Agencies like NOAA and the Navy's Fleet Numerical Weather Central (FNWC) have direct responsibilities for improving operational weather forecasting capabilities and NOAA is responsible for coordinating a National Climate Research Plan. EPA on the other hand is responsible for eventual regulation of products which may have deleterious effect on the environment. We at NASA have been serving these agencies by defining and demonstrating new space techniques and systems which would facilitate their tasks and could eventually be used operationally. There are four major elements of this program. Their status was discussed in detail last October. Today I would like to update the status and discuss the future thrust of each of these program areas.

- Ocean Conditions Monitoring and Forecasting Program

Observation of the oceans from space offers the unique advantage of frequent examination of all the ocean areas, no matter how remote. Our program in Ocean Monitoring is currently focused on demonstrating new capabilities in space for providing the information needed by institutions responsible for ocean activities on an operational basis, viz. the Navy, Coast Guard, NOAA, shipping industry, oil and gas industry, and fishing industry. Particular attention is being devoted to establishing the basis for an economical operational system. In addition to the development of space missions, research is underway to advance the understanding and modeling of ocean phenomena, to develop advanced concepts for the processing and timely dissemination of ocean data, and to evaluate the economic benefits of ocean data use.

Current participants in the program include: National Oceanic and Atmospheric Administration, the Navy's Fleet Numerical Weather Central, Office of Naval Research, Naval Research Laboratory, Defense Mapping Agency, National Science Foundation, United States Coast Guard, United States Geological Survey, domestic universities, scientific institutions, commercial U.S. companies, Canada, and the European Space Agency.

After three years of successful operations, the routine acquisition of data from the GEOS-3 mission will be terminated in mid 1978 because Seasat-A will be able to acquire more accurate measurements of the geoid and other ocean parameters. GEOS-3 has provided for the first time a detailed near-global map of the ocean geoid. This is significant in that the 1-2 meter accuracies achieved have been sufficient to identify short-wavelength undulations of the geoid and to relate local high frequency variations with subsurface features such as ocean trenches, escarpments, plateaus, ridges and sea mounts. This improved knowledge of the geoid enables us to more accurately predict the effects of land and water masses on the orbital paths of our space vehicles and to predict expected currents, tides, and sea state. Data from GEOS-3 have also proved useful in monitoring sea state conditions, in mapping ice topography in Greenland, and in demonstrating that the boundaries of ocean currents such as the Gulf Stream and the associated eddies can be detected from space.

Seasat-A, under development for the past three years, is being readied for launch in the next few months. The development of the sensors has been completed and they have been integrated with the spacecraft sensor module. Following completion of environmental system tests in March 1978, Seasat-A will be shipped to the Vandenberg Air Force Base in California for a May 1978 launch.

Preparations are also being finalized for the validation and use of Seasat-A data. NASA, NOAA and DoD will be acquiring ocean data from ships, towers, and aircraft to validate the measurements obtained from space. Seasat-A data will be transmitted in near real time to the FNWC for processing and use in the forecasting of ocean conditions by the Navy. FNWC and NASA will also make available to several commercial users data applicable to shipping and offshore operations. These users will evaluate the economic benefit of this service and assess the improvements achieved. NOAA plans to use Seasat data in their ocean and weather forecasting. NOAA will also make processed data available to domestic non-government scientific investigators selected through an interagency solicitation issued by NOAA on the behalf of NOAA, NASA, ONR, NSF, USGS and the USCG. Areas of investigation are listed in Chart 17. They include open ocean directional wind and wave fields, surface temperature, ocean currents and tides, ice area extent, and other phenomena important for weather and climate modeling.

Although Seasat-A is planned for one year of orbital operations, the spacecraft design included sufficient consumables to support a three year mission. In the FY 1979 budget request, funds are provided for the extension of the Seasat-A mission for one year, to May 1980. At the present time, studies are underway to establish the design of a follow-on oceanographic satellite capability to that

provided by Seasat-A. The emphasis is on providing more and earlier data products in formats required by the end users. Some changes are planned to also provide improved measurement accuracy and resolution. The long range objective is to provide an operational satellite capability.

Environmental Quality Program

In our Environmental Quality Program, we address three broad areas: the quality of the stratosphere, including an understanding of the roles of its interacting constituents; the quality of the lower atmosphere, or troposphere, with its regional and urban air pollution problems; and the quality of the surface waters associated with lakes and ocean coastlines.

The upper atmospheric layer, the stratosphere, continues to be of concern. The Office of Space and Terrestrial Applications supports the NASA Upper Atmospherics Research Program, managed by the Office of Space Science, by focusing on the development of systems for measuring the amount and distribution of ozone and trace species which influence its abundance. The need for continued measurements of global ozone and other important stratospheric constituents, including aerosols, highlights the value of Nimbus-G, planned for launch in August 1978 (Chart 18). Data from Nimbus-G and the Applications Explorer Mission-B/Stratospheric Aerosols and Gas Experiment (AEM-B/SAGE), scheduled for an early 1979 launch, will also help evaluate the role of stratospheric aerosols and trace gases in the energy balance of the earth and its impact on world climate. Both of these satellite projects are proceeding on schedule. In addition, we will use sounding rocket measurements to supplement and verify the performance of many of the instruments aboard these two satellites.

In stratospheric pollution research, it is of importance to know not only the stratospheric constituents present and how they react chemically, but also to know the dynamic processes which move these species about. One of these processes is the transport or exchange between the primary atmospheric regions, the troposphere and the stratosphere. Classical circulation theory indicates that the troposphere-to-stratosphere exchange takes place mainly in the tropics, in a region known as the Intertropical Convergence Zone (ITCZ). A joint OSTA-OSS experiment to study this exchange was conducted this past year in the Panama Canal Zone. The experiment was planned by participants from four universities, NOAA, NCAR (National Center for Atmospheric Research), and NASA and was managed by the Ames Research Center. Low and high flying aircraft, including the NASA U-2, balloons, and sounding rockets were used, thus involving the assistance of the Wallops Flight Center and the Department of Defense in the operational aspects. A preliminary assessment of the measurements indicates that the ozone levels were constant during the daytime measurement periods, and from day to day during the experiment, all of which was unexpected for such a dynamic region. Even though the atmosphere is very dynamic in this area, the measurements also indicate a very uniform distribution of the major trace constituents throughout the altitude range surveyed. Additional analyses are expected to define the actual amount and extent of troposphere-to-stratosphere exchange. Planning is now under way for a similar joint experiment this coming year to measure the exchange in reverse, from the stratosphere to the troposphere, at a mid-latitude site where theory indicates significant exchange is taking place.

A new initiative in FY 1979 will be the Halogen Occultation Experiment (HALOE). The objective of this experiment is to measure the distribution of key chlorine compounds involved in the catalytic destruction of ozone. The chlorine is produced when natural chlorine compounds and manmade chlorofluoromethanes are dissociated in the stratosphere by solar UV. When these processes take place, two specific compounds result, viz. hydrogen chloride (HCl) and hydrogen fluoride (HF). In addition to measuring these two compounds, HALOE (see Charts 19 and 20) will measure concentration profiles of methane (CH_4), water vapor (H_2O), ozone (O_3), nitric oxide (NO), and freon 12 (CF_2Cl_2). The technique used in the HALOE gas-filter-correlation-analyzer instrument affords the spectral discrimination which, when used in the solar occultation mode, provides the sensitivity needed to measure these very tenuous stratospheric gases. The preliminary design of the advanced flight experiment version of this instrument is currently underway. The FY 1979 funding will initiate the fabrication and testing of an engineering model on short duration Spacelab missions and the design and fabrication of a later version for a longer duration satellite at high inclination.

In addressing the problem of tropospheric pollution, our program deals with problems which are local, regional, and global in extent. Our focus is on the development of space systems which can assist agencies such as the Environmental Protection Agency in detecting and monitoring the sources and effects of low altitude pollutants. As an example of a local scale problem, lidar techniques have been used to characterize plume dispersion for model verification in cooperation with the Maryland Department of Natural Resources Power Plant Siting Office. As for regional problems, aircraft remote sensing using gas-filter-correlation radiometry has been used to study the urban plume from the Chicago-Gary area over Lake Michigan. Because of recent research which indicates that atmospheric transport can cause local and regional pollutants to spread over large areas of the globe, we are undertaking an experiment on the Shuttle OFT-2 mission to provide the first orbital test for globally monitoring carbon monoxide (CO), a tropospheric pollutant which will serve as a tracer for measuring inter-hemispheric transport.

Remote sensing techniques are also being applied to problems in ocean dumping, oil spill monitoring, red tide detection, and lake classification. This past year we carried out a cooperative activity between the NASA Lewis Research Center and directed by EPA Region V (Michigan, Ohio, Indiana, Illinois, Minnesota and Wisconsin) in remote sensing surveys for determining the impact of river inputs to the Great Lakes. Five river inputs to four of the Great Lakes were surveyed using Landsat and aircraft multispectral scanners. Surface truth measurements were used with the scanner data to produce contour maps of sediment, silica, sulfates, nutrients, and light extinction depth. These surface truth results are being used to improve methods for detecting the type and quantity of water borne pollutants from satellite altitudes. This cooperative activity further demonstrated the utility of the perspective one obtains with aerial and space observation when used in conjunction with a carefully planned water truth gathering program.

The remote sensing data was valuable in two significant applications: (1) airborne data was transmitted to water sampling ships in near real time (within a few hours) to assist in locating optimum sampling locations for analyzing the

effects of river out-flow on the lakes; and (2) the comparison of water truth with the reflectance imagery has allowed an inferred extension of water parameters from the small number of in-situ measurements to the larger area covered by the imagery.

The development of remote measurement techniques for both air and water pollutants presents a host of technical challenges to the researcher. Such measurements invariably involve attempts to detect small concentrations of a substance by measuring the effects that the presence of the substance has on the observed radiation field. The problem is complicated by the influences on the measurements of such physical processes as atmospheric scattering and absorption, reflections from clouds, and radiation emitted by the land and water. In FY 1979 these complexities will continue to be areas of in-house and university research. These will include such topics as atmospheric effects on upwelling spectra of water pollutants, spectral surveys of water pollutants carried out in laboratories, radiative transfer inversion techniques, and the physical limitations of remote sensing techniques. The results from the studies will contribute to the ability to more rapidly ascertain types and quantities of pollutants from satellite altitudes.

Weather Program

NASA's Weather Program consists of two major areas: Global Weather and Severe Storms.

- Global Weather

It has long been recognized that our ability to provide accurate predictions of large scale weather phenomena has been severely limited by the availability of adequate global information on the current state of the atmosphere for use as input to weather forecast models. The advent of the meteorological satellite has made the obtaining of such global data economically feasible. NOAA is currently utilizing the data from operational meteorological satellites in their routine short range weather forecasts.

Over ten years ago the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) jointly conceived a global observation and analysis experiment to obtain a better understanding of atmospheric processes for improving extended range forecasting. There have been numerous scientific studies and planning for such an experiment which will come into being when the operational year of the internationally-sponsored (145 countries) First GARP (Global Atmospheric Research Program) Global Experiment (FGGE) gets underway on December 1, 1978 (Chart 21). Many types of observational platforms will obtain atmospheric data over the entire globe during this period. NASA has played a major role in the planning for FGGE under NOAA leadership. Six Data System Tests (DST's) were conducted by NASA during the period 1973-1976 as controlled investigations in an attempt to simulate the operation of the observing, data communications, and data processing systems likely to be available

for FGGE. NASA is already using the DST data in modeling studies concerned with assessing the impact of satellite temperature sounding on 48- and 72- hour forecast accuracies. As we reported last fall, the preliminary results are very encouraging. These results have produced the first evidence of measurable improvement in both 48 and 72 hour forecast accuracies when satellite derived temperature profiles are included in the analysis. The meteorological data sets resulting from these DST's will also be used by many university and government scientists working on research sponsored by NASA through an Announcement of Opportunity.

During the FGGE operational phase, an Aircraft-to-Satellite Data Relay (ASDAR) system, developed by NASA, will relay meteorological observations through a geosynchronous satellite from an international fleet of commercial jet aircraft operating over data sparse global oceanic areas to a ground control station for near real-time processing. Additional FGGE data will be provided by the Nimbus-G and Seasat research satellites and processed by NASA. Ocean buoys and constant level balloons will be tracked and the data relayed to a ground station through the Data Collection and Location System of the polar orbiting TIROS-N operational satellite (Chart 22). These special data will supplement the conventional meteorological data to make up full global data sets which will be made generally available for scientific research.

The FGGE observation system, which has been designed to improve our diagnostic understanding of large-scale atmospheric dynamics and help assess the ultimate predictability of weather systems, will provide global distributions of key meteorological parameters, including temperature profile, moisture profile, wind speed, surface pressure, and sea surface temperature.

The results of this research are critical to our quest for improved long range weather forecasts and should substantiate the benefits which space observations of the atmosphere have to offer in changing the "art" of weather forecasting into an exact science.

- Severe Storms

The approach taken in NASA's Severe Storms research is to develop the technology and interpretation techniques which will be of the greatest benefit to NOAA and the FAA in fulfilling their operational responsibilities to forecast severe weather situations and to provide timely public warnings.

The four primary Severe Storms program areas are: (1) basic research to improve our understanding of severe weather initiation, development, and its life cycles; (2) measurement and analysis technique development and demonstration; (3) instrument definition, development, evaluation and demonstration; and (4) the transfer of our applied research techniques and instrumentation to the appropriate users.

The Synchronous Meteorological Satellite (SMS) currently enables us to observe and track severe storm systems. Advanced instruments in the early 1980's

will improve our capability to delineate potential storm areas and thereby, provide more timely forecasts. It is expected that an operational system will exist in the late 1980's for improved monitoring, predicting and warning of severe storms.

