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NASA CR-112330

EARTH ORBITAL EXPERIMENT PROGRAM
AND
REQUIREMENTS STUDY

VOLUME 6

EARTH OBSERVATIONS

(APPENDICES A, B, C)

Prepared under Contract No. NAS1-9464 by
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5301 Bolsa Avenue
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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

The information presented in this report summarizes three major steps toward production of a reference manual for planners of manned earth-orbital research activity. The reference manual will serve as one of the principal tools of a systems approach to experiment and mission planning based on an integrated consideration of candidate research programs and their attendant vehicle, mission, and technology development requirements.

The first major step toward preparation of the manual was the development of long-range goals and objectives suitable for NASA's activities during the 1970-1980 time period. This work was completed by NASA Headquarters with active center support and was published in September 1969 as a portion of a report for the President's Space Task Group entitled, "America's Next Decade in Space."

The second major step was a contractual study effort undertaken in September 1969 by McDonnell Douglas Astronautics Company-West with the TRW Systems Group, the IBM Federal Systems Division, and the RPC Corporation. The purpose of the study was to structure the NASA-developed goals and objectives into an orderly, system-oriented set of implementation requirements. The contractor examined, in depth, the orbital experiment program required to achieve the scientific, technological, and application objectives, and determined in a general way the capabilities required in future manned orbital programs to accommodate the defined experiments. Thus, the basic task of the contractor was to aid NASA in studying the useful and proper roles of manned and automated spacecraft by examining the implementation alternatives for NASA experiments.

The third major step presented in this document is the result of an integrated consideration of NASA's long-range goals and objectives, the system and mission requirements, and the alternative implementation plans. It will serve as a source of detailed information and methodology for use by NASA planners in development and justification of future programs.

Management

Technical direction (fig. 1) of the contracted study effort is the responsibility of the Advanced Aerospace Studies Branch (AASB) of the Space Systems Division (SSD) at the Langley Research Center (LRC). Technical guidance is provided by the Earth Orbital Experiment Program Steering Group which reports through the Planning Steering Group (PSG) to the Associate Administrator. Technical coordination is also maintained with appropriate personnel at ARC, GSFC, MSC, and MSFC.

The membership of the Steering Group (fig. 2) comprises representatives of the working groups of the PSG under the chairmanship of Dr. R. G. Wilson, Director, Advanced Programs, OSSA. The NASA Study Management Team is headed by Mr. W. R. Hook of the AASB. Technical support is supplied by elements of the Langley Research Center as required.

The contractor's Study Team is headed by Dr. H. L. Wolbers, MDAC, and the Senior Management Review Council is chaired by Mr. C. J. Dorrenbacher, Vice President, Advanced Systems and Technology, MDAC.

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

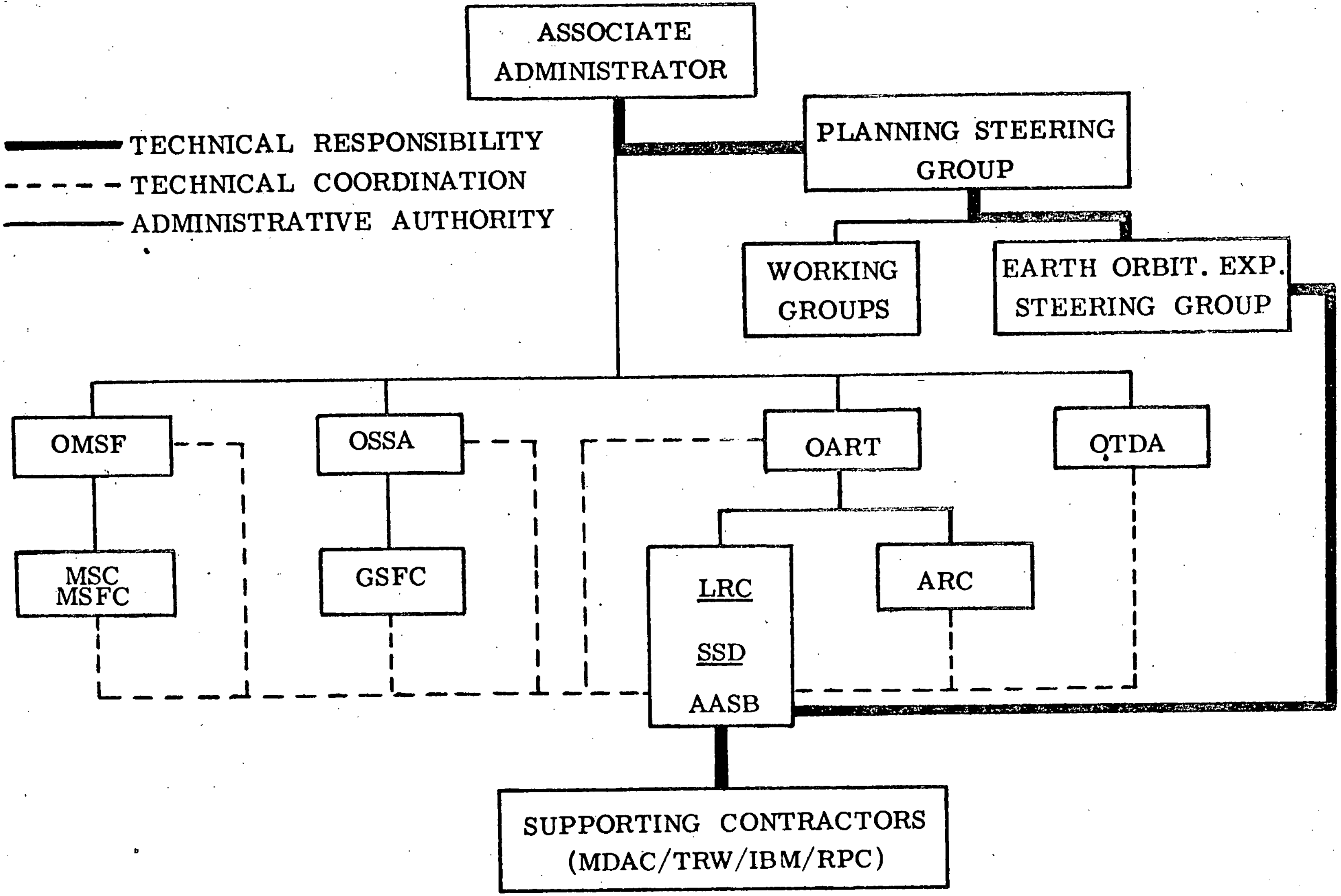


Figure 1. - Management Plan.