The focus of the program is the development of observing and analysis techniques which will be of use to forecasters in delineating areas which have a high probability of severe weather occurrence. Recent progress has included: (1) the development of an interactive man-computer system at the University of Wisconsin to interpret multi-level wind fields from sequential SMS/GOES cloud images in near real-time, (2) the refinement and testing of a real-time severe storm forecasting system on the STAR computer at Langley Research Center (Chart 23), (3) the measurement of cloud heights with accuracy to within 500 meters, (4) the continued development and demonstration with NOAA of a frost-freeze prediction system for the Florida citrus industry using satellite observations (Chart 24), and (5) detailed observations of tornado-producing storms to further understand their mechanisms.

Two major instrument developments being conducted in the program are the Atmospheric Cloud Physics Laboratory (ACPL) and the Visible and Infrared Spin-Scan Radiometer for vertical atmospheric soundings (VAS).

The ACPL is a Shuttle-based experimental laboratory facility which will provide cloud physics experiments in the near-weightlessness of orbit that are impossible within ground based laboratories because of the rapid onset of gravity-produced motions inside the ground-based cloud chambers. These experiments will permit an evaluation of current theories of cloud formation, precipitation, and electrical behavior.

The ACPL development is proceeding on schedule at the prime contractor and will be ready for its projected launch on Spacelab-3 in mid 1981. The near term plans are to expand the current warm-cloud investigations capability of the ACPL to study the interactions between ice-phase and water-phase cloud processes, as well as cloud electrification processes and droplet coalescence through collisions. This enhanced capability is planned for the subsequent ACPL flights (ACPL-2 and -3), planned for launch soon after ACPL-1.

The VAS instrument, designed to measure temperature and humidity at different heights in the troposphere from a geostationary GOES satellite, is undergoing its performance evaluation tests and will be placed in orbit in FY 1980. FY 1978 and FY 1979 will see significant buildup of the research and operational prototype analysis centers at Goddard Space Flight Center and the University of Wisconsin, respectively. The VAS sounding data, when combined with conventional radiosonde data, promises to provide the high density of measurements needed to quantitatively specify the environmental conditions which precede severe storm development and, thus, the VAS will contribute to an improved severe storm forecasting capability.

The FY 1979 program will stress research in the physics and meteorology which underlies remote sensing as well as the development and transfer of forecast aids for near-term operational use. Other research on storms and their environments involves combinations of the unique remote storm observations made by NASA from space and aircraft, with the ground and upper air observations made routinely by NOAA. This research will help us to determine storm severity indicators, to refine storm predictions from remotely-sensed data, to evaluate model accuracies, and to specify and develop improved instruments and measurement techniques.

Climate Program

As we reported last fall, NASA participated with the other federal agencies concerned with climate in preparing an overall U.S. Climate Program Plan which was published in July 1977. In parallel, NASA developed and proposed a more specific plan for its contribution to the national program which outlines our role in developing the space segment of the climate program (Chart 25). In order to gain added assurance as to the scientific integrity and soundness of our approach, the NASA plan was submitted to the National Academy of Sciences (NAS) for their review and critique. The NAS evaluation supported the observational requirements defined by NASA, with the assistance of the scientific community, including the need for radiation budget data, and underscored the need to proceed with developing the required radiation budget monitoring space system (Chart 26).

As a first step, NASA proposes to initiate the development of an Earth Radiation Budget Satellite System (ERBSS) in FY 1979 (Charts 27 and 28). This dedicated satellite mission is expected to provide continuous global and regional measurements of Earth reflected solar and emitted thermal radiation as well as incoming solar flux. It is the delicate balance of these quantities which acts as the primary driving force which modulates our climate through its control over the atmosphere, oceans, and cryosphere. The ERBSS, which is an outgrowth of radiation budget experiments carried on previous Nimbus research satellites, will consist of instrumentation on three satellite platforms: two NOAA operational TIROS-N satellites in polar orbit for global coverage, a satellite in a high inclination orbit to provide needed diurnal sampling. The data from ERBSS will be made available to the scientific community for research on climate.

Additional research will deal with improving our understanding of the important physical processes which control climate and climate change. This will involve further refinement of satellite global observational requirements, developing innovative data analysis techniques, and atmospheric modeling. Other key efforts will deal with developing climate data sets from the analysis of past and current NASA satellite data, such as global rainfall, sea ice, and sea surface temperatures.

As a cornerstone of our climate planning effort, we are continuing to work with NOAA and NSF in assuring that the overall national program is properly balanced and coordinated. Over the next few months, we will establish the

mechanisms for obtaining continuing guidance and review from the scientific community to assist us in defining the scientific rationale and priorities of our program.

Materials Processing in Space

NASA's program in materials processing in space is dedicated to exploring the benefits of the weightlessness and ultra-high vacuum of space. The data from our experiments will provide improved understanding of the limitations imposed on earth-bound processes by gravitational forces and by mechanically or cryogenically pumped vacuum systems. In addition to this understanding, exemplary or prototype products can be produced for demonstrations of the ultimate control achievable over composition, geometry, or defect structure of materials under unique space conditions. Such studies will also allow users to learn the advantages offered by the space environment to meet needs on Earth and, in particular, to produce limited quantities of products to allow assessments of their commercial market potential (Chart 29).

An important part of the program will be the establishment of cooperative projects with other government agencies and with industrial users to assist them in these exploratory studies and involve their inputs in early hardware and facility design stages. Such projects will include increasing commitments on the part of such users to most effectively utilize the space environment to solve relevant problems or develop unique products with commercial interest.

A study of plans required to allow commercial users access to the space environment to perform proprietary experiments will be initiated. In this program, currently developed hardware will be made available on a cost reimbursable leased basis to perform simple experiments on the Shuttle.

Preliminary experiments in space environment of the Shuttle will explore the effects of density-gradient driven convection, sedimentation and self-deformation on the preparation and properties of materials such as electronic crystals, glass spherical shells, new metal alloys, new composite materials, and biological materials for medical research and treatment. One new method of processing these materials, that will be developed over the next few years, involves containerless handling of reactive materials in acoustic and electromagnetic fields. Such positioning devices will allow many unique materials to be studied for the first time and will avoid problems of container contamination and reactivity that occur on Earth.

To date, the space flight portion of this program has produced a total of 69 experiments in materials processing. The first experiments were performed on early Apollo flights; more recently a sounding rocket flight was performed in June 1977, in which four exploratory experiments were conducted. In one of these, an acoustic containerless processing module was flown for the first time in space and its capability to capture and position a liquid drop was demonstrated. The sounding rocket program will be continued until 1981 to complete a series of investigations already selected for flight.

An important outgrowth of the SPAR program has been the design of a self-contained experimental package for use on early Orbital Flight Test missions of the Shuttle in 1979/80 where hardware from the sounding rocket program will be used to conduct precursor experiments in support of those investigations selected for the early Shuttle missions.

This facility, called the Materials Experiment Assembly (MEA), will contain its own power source, heat rejection capability, and processing apparatus so that only simple interfaces to the Shuttle will be required. This early access to the Shuttle environment will allow experimenters to gain early knowledge of the Shuttle's operating environment, particularly gravitational levels, and their influence on materials processes. In addition, the space flight experimental program will commence more than one year earlier than had been originally anticipated. This self-contained package will be reflown many times on the Shuttle on a space available basis to provide a flexible capability which fulfills the needs of materials scientists for many flight opportunities.

The first Shuttle/Spacelab activities were initiated in 1977 by soliciting materials processing proposals. A total of 120 proposals were received of which 14 were selected for early missions to be flown in 1981. In addition, 18 proposals were selected for further scientific and hardware definition. Hardware development will begin with funds authorized in the FY 1978 budget. The first flight in June 1981 will be a pressurized Spacelab module in which experiments examining the interactions of fluids associated with materials preparation will be examined. The second flight will use an unpressurized Spacelab pallet to perform semiconductor, metal, and glass melting and cooling experiments which require the higher power levels and cooling capability available in this mode of operation. All apparatus is being designed for subsequent reflights to continue these and similar investigations. It is expected that a number of reflights will be required in most instances for the investigators to achieve their experimental objectives.

The budget we have submitted for FY 1979 will provide funds to continue the sounding rocket and MEA programs in FY 1979, to continue the design, fabrication, and integration of the Spacelab hardware, and to continue support of the Principal Investigators in performing their ground-based research and control experiments. In phase with the continuing sounding rocket flights and the buildup of Shuttle flight capabilities, we are planning to focus ground-based investigations and studies to support the on-going program and to generate new investigations for space flight (Chart 30). The following areas of Applications Research and Technology Development are an important program supplement and are therefore being emphasized to:

- o perform materials processing research in crystal growth, bioprocessing, solidification, and glass melting.
- o study the need for an ultra-high vacuum facility in near earth orbit and develop system concepts.
- o develop NASA/commercial user interfaces in the leasing of space flight hardware, marketing of space fabricated products, and the drafting of agreements on cooperative projects.

- o support interagency coordinated research in fields of measurements and standards (with NBS), glass speherical shells for implosion fusion targets (with DoE), infrared detection materials (with DoD), and bioprocessing technology (with NIH).
- o develop mission models and necessary data for Shuttle payload refurbishment and integration so as to allow mission planning and its coordination with both NASA and European flight opportunities.
- o initiate new areas of research by inviting proposals for ground-based research to be submitted at any time.

Space Communications

We are continuing to focus our communications satellite activity on two basic areas; the application of satellites to meet the communications needs of the public service community, and the development and demonstration of advanced, high-risk elements of space communications which are beyond the ability of the private sector.

Since early 1976, the Cooperative Applications Satellite (CAS-C), the experimental communications satellite developed jointly with Canada, has been supporting experiments and demonstrations of public service communications applications to education, health-care delivery, and community services, as well as technical investigations associated with radio performance at the 12 GHz frequency. ATS-6 was used very effectively in the educational television experiments in India and resumed operations with experimenters in the Western Hemisphere in January 1977, while the ATS-1 and ATS-3, early experimental satellites, are still operating after ten years in orbit. We are continuing an extensive program using all four satellites to provide a wide variety of experimental communications including emergency medical, public safety, disaster warning and relief, library retrieval, and other emerging applications of advanced communications satellites. During the coming year, we will continue these tests to establish the technical parameters of future generations of domestic satellites.

The Search and Rescue Satellite mission was initiated in FY 1978 in cooperation with the U.S. Coast Guard and Canada to provide early detection and the position of distress beacons carried by general aviation aircraft and some U.S. and foreign ships (Chart 31). This program has generated international interest and several foreign countries plan to take part. The French space agency has proposed to provide three flight units of a processor and receiver, a communications instrument that stores distress signals when the satellite is out of view of ground receive stations.

The French participation will provide equipment valued at several million dollars. The USSR Ministry of Merchant Marine and NASA have signed a "Protocol" on cooperation in search and rescue. The USSR is considering equipping one or more of its own satellites with communications transponders operating at the same frequency as NASA's and establishing a satellite ground receive station in the USSR. We have held technical discussions with Soviet personnel which we expect to continue in FY 1978.

In FY 1979, we plan to modify the NOAA spacecraft that will carry the search and rescue equipments. Additionally, the design of the new 406 MHz emergency beacons will be completed and a development contract awarded. The Department of Transportation and Department of Defense personnel are working with us in designing the new beacon and the Canadian Department of Communications is directly involved in this work. Canada will provide the three-frequency communications transponder for the spacecraft and the designs of the ground station. Planning for the test and evaluation phase involves the Canadian search and rescue agency.

In FY 1978, NASA initiated a study on the role of space technology to aid in monitoring ship traffic, including fishing vessels and tankers, within the 200 nautical mile coastal region. NOAA, the Maritime Administration and the U.S. Coast Guard are assisting NASA in the study, to be completed in FY 1979. It will examine the needs for improvement in ship monitoring, the systems to meet these needs and the estimated costs and benefits of new systems.

The Advanced Communications Research program provides a broad-based research and development capability in high-risk, high-benefit technology to support future communications applications and maintains a source of expertise on satellite communications. The program planning emphasizes the reduction of overall system cost to the user by making possible simple, small ground terminals using satellites with new, extensive capabilities in voice, video, data transmission. The coming era in communications satellites will require large, multibeam antennas for use with many small terminals, using computer-driven switching on the satellite to provide interconnections between the users of the many radio beams. These and similar systems concepts are developed and investigated with a goal to provide improvements in user access at acceptable circuit and ground hardware cost. Needed technological developments are identified by consulting with users and development experts in the private sector. This applied research in communications provides essential high-risk, high-benefit capabilities for eventual commercial implementation that can improve the U.S. position in the competition to provide new services principally for U.S. domestic small-terminal use; and the systems required by a rapidly-expanding second phase of foreign satellite communications systems deployment.

By this program we also continue to provide opportunities for improved use of our limited frequency spectrum, and make possible new and varied essential capabilities for data, television, and voice communications.

Advanced studies will be conducted on two promising future applications of satellite communications. These studies will develop conceptual designs for experimental satellite systems for nation-wide communications with land vehicles, and for electronic mail transmission via satellites.

Orderly growth of satellite services is dependent on the technical, regulatory and policy formulation support provided by our Technical Consultation Service (TCS) and Support Program. Problems being addressed include: inter-satellite radio frequency interference and spacing; interference between space and terrestrial systems such as radio astronomy, mobile and radio-location services; provisions for inter-satellite relay; frequency spectrum/orbit utilization; and the adverse effects of propagation phenomena.

Specialized studies are being conducted to ensure compatibility of the Office of Space and Terrestrial Applications programs with other radio services and to provide for an anticipated rapid growth in satellite services in the 1980's. The studies emphasize active and passive sensors, earth exploration satellites, meteorology, telecommunications for public services, land mobile satellite and search and rescue. Major progress has been made toward determining the future usefulness of frequency bands above 12 GHz for satellite applications through extensive propagation and storm cell measurements and modeling.

In the future, NASA intends to revitalize its efforts in communications research and development. This will be done with a view toward bringing into being the technology required to fulfill the nation's need for communications services that can be efficiently and effectively provided by space systems taking into consideration economics in both the space and ground segments.

Our studies, experiments and demonstration activities reveal that unfulfilled needs for communications services are found principally in the public sector. These include delivery of health care and education related services and the need for more effective means of communications in the field of public safety such as police, fire, disaster alerting and relief, and emergency medical service. Properly configured communications satellite systems have a demonstrated ability to lower the cost of communications service delivery and require only that the technology necessary to provide the volume and type of service needed be incorporated. However, the high cost of these developments and the technical risk associated with the success of the development inhibits the private sector's voluntarily undertaking such ventures.

As a consequence, NASA will undertake a program to identify, develop and demonstrate the types of communications satellite technologies required to make practical delivery of these communications services in the years ahead. Included are the antenna technologies required to produce multiple spot beams of city size that can be pointed at will and featuring reduction of side lobes to minimize interference; on board switching devices that vastly increase the number of users having independent access to the spacecraft; satellite transmission technology to open new, higher frequency bands at power levels that can overcome attenuation and minimize the complexity of the earth terminal; electrical power generation, conditioning and distribution technology to permit wide flexibility in the spacecraft of power usage; and attitude control system and station keeping technology required for precision antenna beam pointing and accurate orbit position control again to minimize earth station complexity. Successful development of these technologies will strengthen the U.S. industry in a time of surging foreign competition in the communications satellite field. It is envisioned that such technology efforts can be accomplished through cooperative arrangements with industry in which costs would be shared and transfer of the technology into use by the private sector accelerated.

The proposed redirection of NASA communications research and development program will:

- o Bring into being, delivery by the communications carrier industry, new communications services in the public and private sector.

- o Through cooperative programs with industry develop and demonstrate the high risk technology required to meet the nation's service needs of the future.
- o Strengthen the U.S. industries' ability to compete with heavily subsidized foreign industry (Chart 32).

Mr. Chairman, as I stated at the outset, my presentation, in keeping with the theme of the Applications Programs, has been structured around problems of major scope and national concern. I have tried to discuss spacecraft, space instruments, techniques, and supporting research in context of their specific application to these problems. Our planning and advisory interactions are geared specifically to the early identification of such problems so that research can be applied to the phenomena and processes whose understanding is essential to eventual application of space technology to the solution of such problems.

This is not to imply that we do not concentrate much of our effort on spacecraft and instrument development. In the years to come we will concentrate on system solutions to these problems, with emphasis on efficient use of spacecraft as general purpose observation platforms, on the use of spacecraft as an element in the overall system which includes data processing equipment on board and on the ground, data distribution and information dissemination on the ground, and effective systems management which involves many Federal and other government institutions as well as the private sector of the U.S. economy.

One activity which you have heard me discuss in the context of the major program thrusts which it serves is the development and flight of payloads for the Space Shuttle and its Spacelab system. One result of the recent NASA reorganization was the transfer of responsibility for coordinating the planning of all NASA payload activities to the Office of Space and Terrestrial Applications. This important integrated payload planning function in previous years, was budgeted for by the Office of Space Transportation Systems (OSTS). The function will be conducted in cooperation with the other payload program offices, the Office of Space Science, and the Office of Aeronautics and Space Technology. An integrated, well planned NASA payload program, will result in an efficient, effective use of the space flight opportunities provided by the Shuttle.

In the Office of Space and Terrestrial Applications, as in the other offices, the Space Shuttle will play a major role in our observation programs as a test bed for flight of instruments as they evolve from laboratory use, aircraft and sounding rockets testing, through Shuttle flights to eventual use on operational platforms delivered to orbit by Shuttle.

As discussed earlier, Shuttle/Spacelab flights also play a central role in our Materials Processing in Space program.

These brief remarks have covered the content of our major program thrusts, which, I believe, are timely and important, and will prove to be successful contributions to the betterment of mankind.

I have concentrated mostly on National and societal problems, and the programs to address them that are conducted in cooperation with Federal agencies that are mission oriented and largely responsible for solutions to these problems. Perhaps as important as these, and certainly demanding the most of our management skills, are state and local problems to which space and related technology are applicable. The aggregated benefits to the American people which can occur through our efforts to use the data, communications capabilities, technical skills, instruments and training, that are products of our major national programs, may be at least as great as the intended benefits from the primary thrust of our programs.

We are actively pursuing the realization of these important supplemental benefits through our Technology Transfer Program. We are working with the National Conference of State Legislatures and the National Governors Association to identify state and local needs to which our remote sensing and space related technologies can make a contribution. Through our Regional Remote Sensing Applications Program, in partnership with commercial interests, we have conducted many demonstration projects to show the utility and cost effectiveness of remote sensing data to such problems as urban planning, flood plain zoning, and strip mine monitoring. A major objective of this program is to involve the University community in training of users in uses and understanding of remote sensing data, and to develop effective mechanisms for commercial interests to provide services and capability to state and local users.

As you know, during the recent NASA reorganization, the Technology Utilization Program was transferred to the Office of Space and Terrestrial Applications. This brings, for the first time, the agency's efforts in technology transfer into a single organizational entity. We will, over the period of the coming year, examine various means to promote synergism between these programs and gain efficiencies by taking advantage of the strong points in each of these elements. I do not intend to make any changes precipitously.

Since Technology Utilization enjoys a deserved reputation for effectiveness, it will remain unchanged, pending our ability to strengthen and improve this important activity. In keeping with that plan, I have asked Mr. Lou Mogavero to present testimony for the Technology Utilization Program.

GRAPHICS IN SUPPORT OF CONGRESSIONAL TESTIMONY

Anthony J. Calio
Associate Administrator for
Space and Terrestrial Applications

February 7, 1978

| | |
|----------|---|
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ENERGY



AGRICULTURE



NATIONAL CONCERNS



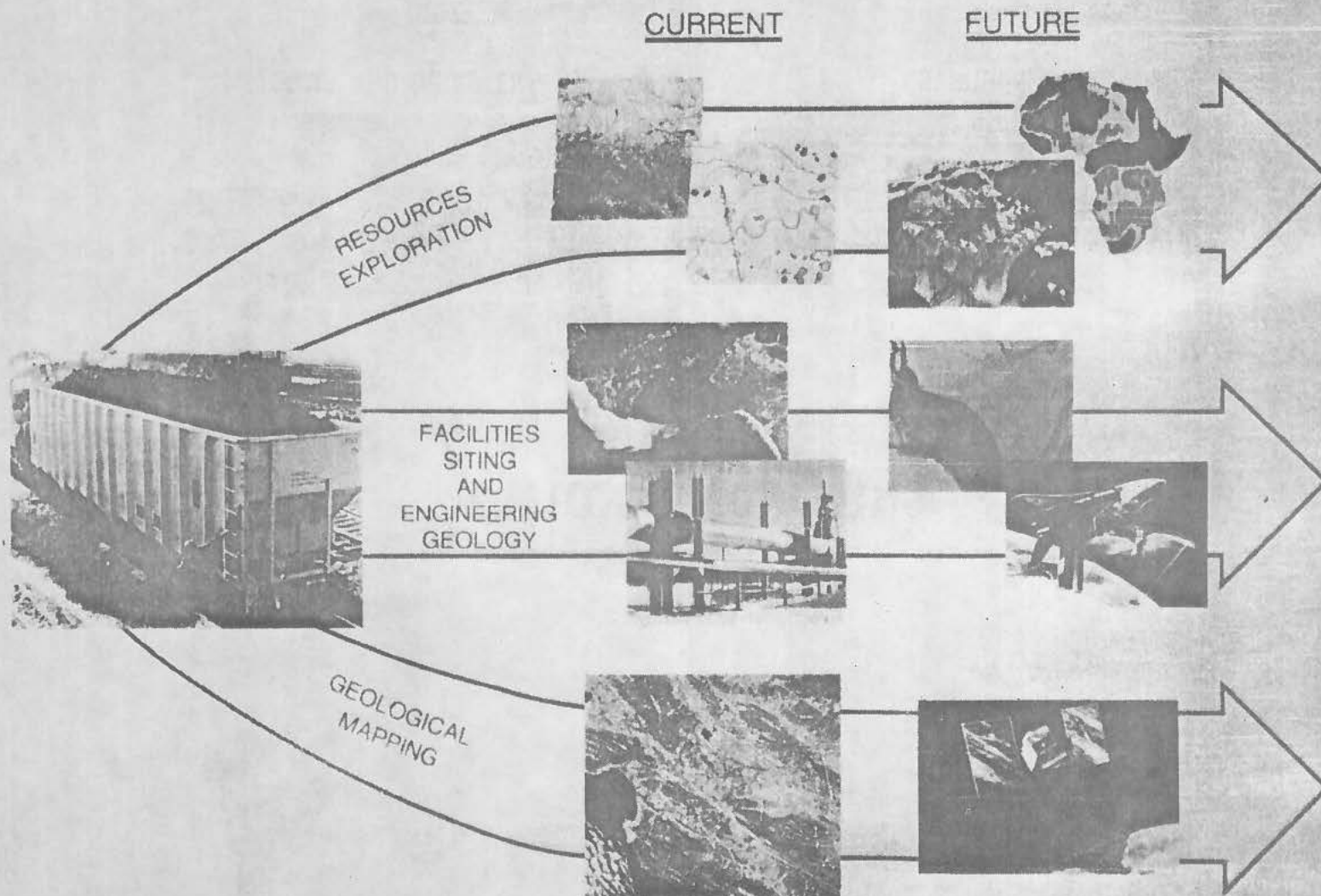
STORMS AND DISASTERS

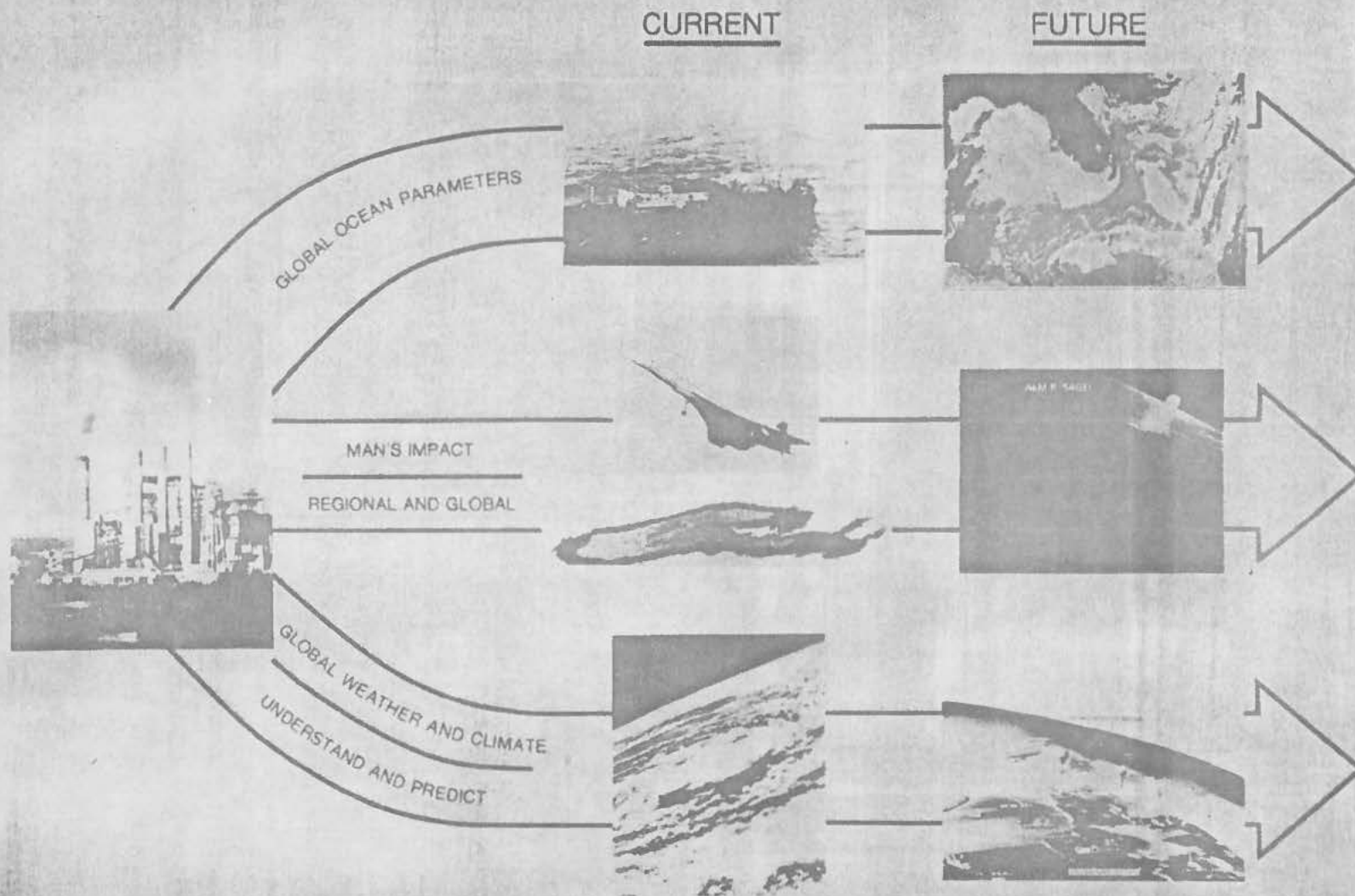


ENVIRONMENT

LARC-EOPG 1/78

NASA
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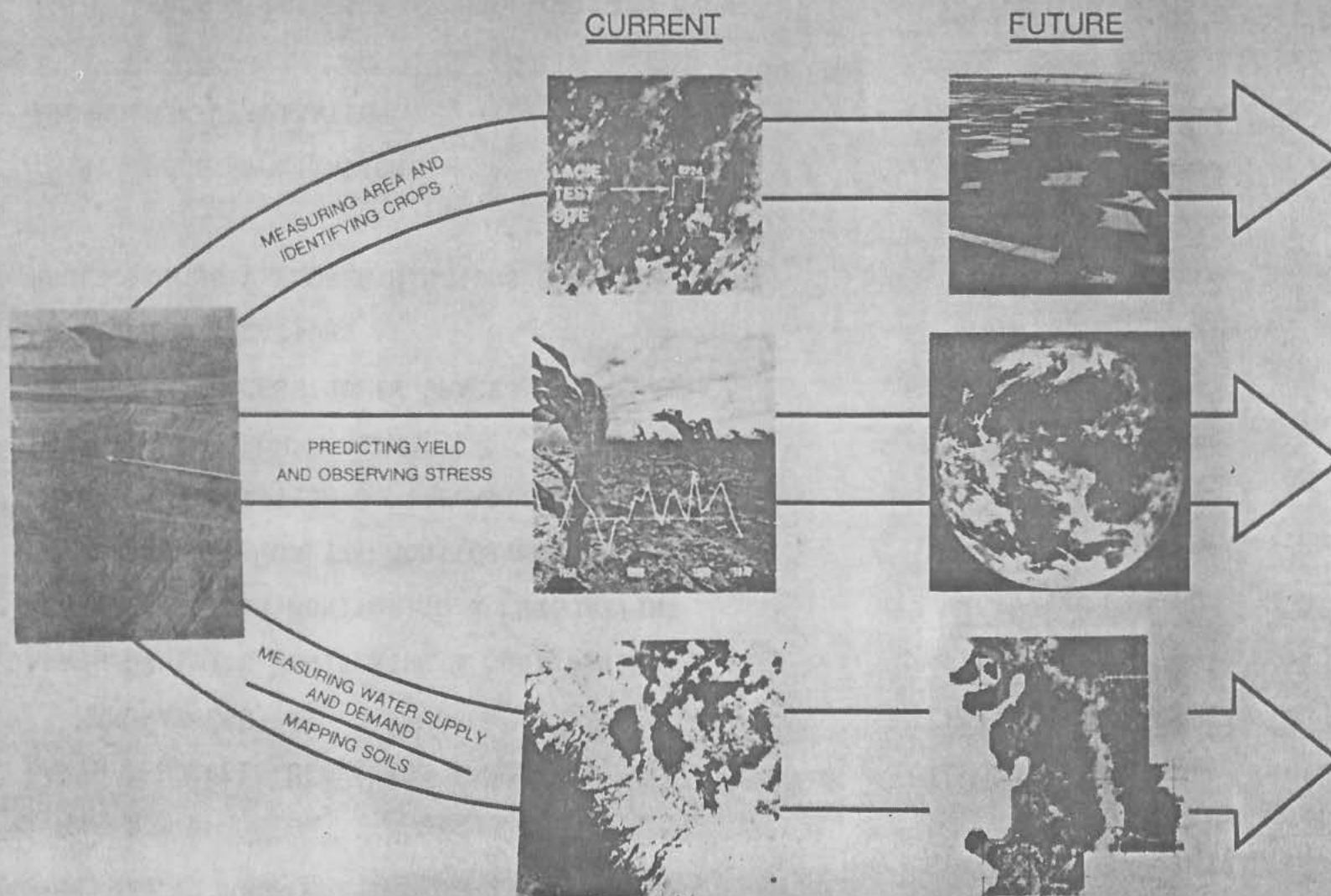




NASA

AGRICULTURE

OFFICE OF
SPACE AND TERRESTRIAL
APPLICATIONS



OFFICE OF SPACE AND TERRESTRIAL APPLICATIONS

(DOLLARS IN MILLIONS)

| | <u>FY 1978</u> | <u>FY 1979</u> |
|--|----------------|----------------|
| EARTH RESOURCES DETECTION & MONITORING | \$106.9 | \$151.5 |
| LANDSAT C&D | (51.4) | (98.2) |
| EARTH DYNAMICS MONITORING & FORECASTING | 7.2 | 8.6 |
| OCEAN CONDITION MONITORING & FORECASTING | 17.0 | 12.4 |
| ENVIRONMENTAL QUALITY MONITORING | 26.2 | 20.2 |
| WEATHER OBSERVATION & FORECASTING | 25.1 | 22.8 |
| CLIMATE RESEARCH PROGRAM | 2.5 | 12.2 |
| MATERIALS PROCESSING IN SPACE | 15.2 | 20.4 |
| SPACE COMMUNICATIONS | 21.2 | 22.0 |
| APPLICATIONS EXPLORER MISSIONS | 13.5 | 4.2 |
| | <hr/> | <hr/> |
| TOTAL SPACE APPLICATIONS | 234.8 | 274.3 |
| TECHNOLOGY UTILIZATION | 9.1 | 9.1 |
| | <hr/> | <hr/> |
| TOTAL SPACE & TERRESTRIAL APPLICATIONS | \$243.9 | \$283.4 |

LAUNCH SCHEDULE

OFFICE
OF
SPACE & TERRESTRIAL
APPLICATIONS

| PROJECT | 1978 | 1979 | 1980 | 1981 | 1982 |
|--|----------------|------------|------|----------------|------------------|
| LANDSAT | ^C △ | | | ^D △ | |
| HEAT CAPACITY MAPPING MISSION (HCMM) | △ | | | | |
| SEASAT-A | △ | | | | |
| MAGSAT | | | △ | | |
| NIMBUS-G | △ | | | | |
| STRATOSPHERIC AEROSOL GAS EXPERIMENT (SAGE) | | △ | | | |
| HALOGEN OCCULTATION EXPERIMENT (HALOE) | | | | ON S/L ▲▲ | WITH ERBSS ▲▲ |
| TIROS-N | △ | | | | |
| NOAA | | | | | |
| GOES | ^C □ | | | | |
| EARTH RADIATION BUDGET (ERBSS) | | | | | △ |
| SEARCH & RESCUE | | | | | ▲▲ (ON NOAA-E) |
| SHUTTLE | | OFT-2 △ | | S/L 3 △ | |

△ NASA LAUNCHES □ NOAA REIMBURSABLE LAUNCHES ▲▲ INSTRUMENTS ON OTHER LAUNCHES
* SUBJECT TO NOAA CALL-UP

NASA HQ ER78-1252 (1)
1-27-78

OFT-2 EXPERIMENTS

ACRONYMS

| | |
|-------|--|
| SMIRR | SHUTTLE MULTISPECTRAL INFRARED RADIOMETER (0018) |
| OCE | OCEAN COLOR EXPERIMENT (0061) |
| NOSL | NIGHT/DAY OPTICAL SURVEY OF THUNDERSTORM LIGHTNING (0081) |
| MAPS | MEASUREMENT OF AIR POLLUTION FROM SATELLITES (0098) |
| SERGE | SHUTTLE EXPERIMENTAL RADAR FOR GEOLOGICAL EXPLORATION (0137) |
| FILE | FEATURE IDENTIFICATION AND LOCATING EXPERIMENT |

0018 - SHUTTLE MULTISPECTRAL INFRARED RADIOMETER EXPERIMENT (SMIRR)

- OBJECTIVE -**
- o MEASURE RADIANCES OF WORLDWIDE GEOLOGIC SCENES
 - o DETERMINE VALUE OF BANDS CHOSEN TO SEPARATE LITHOLOGIC UNITS
 - o DETERMINE CORRELATION BETWEEN ORBIT RADIANCES AND FIELD SPECTROMETER DATA
 - o ASSESS VARIABLE ATMOSPHERIC ABSORPTION EFFECTS ON RADIANCE VALUES

- EQUIPMENT -**
- o NADIR TRACK, 100 METER IFOV, 10 CHANNEL RADIOMETER
 - o 20 CM DIAMETER TELESCOPE

- LOCATION-**
- o PAYLOAD BAY

CREW INVOLVEMENT -

- o KNOWLEDGE OF OBJECTIVES AND PURPOSE
- o TURN ON THERMAL CONTROL POWER SHORTLY AFTER LAUNCH AND OFF SHORTLY BEFORE REENTRY
- o START AND STOP INSTRUMENT ACCORDING TO CREW DECISIONS ON CLOUDINESS FACTORS

0061 - OCEAN COLOR EXPERIMENT OCE)

OBJECTIVE - o EVALUATION OF A PASSIVE OCEAN COLOR SENSING TECHNIQUE
FOR MAPPING CHLOROPHYLL

EQUIPMENT - o 10 CHANNEL SCANNING RADIOMETER (ADAPTED FROM U-2 SYSTEMS)
o TWO MODULES SCANNER PACKAGE
ELECTRONICS DATA COLLECTOR

LOCATION - o PAYLOAD BAY

CREW INVOLVEMENT -

- o KNOWLEDGE OF OBJECTIVES AND PURPOSE
- o TURNING EXPERIMENT ON AND OFF AT PRE-PLANNED POINTS WITHIN
THE FLIGHT TIMELINE.

0081 - NIGHTTIME AND DAYLIGHT OPTICAL SURVEY OF THUNDERSTORM LIGHTNING (NOSL)

- OBJECTIVE -
- o DEVELOPMENT OF LIGHTNING DETECTING SYSTEMS FOR METEOROLOGICAL SATELLITES
 - o DETAILED STUDY OF CONVECTIVE CIRCULATION IN STORMS AND RELATIONSHIP TO THE CHARACTER, LOCATION AND EXTENT OF LIGHTNING DISCHARGES
 - o STUDY ELECTRICAL CHARGING PROCESSES IN THUNDERSTORMS

- EQUIPMENT -
- o CINE -SOUND CAMERA/SENSOR (CANNON SUPER ZOOM)
 - o PHOTO-OPTICAL RECORDING SYSTEM
 - o 1,000 FT. OF KODACHROME 40 SOUND FILM - 1,000 FT EKTACHROME 160 SOUND FILM.

- LOCATION -
- o CABIN

CREW INVOLVEMENT

- o KNOWLEDGE OF OBJECTIVES AND PURPOSE
- o UNSTOW AND ASSEMBLE CAMERA EQUIPMENT
- o OBTAIN PHOTOS AND VOICE OVER VISUAL OBSERVATIONS

0098 - MEASUREMENT OF AIR POLLUTION FROM SATELLITE EXPERIMENT (MAPS)

OBJECTIVE - o MEASURE AND DEFINE CARBON MONOXIDE CONCENTRATIONS
IN THE MID AND UPPER TROPOSPHERE
o DEFINE EXTENT OF INTERHEMISPHERIC AIR MASS TRANSPORT
IN THE TROPOSPHERE
o EVALUATE THE SENSOR SYSTEM AND REMOTE SENSOR DATA ON A
WORLD WIDE BASIS

EQUIPMENT - o RUGGEDIZED NIMBUS G SENSOR EMPLOYING A GAS FILTER
CORRELATION TECHNIQUE

LOCATION - o PAYLOAD BAY

CREW INVOLVEMENT -

- o KNOWLEDGE OF OBJECTIVES AND PURPOSE
- o TURN EXPERIMENT ON AND OFF

0137 - SHUTTLE EXPERIMENTAL RADAR FOR GEOLOGICAL EXPLORATION (SERGE)

- OBJECTIVES -**
- o DEMONSTRATE THE POTENTIAL OF SPACEBORNE IMAGING RADARS FOR GEOLOGIC MAPPING, MINERAL EXPLORATION, PETROLEUM EXPLORATION AND FAULT MAPPING
 - o DEVELOP AND TEST NEW TECHNIQUES FOR EXTENDING SENSOR SPECTRAL COVERAGE TO NEW PORTIONS OF THE ELECTROMAGNETIC SPECTRUM

- EQUIPMENT-**
- o A SYNTHETIC APERTURE IMAGING RADAR (SEASAT L-BAND)
 - o APOLLO OPTICAL RECORDER (MODIFIED TO INCREASE FILM CAPACITY)

- LOCATION -**
- o PAYLOAD BAY

CREW INVOLVEMENT -

- o KNOWLEDGE OF OBJECTIVES AND PURPOSE
- o INITIATE AND TERMINATE EXPERIMENT OPERATION AT PREPLANNED TIMES BY OPERATING CONTROL SWITCH LOCATED ON THE AFT DECK

OFT-2 EXPERIMENTS

| EXPERIMENT | PI | PHONE |
|------------|--|---|
| 0018 SMIR | Dr. Alexander F. H. Goetz Jet Propulsion Laboratory | FTS 792-3254 CML 213-354-3254 |
| 0061 OCE | Mr. Hongsuk H. Kim Goddard Space Flight Center | FTS 982-6465 CML 301-982-6465 |
| 0081 NOSL | Dr. Bernard Vonnegut SUNY-Albany | FTS 562-4411 (Opr) CML 518-457-4607 |
| | Mr. Otha H. Vaughn, Jr. (Co-I) Marshall Space Flight Center | FTS 872-5218 CML 205-453-5218 |
| 0098 MAPS | Dr. Henry G. Reichle, Jr. Langley Research Center | FTS 928-2576 CML 804-827-2576 |
| 0137 SERGE | Dr. Charles Elachi Jet Propulsion Laboratory | FTS 792-5673 CML 213-354-5673 |
| FILE | Mr. Rogert T. Schappell Martin Marietta - Denver | FTS 327-0111 (Opr) CML 303-979-7000, ext. 4279 |
| | Mr. R. Gale Wilson (Co-I) Langley Research Center | FTS 928-3551 CML 804-827-3551 |

OFT 2 CANDIDATE PAYLOAD STUDY

Experiment Systems Division-ED
Lyndon B Johnson Space Center



C. J. LE BLANC

4-22-77

● OFT 2 FLIGHT SUMMARY (CONTINUED)

CURRENT OFT 2 MISSION CHARACTERISTICS

- TWO CREWMEN
- NO ASCENT OR DESCENT PAYLOAD DISPLAY AND CONTROL MONITORING
- 16 HOURS AWAKE: 8 HOURS SLEEP (SIMULTANEOUS)
- NO EXTRAVEHICULAR ACTIVITY SCHEDULED WITH 2-MAN CREW
- TRAINING REQUIREMENTS NOT TO EXCEED 40 HOURS PER CREWMAN FOR PAYLOADS
- LANDING AT EDWARDS AIR FORCE BASE
- PLANNED LAUNCH DATE JULY 1979
- 5 DAY FLIGHT (APPROXIMATELY 125 HOURS)
- NOMINAL 150 NAUTICAL MILE CIRCULAR ORBIT WITH A 38 DEGREE INCLINATION
- FLIGHT EVENTS TIMELINE: OPEN PAYLOAD BAY DOORS AT 01:32:00 GET: CLOSE PAYLOAD BAY DOORS AT 121:36:00 GET

OFT 2 CANDIDATE PAYLOAD STUDY

Experiment Systems Division-ED
Lyndon B. Johnson Space Center



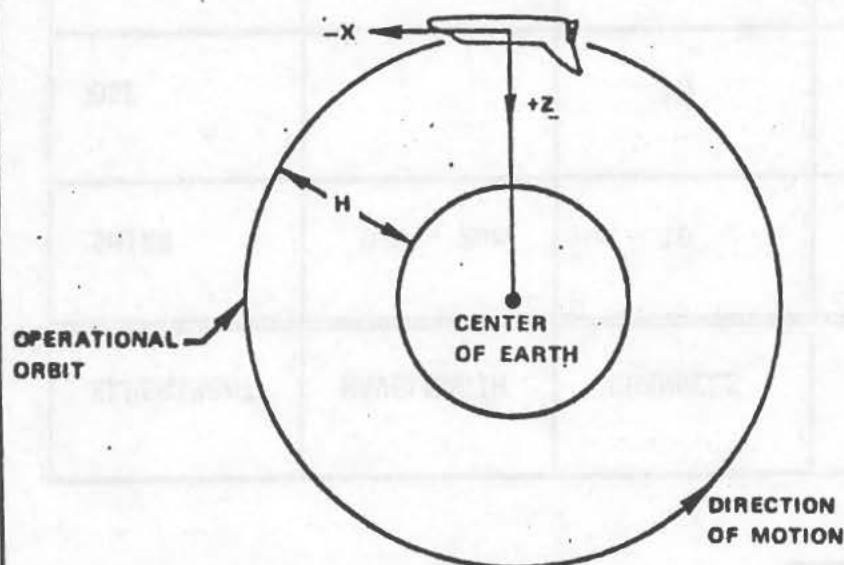
C. L. LE BLANC

4-22-77

● OFT 2 FLIGHT SUMMARY (CONCLUDED)

CURRENT OFT 2 MISSION CHARACTERISTICS (CONCLUDED)

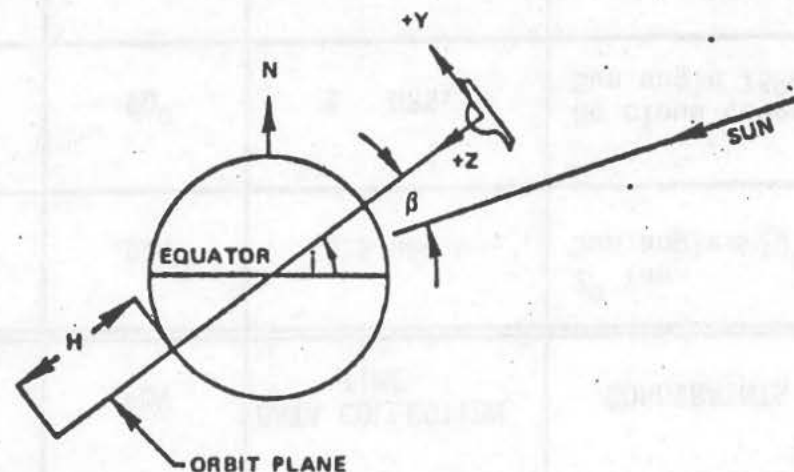
- THERMAL TESTS REQUIRE AN ORBITER ATTITUDE OF +Z LOCAL VERTICAL TOWARD EARTH (PAYLOAD BAY TOWARD EARTH) WITH -X FORWARD IN THE ORBIT PLANE FOR 96 HOURS
- APPROXIMATELY 95 PERCENT OF FLIGHT CONSUMED BY THERMAL TEST ACTIVITIES
- DURING THERMAL TEST PERIOD, OPPORTUNITIES EXIST FOR EARTH VIEWING PAYLOADS



OFT 2 THERMAL TESTS ATTITUDE

-X (ORBITER NOSE) FORWARD IN ORBIT PLANE

+Z (PAYLOAD BAY) ALONG RADIUS VECTOR TOWARD CENTER OF EARTH



OFT 2 GEOMETRY

BETA ANGLE (β) = 1.6°

INCLINATION (i) = 38°

BASE ALTITUDE (H) = 150 N. MI.

ORBIT PERIOD = 90.1 MIN

% SUNLIGHT = 59.4

(AVERAGE DAY 1 β = -7.8°
DAY 5 β = +10.9°)

OFT-2 EXPERIMENTSKEY PARAMETERS

| EXPERIMENT | WAVELENGTH | CHANNELS | DATA RATE | IFOV | DATA COLLECTION TIME | CONSTRAINTS |
|------------|-----------------|----------|-------------|------------------------------|----------------------|---|
| SMIRR | 0.6 - 2 μ m | 10 | 8 KBPS | .014 $^{\circ}$ | 3.5 HRS. | 2 $^{\circ}$ Yaw Sun angle $\leq 70^{\circ}$ |
| OCE | | 10 | 122 KBPS | 90 $^{\circ}$ | 2 HRS. | No cloud cover Sun angle 15 $^{\circ}$ -90 $^{\circ}$ |
| NOSL | Visible | - | Film | 38 $^{\circ}$ | 1 HR. | Thunderstorms in FOV |
| MAPS | Visible | - | Film & Tape | 4.33 $^{\circ}$ | 96 HRS. | |
| SERGE | 1.725 GHz | | 20 MB | 6 $^{\circ}$ x 40 $^{\circ}$ | 8 HRS. | 50 $^{\circ}$ off nadir |
| FILE | | | Film | | 30 MIN. | ZLV + 30 $^{\circ}$ Sun angle 60 $^{\circ}$ -90 $^{\circ}$ |

OFT-2 EXPERIMENTS

TIME - POWER REQUIREMENTS

| EXPERIMENT | STANDBY/WARM UP | | DATA COLLECTION | | |
|------------|-----------------|-------|-----------------|--------|------|
| | TIME | WATTS | TIME | WATTS | |
| | | | | NORMAL | PEAK |
| SMIRR | 1 HR. | 70 | 3.5 HRS. | 120 | 150 |
| OCE | 1 MIN. | 50 | 2 HRS. | 160 | 160 |
| NOSL | - | - | 1 HRS. | - | - |
| MAPS | 2 HRS. | 80 | 96 HRS. | 105 | 105 |
| | (30 MIN. CAL) | (95) | | | |
| SERGE | 1 HR. | 34 | 8 HRS. | 750 | 850 |
| FILE | 95.5 HRS. | 9 | 30 MIN. | 40 | 40 |

Skylab

EARTH RESOURCES INVESTIGATIONS



FEBRUARY 1973



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF MANNED SPACE FLIGHT / OFFICE OF APPLICATIONS

FOREWORD

Remote sensing of the Earth from orbital altitudes has the potential of yielding information which is of fundamental importance for effective use and conservation of natural resources in both underdeveloped and technologically advanced nations. Skylab offers a unique opportunity for an expansion of earth resources remote sensing technology by carrying relatively large, flexible and high performance sensors and by utilizing the crew to operate them in laboratory fashion.

The Earth Resources Experiment Package (EREP) on Skylab will test and validate remote sensing techniques over a wide spectral region from orbital altitudes. Specifically, five experiments in the EREP will permit simultaneous remote sensing of ground test sites in the visible, infrared and microwave spectral regions. These Skylab data will be correlated with information obtained about the ground sites from aircraft and/or from on site measurements. Particular emphasis will be placed on validating the utility of spectral signature identification from orbital altitudes.

In December 1970 NASA announced that data to be acquired by the EREP facility could be made available to qualified users for investigations in the earth resources disciplines. Proposers were also encouraged to consider the use of data acquired by the automated Earth Resources Technology Satellite (ERTS) and instrumented aircraft and to describe requirements for ground measurements at the sites to be observed. In response to this announcement approximately 300 proposals, both domestic and foreign, were received from universities, industry and local governments and research organizations.

The data user program, as currently defined, is composed of approximately 164 individual tasks to be accomplished by Principal Investigators located in 32 states and 19 foreign countries. These tasks are defined by number, principal investigator, and location in the following pages.

The purpose of this document is to provide a ready reference for all users and potential users of EREP data, to inform them of investigations to be conducted and to facilitate the exchange of ideas, results, and applications.

SKYLAB EREP - TASK NUMBERING SYSTEM

| | | | | | |
|------------------|-----|-----------|------------------------------------|-----|--|
| | | 1st Digit | Major Discipline | | |
| | 100 | | <u>AGRICULTURE/RANGE/FORESTRY</u> | 500 | <u>ATMOSPHERIC INVESTIGATIONS</u> |
| Subdiscipline | | | 01 to 15 CROP INVENTORY | | 01 to 15 STORMS, FRONTS, AND CLOUDS |
| | | | 16 to 30 INSECT INFESTATION | | 16 to 30 RADIANT ENERGY BALANCE |
| 2nd & 3rd Digits | | | 31 to 45 SOIL TYPE | | 31 to 45 AIR QUALITY |
| | | | 46 to 60 SOIL MOISTURE | | 46 to 60 ATMOSPHERIC EFFECTS |
| | | | 61 to 75 RANGE INVENTORY | | |
| | | | 76 to 90 FOREST INVENTORY | 600 | <u>COASTAL ZONES, SHOALS, AND BAYS</u> |
| | | | 91 to 99 FOREST INSECT DAMAGE | | 01 to 15 CIRCULATION AND POLLUTION IN BAYS |
| | 200 | | <u>GEOLOGICAL APPLICATIONS</u> | | 16 to 30 UNDERWATER TOPOGRAPHY AND SEDIMENTATION |
| | | | 01 to 20 MAPPING | | 31 to 45 BATHIMETRY |
| | | | 21 to 40 METALS EXPLORATION | | 46 to 60 COASTAL CIRCULATION |
| | | | 41 to 55 HYDRO CARBON EXPLORATION | 700 | 61 to 75 WETLANDS ECOLOGY |
| | | | 56 to 70 ROCK TYPES | | <u>REMOTE SENSING TECHNIQUES DEVELOPMENT</u> |
| | | | 71 to 85 VOLCANOS | | 01 to 15 PATTERN RECOGNITION |
| | | | 86 to 99 EARTH MOVEMENTS | | 16 to 30 MICROWAVE SIGNATURES |
| | 300 | | <u>CONTINENTAL WATER RESOURCES</u> | | 31 to 45 DATA PROCESSING |
| | | | 01 to 15 GROUND WATER | | 46 to 60 SENSOR PERFORMANCE EVALUATION |
| | | | 16 to 30 SNOW MAPPING | 800 | <u>REGIONAL PLANNING AND DEVELOPMENT</u> |
| | | | 31 to 45 DRAINAGE BASINS | | 01 to 15 LAND USE CLASSIFICATION TECHNIQUES |
| | | | 46 to 60 WATER QUALITY | | 16 to 30 ENVIRONMENTAL IMPACTS - SPECIAL TOPICS |
| | 400 | | <u>OCEAN INVESTIGATIONS</u> | | 31 to 50 STATE AND FOREIGN RESOURCES |
| | | | 01 to 15 SEA STATE | | 51 to 65 URBAN APPLICATIONS |
| | | | 16 to 30 SEA/LAKE ICE | | 66 to 80 COASTAL/PLAINS APPLICATIONS |
| | | | 31 to 45 CURRENTS | | 81 to 95 MOUNTAIN/DESERT APPLICATIONS |
| | | | 46 to 60 TEMPERATURE | 900 | <u>CARTOGRAPHY</u> |
| | | | 61 to 75 GEODESY | | 01 to 15 PHOTOMAPPING |
| | | | 76 to 90 LIVING MARINE RESOURCES | | 16 to 30 MAP REVISION |
| | | | | | 31 to 45 MAP ACCURACY |
| | | | | | 46 to 60 THEMATIC MAPPING |

EXAMPLES:

Task 117 is an Ag/Range/For. Discipline,
studying insect infestation.

Task 903 is Cartography, Photomapping

SKYLAB

EARTH RESOURCES EXPERIMENT PACKAGE

200 SERIES

GEOLOGICAL APPLICATIONS

Geomorphology, soil erosion, volcanic activity, resources and environment, geothermal anomalies, lithology, surface water loss, fault tectonics, earthquake hazards, geologic mapping, mineral exploration, highway engineering.

| Task No. | Principal Investigator and Affiliation. | Investigation | Test Site(s) |
|----------|---|---|---------------------|
| MAPPING | | | |
| 201 | Dr. Robert S. Houston Department of Geology University of Wyoming | Analyze EREP imagery using stereoscopic viewers and color additive viewers for a first-look evaluation of the data. Illustrate positive and negative results of the analyses. | Wyoming |
| 202 | Dr. H.E.C. Van Der Meer Mohr I.T.C. The Netherlands | Evaluate the potential of EREP data for geological mapping in Spain. Compare results of EREP data analysis with geologic maps. | Spain |
| 203 | Professor Richard Hoppin Department of Geology The University of Iowa | Interpret EREP imagery data to detect and map (a) possible rejuvenated crustal fractures; (b) suspected township-sized structural blocks; (c) correlations of glacial land forms and ancient nonglacial surfaces; and (d) major rock types. Compare ERTS and EREP imagery to evaluate atmospheric effects on mapping. | Wyoming/ Montana |
| 204 | Dr. N. H. Fisher Bureau of Mineral Resources Geology and Geophysics Australia | Evaluate the use of EREP imagery for agricultural, forestry, geologic, hydrologic, and geographical studies in three geographic areas of Australia. Prepare maps from the data. | Australia |
| 205 | Dr. Keenan Lee Colorado School of Mines | Use photointerpretation of EREP imagery, field checking, and previously existing information to map geological features in the Silverton-Ouray, Salida, and Leadville-Climax areas. | Colorado |

200 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|---|---|-----------------|
| 206 | Dr. Dieter Bannert Geological Survey of the Federal Republic of Germany | Analyze (with multispectral techniques) geological structures, distribution of rock types, marine sediment transport, interaction between industrial and urban pollution and land use, distribution of glacial sediments and their soils. Investigate the suitability of space imagery for small scale map production. Study automatic image processing for mapping and calibration purposes. | Germany |
| 207 | Dr. H.T.U. Smith Geology Department University of Massachusetts | Study type, pattern, color, lateral variations, form, spacing orientation, and geologic factors which control dune fields in the Namib and Kalahari Deserts of southwest Africa. | Southern Africa |
| 208 | Jack Ouade Mackay School of Mines University of Nevada | Use field studies, RB-57 multiband photographs, and EREP S190 photographs to evaluate the utility of multiband photographs for distinguishing between geological units, mapping geological structures, and identification of major drainage basins features in Nevada. | Nevada |
| 209 | Jacques Guillemot Institute Francais Du Petrole France | Assess aircraft, balloon and ERF imagery at various scales to develop a synthesis of the major geologic alignments while delimiting the mutual influence zones of the tectonic systems between the Eastern Pyrenees to the Southern Alps. | Southern France |
| 210 | Dr. Klaus Giessner Geographisches Institut University of Technology Federal Republic of Germany | Use S190A, S190B, and S192 data for preparation of geologic and geomorphic maps. Visually interpret imagery using color enhancement and compare with field data. The main interest being geomorphology and the factors such as vegetation, hydrology, type of soil, and erosion which affect the landscape. | Tunisia |

200 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|---------------------------|--|---|---|
| 211 | Dr. Peter Kronberg Geological Institute Tu Clausthal West Germany | Interpret enhanced imagery for a photogeology study of the Afar Triangle Area of Ethiopia. Make 1:500,000-scale geological and tectonic maps from the interpretation and compare to existing field geology and geophysical maps. | Ethiopia |
| METALS EXPLORATION | | | |
| 221 | Dr. M. L. Jensen Department of Geological & Geophysical Sciences University of Utah | Interpret S190 and S192 imagery, visually and by means of densitometry and additive color viewing, to identify fracture patterns, offset of formations, rock color differences, and vegetation patterns. Correlate features identified with known mineral deposits. | Nevada Utah |
| 222 | Ira C. Bechtold Argus Exploration Company Cyprus Mines Corporation | Evaluate and compare EREP data and its correlation with existing data including Apollo earth-looking photography, ERTS-A imagery, NIMBUS High Resolution Infrared data, geophysical data, X-15 photography, SLAR, and other information to be used in the interpretation of geology and tectonics in the test site areas. | Arizona Nevada California Utah |
| 223 | Dr. George J. McMurtry Office for Remote Sensing of Earth Resources The Pennsylvania State University | Study the various scales of EREP, ERTS and aircraft imagery of the Susquehanna River Basin to characterize and classify gross geologic structure and tectonic features. Correlate the observable features to ground truth to develop information and recognition techniques for geologic interpretation. Evaluate the use of spacecraft remote sensing for geologic interpretations and for predicting favorable locations for mineral exploration. | Pennsylvania |
| 224 | Dr. Fernando de Mendonca INPE Brazil | Perform sensor evaluations and inventory agricultural resources in Brazil. | Brazil |

200 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|--|--|---------------------|
| 225 | Professor R. M. Shackleton Research Institute of African Geology University of Leeds England | Study and develop the uses to which satellite imagery can be used for geological purposes. Prepare structural and lithological maps of a large area of Ethiopia. Compare the results with ERTS data. | Ethiopia |
| 227 | Dr. Jose Antonio Galavis Ministry of Mines and Hydrocarbons Venezuela | Analyze data by standard photo-interpretation techniques with possibly selected portions of imagery subjected to enhancement techniques, and prepare overlays of Universal grid, water borne pollution, shoreline geometry, surf and submarine morphology, ocean circulation patterns, beach mineral composition, fresh/saltwater interfaces, geologic and tectonic features, seismic related geological hazards and areas of potential economic interest. | Venezuela |
| 228 | Eduardo J. Methol Direccion Nacional de Geologia y Minería Argentina | Investigate the use of imagery for regional geologic mapping and exploration for mineral deposits. Use mapping of regional faults, fractures, and structures for the location of minerals. | Argentina |
| 229 | Coronel Ingeniero Militar D. Rodolfo Liendo Soula Argentina | Investigate the use of multi-spectral photography for the exploration of the natural resources of northern Argentina. | Argentina |
| 230 | Dr. Luis Del Castillo Univ. Nal. Aut. De Mexico Instituto De Geofisica De Exploracion CD. Universitaria Mexico | Determine the usefulness of Skylab data for metals exploration and mining activities in Mexico. | Mexico (Durango) |

HYDRO CARBON EXPLORATION

| | | | |
|-----|---|--|----------|
| 241 | Dr. Robert J. Collins, Jr. Eason Oil Company | Compare the content of geological information in EREP imagery of the Test Site Area with that of ERTS-A and aircraft imagery. Evaluate the usefulness of EREP imagery for the location of potential accumulations of hydrocarbons. | Oklahoma |
|-----|---|--|----------|

200 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|---|--|--------------------|
| 243 | Carlos Castillo-Tejero Instituto Mexicano del Petroleo Mexico | Determine the application of space remote sensing data to hydrocarbon exploration. | Mexico (Chihuahua) |

ROCK TYPES

| | | | |
|-----|---|---|-------------------|
| 256 | Robert K. Vincent Environmental Research Institute of Michigan The University of Michigan | Determine whether or not EREP data can be used to differentiate silicate rock types and produce recognition maps of ferric and ferrous compounds in exposed rocks and soils. Analyze S191 and S192 data from two lava flows at Pisgah Crater, California. | California |
| 257 | Dr. Kenneth Watson U.S. Geological Survey | Discriminate rock and soil units and zones of mineralization; determine their physical characteristics and develop criteria for remote identification of these units in two sites that offer excellent exposures of materials having a broad range of composition and surface states. | California |
| 258 | Dr. Alexander F. H. Goetz Jet Propulsion Laboratory | Calibrate S190A, S190B, S192 imagery and S191 data radiometrically with spectral data from an aircraft underflight simultaneous with the EREP pass and ground-based spectral data to solve problems. | Northwest Arizona |
| 259 | Dr. Ronald J.P. Lyon School of Earth Sciences Stanford University | Test the feasibility of determining the composition of geological targets when seen through a long atmospheric column (S191) for determining the surface composition of geologic units in large, vegetation-free areas of the earth's surface. | Nevada |

VOLCANOS

| | | | |
|-----|---|---|-------|
| 271 | Professor Roberto Cassinis Geolab Italy | Compare interpretation of EREP data to the actual situation in the field to enable control of the extension of volcanic and related phenomena, tectonic characteristics and environmental quality. Prepare a series of thematic maps. | Italy |
|-----|---|---|-------|

200 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|---|---|-----------------|
| 272 | Dr. Richard E. Stoiber Department of Earth Sciences Dartmouth College | Interpret nighttime S192 thermal infrared imagery of Central America to identify hot water, lava, and steam associated with volcanos. Interpret the regional infrared pattern to determine the relationship between volcanos, active faults, and hydrothermal features. | Central America |
| 273 | Dr. J. Bodechtel Institut fur Allgemeine und Angewandte Geologic und Mineralogie der Universitat Munchen West Germany | Investigate the use of EREP data for the geologic, hydrological and oceanographic interpretation of the Tuscan Appenine Regine of Italy. | Italy |
| 274 | Dr. Franz K. List Free University of Berlin Germany | Identify the different lithological and structural units of the Tibesti Mountains of Chad, and determine if the mountains are located at the junction of two major fracture systems. | Central Africa |
| 275 | Troy A. Crites Kent Jr. High School Kent, Washington | Investigate the feasibility of predicting volcano eruptions using thermal infrared data obtained by remote sensors. | Central America |
| 276 | Arturo Gonzalez Salazar Comision Federal de Electricidad Mexico | Study volcanic activity and thermal patterns in NW Mexico. | N.W. Mexico |

EARTH MOVEMENTS

| | | | |
|-----|---|--|---|
| 286 | Dr. Paul M. Merifield Earth Science Research Corporation | Detect and map previously unrecognized faults in southern California and develop criteria for the detection of active versus inactive fault zones. | Southern California |
| 287 | Dr. Monem Abdel-Gawad North American Rockwell Corporation | Determine the utility of Skylab S190 photographs for the detection of fault and tectonic line intersections, and analyze in terms of bearing on theories of crustal structure, the distribution of mineral deposits, and the location of active fault zones. | Southern California, Nevada, New Mexico |

200 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|-----------------|--|--|---------------------|
| 288 | Dr. Charles Wier Department of Natural Resources Indiana Geological Survey | Visually analyze S190A, S190B, and S192 imagery, by additive color techniques and by density coding techniques, to detect geologically significant structural lineaments. Compile information on mine safety, roof and wall collapses, known underground fractures, and basic geology of the test site. | Indiana |
| 289 | Dr. Jose Antonio Galavis Ministry of Mines and Hydrocarbons Venezuela | Analyze data by standard photo-interpretation techniques with possibly selected portions of imagery subjected to enhancement techniques, and prepare overlays of Universal grid, water borne pollution, shoreline geometry, surf and submarine morphology, ocean circulation patterns, beach mineral composition, fresh water/saltwater interfaces, geologic and tectonic features, seismic related geological hazards and areas of potential economic interest. | Venezuela |

SKYLAB

EARTH RESOURCES EXPERIMENT PACKAGE

300. SERIES

CONTINENTAL WATER RESOURCES

Mapping snow field distribution and water equivalent, investigating soil moisture distribution in plains area, measuring ice parameters, charting and cataloging estuary effluents, measuring changes in migratory bird habitats, delineation of good quality ground water and areas of high saline, and monitoring of flood control.

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|--|---------------|--------------|
|----------|--|---------------|--------------|

GROUND WATER

| | | | |
|-----|--|---|---------------------|
| 301 | Gerald K. Moore Water Resources Division USGS | Investigate S190 photographs and S192 images of the test site to identify lineations, and compare these features with the known faults. Correlate regional fracture zones with the location of abundant ground-water supplies. Verify the correlation by drilling test holes. | Tennessee |
| 302 | Dr. Dieter Bannert Geological Survey of the Federal Republic of Germany | Search for fresh ground water in the Pampa of Argentina using vegetation as an indicator of fresh or salt water aquifers and saline soils and using imagery from the S190A, S190B, and S192 Skylab instruments. | Argentina Pampas |
| 303 | Dr. Roger B. Morrison USGS | Identify and map: (a) End-moraine systems of the last glaciation, (b) end-moraine systems which may be buried by younger glacial drift and loesses, (c) buried river valleys, and four middle and early Pleistocene river terrace sequences along the main rivers. Use EREP sensor data from Skylab to extend the knowledge of the above features. | Great Plains USA |

300 SERIES (Continued)

Task Principal Investigator
No. and Affiliation

Investigation

Test Site(s)

SNOW MAPPING

- | | | | |
|-----|--|--|---|
| 317 | Professor Dr. Harold Haefner Department of Geography University of Zurich Switzerland | Determine the areal extent of snow cover in the Alps and Pre-Alps to develop a model of the relation between snow cover and vegetation growth and between snow cover and surface runoff. Study surface temperatures of lakes, glaciers and snowfields, determine national glacier inventory, and for avalanche prediction. | Switzerland |
| 318 | James C. Barnes Environmental Research & Technology, Inc. | Compare and evaluate the Skylab/ EREP spectral regions and operating modes for mapping of snow cover. Assess the extent of snow cover in the U.S. water resources. Use EREP data to determine how much additional information on areal extent of snow can be obtained from various spectral bands, thermal data, and microwave data. | California, Idaho/ Montana, North Central U.S. |

DRAINAGE BASINS

- | | | | |
|-----|---|--|--------------|
| 331 | Fabian C. Polcyn Environmental Research Institute of Michigan The University of Michigan | Perform a land use and standing-water inventory of portions of the Lake Ontario drainage basin, measure soil moisture content in selected areas of the basin, and map the pattern of surface currents in the western part of the Lake. Compare EREP data with A/C and ground truth data. | Lake Ontario |
| 332 | Dr. Victor R. Baker Department of Geological Sciences The University of Texas | Perform a stream network analysis of the Guadalupe River Basin in Central Texas. | Texas |
| 333 | Dr. Robert N. Colwell School of Forestry and Conservation University of California | Classify data to indicate general management zones, vegetation/ terrain types, vegetation cover, boundaries of watershed and stream channels, geology/soils, and sequential boundaries of snow-covered areas. | California |

300 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|--|--|---|
| 335 | Dr. R. B. Morrison USGS | Identify and map large areas of recent gully erosion of south-central Arizona. Detect and identify areas susceptible to rapid soil erosion and sheet-wash, for use in planning urban development, zoning, and in reclamation of watersheds, farmlands, and rangelands. | Arizona Regional Ecological Test Site (ARETS) |
| 336 | Dr. Gunther Stuckmann Geographisches Institut University of Technology West Germany | Interpret color enhanced imagery and annotate with results of field studies for mapping of fossil drainage systems in Niger. Map structures, lithology, ground and surface water, and drainage patterns for land use studies. | Niger |
| 337 | Dr. G. Gummerman Prescott College | Delineate small vegetational communities and associated plant-water relationships and animal species. Define geometric characteristics of small drainage basins, and subenvironments by mapping vegetation communities. Measure area, subdivisions, stream length, slope, and stream order numbers to estimate the water available for each significant location within the basin. | Arizona |
| 338 | Saul Cooper Reservoir Control Center U.S. Army Corps of Engineers | Correlate the apparent extent of floods as shown on EREP imagery with data from an extensive network of stream and reservoir gauging stations, ERTS, and aircraft data to determine the utility of EREP photography for flood/land use/vegetation in Connecticut and Merrimack River Valleys. | Connecticut |

WATER QUALITY

| | | | |
|-----|---------------------------------------|--|------------|
| 346 | Dr. Kenneth R. Piech Calspan, Inc. | Develop interpretation techniques for satellite monitoring of lake turbidity and eutrophication. Obtain accurate turbidity measures of recreational fresh-water lakes and study eutrophication processes of three lakes important to New York State water resources. | N.Y. State |
|-----|---------------------------------------|--|------------|

300 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|--|--|------------------------|
| 347 | Harold L. Yarger Kansas Geological Survey University of Kansas | Determine the spectral reflectance of several Kansas reservoirs from S190A, S190B, and S192 data, and determine the correlation of water color with water depth, turbidity, and algae content. | NW Kansas |
| 348 | Robert Horvath Environmental Research Institute of Michigan The University of Michigan | Determine the feasibility of using remote sensing from space to detect, locate, and map the areal extent of oil slicks on water resulting from illegal or or in-effective shipping practices and from major pollution incidents. | California & Louisiana |
| 349 | Dr. K.P.B. Thomson Canada Centre for Inland Waters Canada | Evaluate Skylab data for limnological research and water management studies in order to use satellite acquired data to supplement, and in some cases replace, data collected by ship surveys. | Lake Ontario |

500 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|--|--|--------------------------------------|
| 519 | Joseph B. Zmolek Lourdes High School Oskosh, Wisconsin | Determine the attenuation of radiation in the visible and near IR regions caused by the the earth's atmosphere over industrialized and non-industrialized sites. | Four Corners White Sands, HATS |

AIR QUALITY

ATMOSPHERIC EFFECTS

| | | | |
|-----|--|--|---|
| 546 | Dr. Thomas L. Barnett NASA-MSD | Develop methods to permit operational satellites to collect their own correction data through comparison of mathematical inversion to extract temperature and water vapor vertical distribution profiles from observed radiances used to calculate attenuation effects in atmospheric windows, spectra of target taken at two or more angles to yield gross atmospheric effects directly, and ratio of radiances in wing of water vapor band and nearby clear region to yield total water vapor amounts. | White Sands area, Padre Island, HATS |
| 547 | David T. Chang Environmental Research & Technology, Inc. | Improve the usefulness of remote sensing data in earth resources surveys by experimentally evaluating the radiative effects of the atmosphere on such measurements from spacecraft altitudes in order to develop interpretative techniques of high resolution multispectral observation to eliminate atmospheric effects. Evaluate the efficacy of climatological modeling techniques in determining atmospheric attenuation effects using S190A and S190B photographs. | Imperial Valley, Smoke Creek Desert, Great Salt Lake |

500 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|---|---|----------------|
| 548 | Frederick J. Thomson Environmental Research Institute of Michigan The University of Michigan | Determine effects of different atmospheric conditions on ability of computers to recognize terrain classes. Provide information necessary to devise correction techniques for preprocessing data and define weather conditions for collection of usable spacecraft multispectral data. Compare probabilities of misclassification for objects using spacecraft data and ground or aircraft data. Correlate with weather conditions to attempt to define those conditions under which usable data can be obtained. | Michigan State |

SKYLAB

EARTH RESOURCES EXPERIMENT PACKAGE

700 SERIES

REMOTE SENSING TECHNIQUES DEVELOPMENT

Relate signatures of EREP imagery to ground spectra, adaptation of discrimination techniques, radar altimeter terrain characteristics identification, microwave pulse response of rough surfaces, and sensors performance evaluations.

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|--|---------------|--------------|
|----------|--|---------------|--------------|

PATTERN RECOGNITION

| | | | |
|-----|---|---|----------------------|
| 701 | Dr. Edward Yost Science Engineering Research Group C.W. Post Center Long Island University | Relate in situ radiometric ground spectra measurements to space acquired imagery. Determine relative signatures (densities) of imagery to ground spectra. Acquire ground truth spectral signature data. Analyze EREP S190 and S192 imagery desnitometrically and colorimetrically and relate the data to absolute radiance units. Relate EREP image characteristics to in situ spectroradiometric signatures. | Arizona & HATS |
| 703 | Richard F. Nalepka Environmental Research Institute of Michigan The University of Michigan | Adapt data and test information extraction and discrimination techniques (developed for aircraft and ERTS-A multispectral scanner data) to Skylab S192 data. | Southern Michigan |

MICROWAVE SIGNATURES

| | | | |
|-----|--|--|---|
| 716 | Dr. R. K. Moore University of Kansas Center for Research Inc. | Collect data into a catalog permitting future designers to determine required sensitivities and dynamic ranges for spacecraft instruments operating at different angles of incidence. Collect design scattering coefficient and brightness temperature data. Obtain radiometer data over cloudy and rainy areas. | Any overland U.S. pass, Any uniform water body |
| 717 | Allan Shapiro U.S. Naval Research Laboratory | Utilize the S193 radar altimeter to identify terrain characteristics from space. Provide information for remote sensing with satellite radar altimeter of topography and surface properties. | Any overland U.S. pass |

700 SERIES (Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|---|---|--|
| 718 | Dr. Harbhajan S. Hayre Department of Electrical Engineering University of Houston | Correlate ground truth, aircraft data, and Skylab data to verify microwave pulse response of various rough surfaces. Provide the necessary information for improved design of spacecraft microwave system; ocean and terrain roughness measure by pulsed altimeter, and soil and crop signature deduction over at least one test site. Develop a roughness signature technique to correlate altimeter signatures with ground scene. | HATS, Colorado, and Oregon Coast |

DATA PROCESSING

| | | | |
|-----|--|---|---------------------|
| 731 | Robert Jayroe NASA-MSFC S & E - AERO - F | Evaluate the utility of automated feature extraction algorithms for change detection, multistage sampling, data compression, and onboard processing of EREP multispectral photography and scanner data over the state of Alabama. | State of Alabama |
|-----|--|---|---------------------|

SENSOR PERFORMANCE EVALUATION

| | | | |
|-----|-----------------------------------|---|--|
| 746 | NASA-MSC Skylab Program Office | Evaluate the performance of the S190A and the S190B. Provide support required by the Quick Look II Mission Evaluation. Provide performance and calibration data required by science/applications investigators based upon the realized performance of the sensor. Provide data required for definition of future experimental and operational sensor requirements. | HATS or alternate sites |
| 747 | NASA-MSC Skylab Program Office | Evaluate the performance of the S191 Infrared Spectrometer. Provide support required by the Quick Look II Mission Evaluation. Provide performance and calibration data required by science/applications investigators based upon the realized performance of the sensor. Provide data required for definition of future experimental and operational sensor requirements. | Great Salt Lake; Wilcox Playa area; Dillon Lake, Color- ado; Rio Grande Lake; Lake Titicaca, Peru-Bolivia; White Sands, New Mexico; Padre Island, Texas |

700 SERIES(Continued)

| Task No. | Principal Investigator and Affiliation | Investigation | Test Site(s) |
|----------|---|---|--|
| 748 | NASA-MSC Skylab Program Office & J. Braithwaite Environmental Research Institute of Michigan The University of Michigan | Evaluate the performance of the S192 Multispectral Scanner. Provide support required by the Quick Look II Mission Evaluation. Provide performance and calibration data required by science/applications investigators based upon the realized performance of the sensor. Provide data required for definition of future experimental and operational sensor requirements. | Great Salt Lake; Wilcox Playa Area; Dillon Lake, Colorado; Rio Grande Lake; HATS; Rosenberg Rangeland or selected Alternate Sites |
| 749 | NASA-MSC Skylab Program Office Dr. R.K. Moore University of Kansas Joseph McGoogan NASA-Wallops Station | Evaluate the performance of the S193 Microwave System. Provide support required by the Quick Look II Mission Evaluation. Provide performance and calibration data required by science/applications investigators based upon the realized performance of the sensor. Provide data required for definition of future experimental and operational sensor requirements. | Lake Michigan; Deep Space; White Sands, New Mexico Gypsum Beds, Great Salt Lake Desert; Baja, Cal. (Land/water interface) North Atlantic Ocean; Fort Huachuca, Arizona |
| 750 | NASA-MSC Skylab Program Office | Evaluate the performance of the S194 L-band Radiometer. Provide support required by the Quick Look II Mission Evaluation. Provide performance and calibration data required by science/applications investigators based upon the realized performance of the sensor. Provide data required for definition of future experimental and operational sensor requirements. | Deep Space; Gulf of Mexico; Great Salt Lake Desert; Ar Rub Al Khali Desert; Sahara Desert; Baja, Cal.; Lake Michigan |

EREP SENSOR DESCRIPTION

MULTISPECTRAL PHOTOGRAPHIC FACILITY (S190A AND S190B)

The experiment objective is to photograph the earth's surface in a spectral range that includes visible light and extends into the near infrared, with sufficient resolution and spectral definition to allow detailed analysis and interpretation by specialists in a variety of earth resources disciplines.

The facility is arranged in two parts. S190A consists of an array of six 70mm cameras, precisely matched and boresighted so that photographs from all six will be accurately in register. Thus, all of the features seen in one photograph can be simultaneously aligned with the same features in the photographs from the other cameras. A combination of black and white and color films is used in conjunction with selective filters for spectral analysis, allowing comparison with imagery obtained with the IR spectrometer and multispectral scanner (S192) and with the Earth Resources Technology Satellite (ERTS). The camera array is mounted behind a 42 cm (16.5 in.) by 56 cm (22 in.) optical glass window just forward of the radial docking hatch in the MDA.

The second part, S190B Earth Terrain Camera, consists of a single camera that will be operated in the Scientific Airlock on the antisolar side of the Orbital Workshop. This camera is an adaptation of the Lunar Topographic Camera carried on the Apollo 14 mission.

Controls for the six-camera array are integrated with the controls for the other EREP sensors located in the MDA. However, the Earth Terrain Camera controls are mounted on the side of the camera housing and are independent of other EREP sensors.

For earth resources operations, Skylab departs from its normal solar orientation to an orbital mode that provides continuous pointing of cameras and other sensors at the ground directly below. The crewmen load film, install filters, set up the camera controls, remove the covers from the camera ports, uncover the window, install the Earth Terrain Camera in the Scientific Airlock, and make other preparations for camera operations.

The exposed film is the primary data returned at the end of each Skylab mission for processing and analysis on the ground.

INFRARED SPECTROMETER (S191)

The primary objective of this experiment is to make a fundamental evaluation of the applicability and usefulness of sensing Earth Resources from orbital altitudes in the visible through near-infrared and in the far-infrared spectral regions. Another specific objective is to assess the value of realtime identification of ground test sites by an astronaut.

The spectrometer has a pointing and tracking capability of 45 deg. forward, 10 deg. aft and 20 deg. to the side of the ground track. The astronaut

will use the view-finder/tracker to acquire the site which will be in his field of view for less than a minute. At the start of each field of view scan, the scene in the viewfinder will be photographed with a small camera attached to the viewfinder. The astronaut will select secondary ground sites if the primary site is obscured by cloud cover, as well as other sites of opportunity as they become available.

The primary data will be recorded on a magnetic tape. The magnetic tape and the film from the viewfinder camera will be returned with each crew rotation.

MULTISPECTRAL SCANNER (S192)

The primary objective of this experiment is to assess the feasibility of multispectral techniques, developed in the aircraft program, for remote sensing of earth resources from space. Specifically, attempts will be made at spectral signature identification and mapping of ground test sites in agriculture, forestry, geology, hydrology, and oceanography.

The basic instrument design is that of an optical mechanical scanner using an image plane scanning mirror, with a folded reflecting telescope used as a radiation collector. The scanner will operate in 13 relatively wide bands located in spectral regions with high atmospheric transmission.

The spectral range covered by the scanner overlaps the range of the multispectral cameras (S190) and the IR spectrometer (S191), permitting a very useful cross check of results deduced from these three systems. In addition, the IR Spectrometer data may provide atmospheric density profiles, which would be extremely useful for correcting the primary causes of atmospheric attenuation of the scanner data.

The primary data will be recorded on magnetic tape and will be returned with each crew rotation.

MICROWAVE RADIOMETER/SCATTEROMETER & ALTIMETER (S193)

The objectives of this experiment are simultaneous measurement of the radar differential backscattering cross section and passive microwave thermal emission of the land and ocean on a global scale, and engineering data for use in designing radar altimeters.

The proposed microwave radiometer/scatterometer experiment is a combination of an active radar scatterometer and passive radiometer. The radar backscattering cross section measurement gives a measure of the combined effect of the dielectric properties, roughness, and brightness temperature of the terrestrial surface. Astronauts will assist in test site identification and operate and monitor equipment. Information desired over test sites will be obtained by the NASA earth resources aircraft for validation and extrapolation of spaceborne measurements.

All data will be recorded on magnetic tape on one digitized channel: the radiometer/scatterometer data is recorded at 5.33 kilobits/sec; the altimeter data at 10 kilobits/sec.

L-BAND MICROWAVE RADIOMETER (S194)

The experiment objective is to obtain measurements of the brightness temperature of the earth's surface along the spacecraft track.

The experiment uses an L-band radiometer that is basically the same in operating principle as the radiometer part of the microwave radiometer/scatterometer experiment (S193) except the operating frequency is changed from 13.9 GHz to 1.42 GHz. A function of the experiment is to supplement the measurement results of Experiment S193 by taking into consideration the effect of clouds on radiometric measurements. By using two frequencies (S193 at 13.9 GHz and S194 at 1.42 GHz) simultaneously in measurements, corrections can be made on radiometric data to include the cloud effects. When this experiment is carried out simultaneously with Experiment S193, the astronaut will control and monitor the equipment.

All data will be recorded on magnetic tape.

EREP GROUND COVERAGE

S192-40 N MI

S193-6 N MI
AT NADIR

S194-60 N MI

S190B-59 N MI
S190A-88 N MI

S191-1/4 N MI
AT NADIR

11193 3309

SKYLAB EREP SENSOR CHARACTERISTICS

| SENSOR | DESCRIPTION | SPECTRAL COVERAGE | SPECTRAL RESOLUTION | GROUND COVERAGE | SPATIAL RESOLUTION |
|---|---|--|---|---------------------------------------|-------------------------|
| S-190(A) MULTISPECTRAL PHOTOGRAPHIC CAMERA | SIX 70mm CAMERA MATCHED DISTORTION AND FOCAL LENGTH (15.2cm) 12 METERS REGISTRATION 18 FILTERS 21° FOV | MICROMETERS .5 - .6 PANX B&W .6 - .7 PANX B&W .7 - .8 IR B&W .8 - .9 IR B&W .5 - .88 IR COLOR .4 - .7 HR COLOR | 0.1 MICROMETERS | 163 x 163 Km | APPROX. 24m TO 68m * |
| S-190(B) EARTH TERRAIN CAMERA | 460 mm FOCAL LENGTH 114mm FILM FORMAT 3 FILTERS | 0.4 TO 0.7 H, R, AERIAL COLOR 0.5 TO 0.88 IR COLOR 0.5 TO 0.7 HIGH DEFINITION AERIAL B & W | 0.1 MICROMETERS | 109 X 109 Km | APPROX. 10m TO 38m * |
| S-191 INFRARED SPECTROMETER | POINTED BY CREW FILTER WHEEL ONE SEC. SCAN RATE ONE mRAD FOV CRYOGENIC COOLER 16mm CAMERA | 0.4 TO 2.4 AND 6.2 TO 15.5 MICRO- METER | 1% TO 4% | 0-45° FWD 0-20° SIDE 0-10° REAR | 0.44 Km SPOT |
| S-192 MULTISPECTRAL SCANNER | IMAGE PLANE SCANNER 6000RPM SCAN MIRROR CRYOGENIC COOLER HgCdTe DETECTORS (13 USED) 0.186 mRAD FOV | 0.4 TO 2.35 AND 10.2 TO 12.5 MICROMETERS | 13 BANDS: 0.04 TO 0.1 MICROMETERS | 68 Km SWATH | 80 x 80 m SPOT |
| S-193 MICROWAVE RADIOMETER/SCATTEROMETER AND ALTIMETER | 1.1m PARABOLIC ANTENNA TWO AXIS GIMBAL (0-48° IN FIVE STEPS) 1.5° FOV DUAL POLARIZATION ALTIMETER NADIR SEEKER | 13.8 TO 14.0 GHz (13.9 GHz CENTER FREQUENCY) | SCAT RECEIVER: FIRST IF: 500 MHz SECOND IF: 50 MHz RAD RECEIVER: SINGLE FREQUENCY | 0-48 FWD 0-48 SIDE | 11 x 11 Km SPOT |
| S-194 L-BAND RADIOMETER | 1 m PHASED ARRAY (8 x 8 ELEMENTS) COLD AND HOT REF. | 1.400 TO 1.427 GHz | 18 MHz FROM CENTER FREQUENCY | 111 Km CIRCLE | 111 Km SPOT |

NOTES: FOV = FIELD OF VIEW

* - DOES NOT INCLUDE LOSS DUE TO ATMOSPHERE EFFECTS OR FILM PROCESSING.

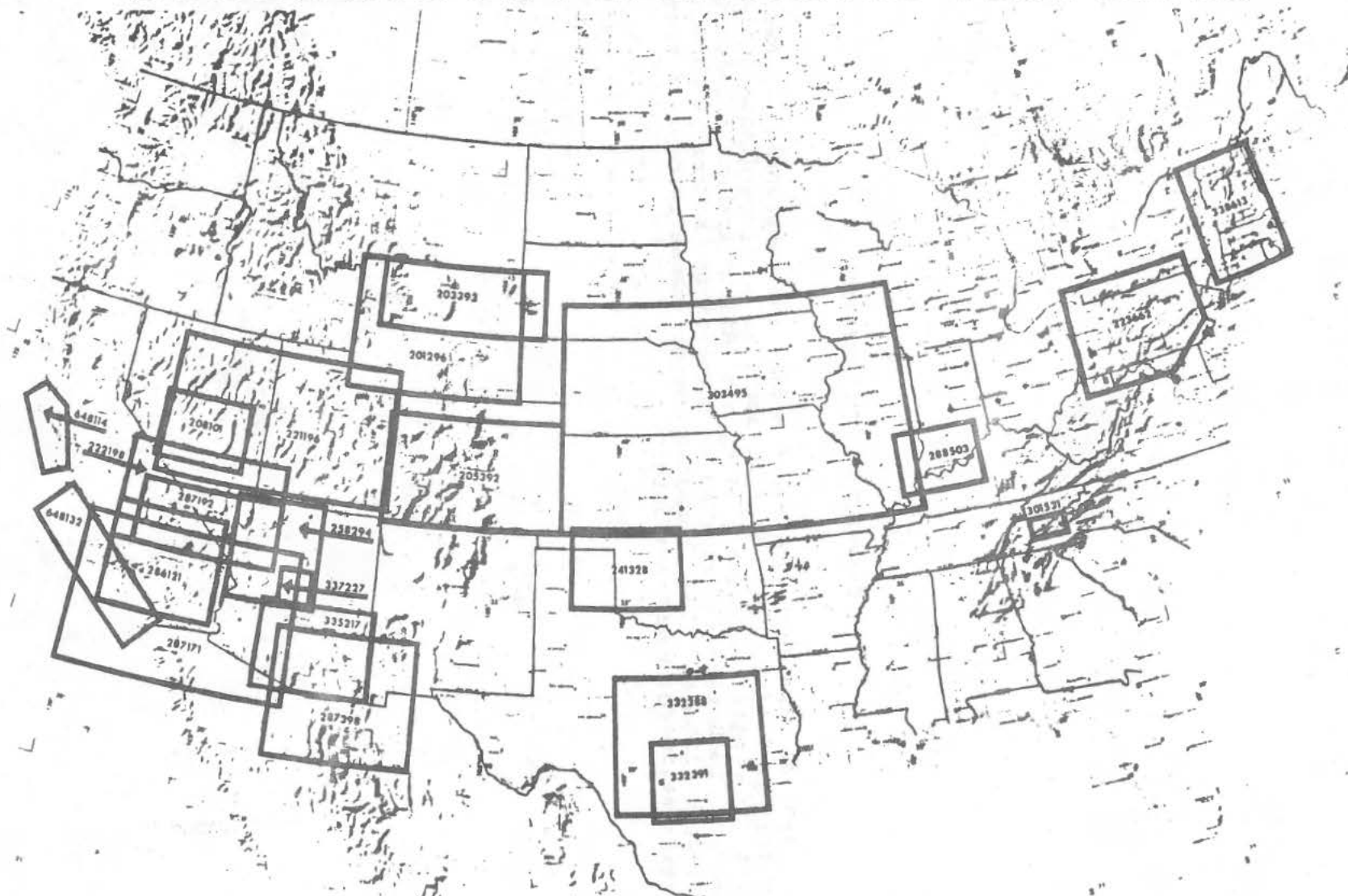
NASA HQ ML71-5751
REV. 2-10-73

TASK-SITE IDENTIFICATION

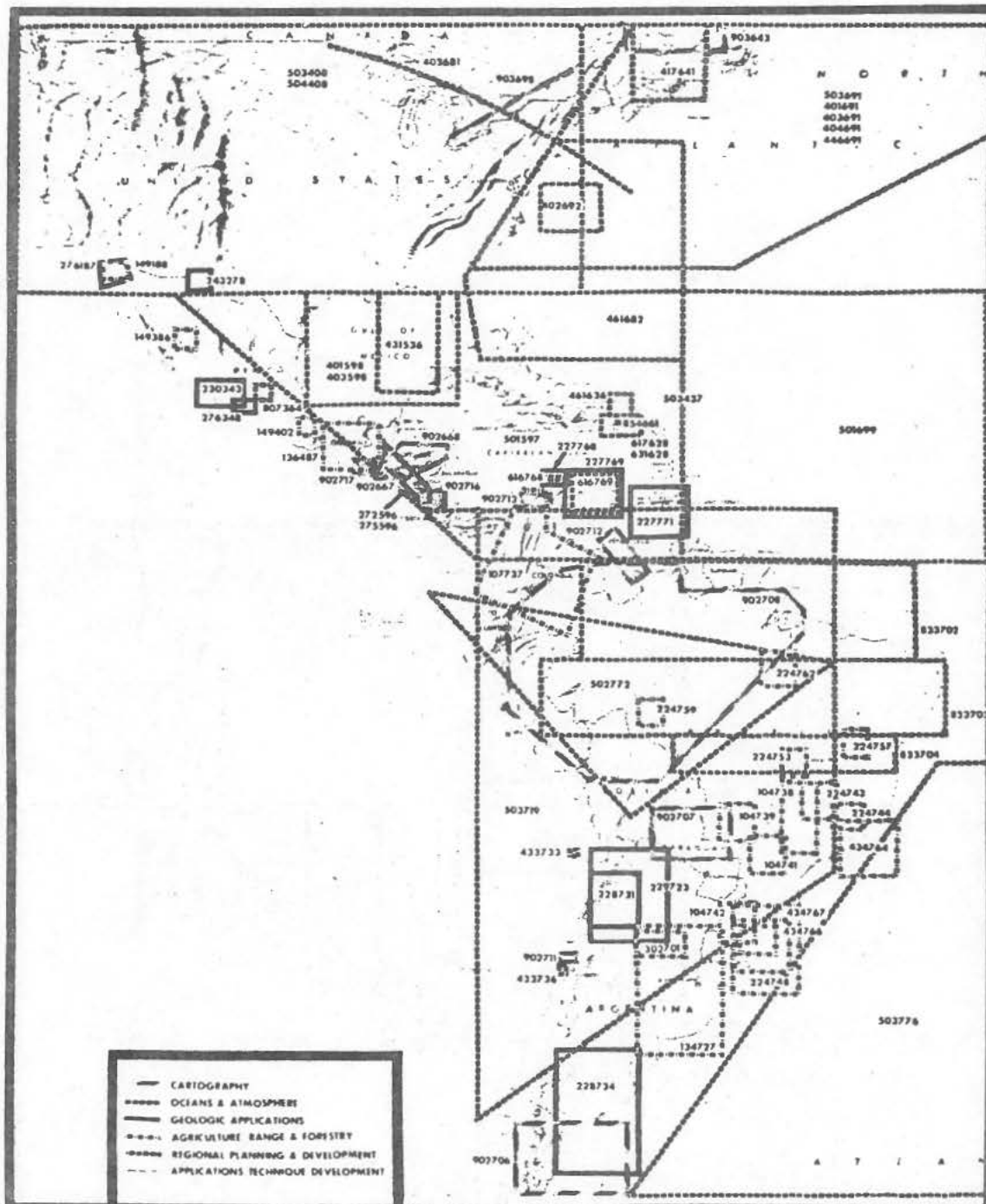
The maps on the following pages define the geographical location of each task-test site. Each task is accorded a three-digit designator (first 3 digits) according to type of discipline and sub-discipline involved. Each site is accorded a three-digit number according to geographic locale. The combination of these forms is a six-digit identification for each task/site.

NASA-S-72-3604-V

GEOLOGIC APPLICATIONS TEST SITES



EREP TEST SITES-NON U S

NASA
S-73-17100

Listed below are some other references that were not reprinted because of possible copyright restrictions.

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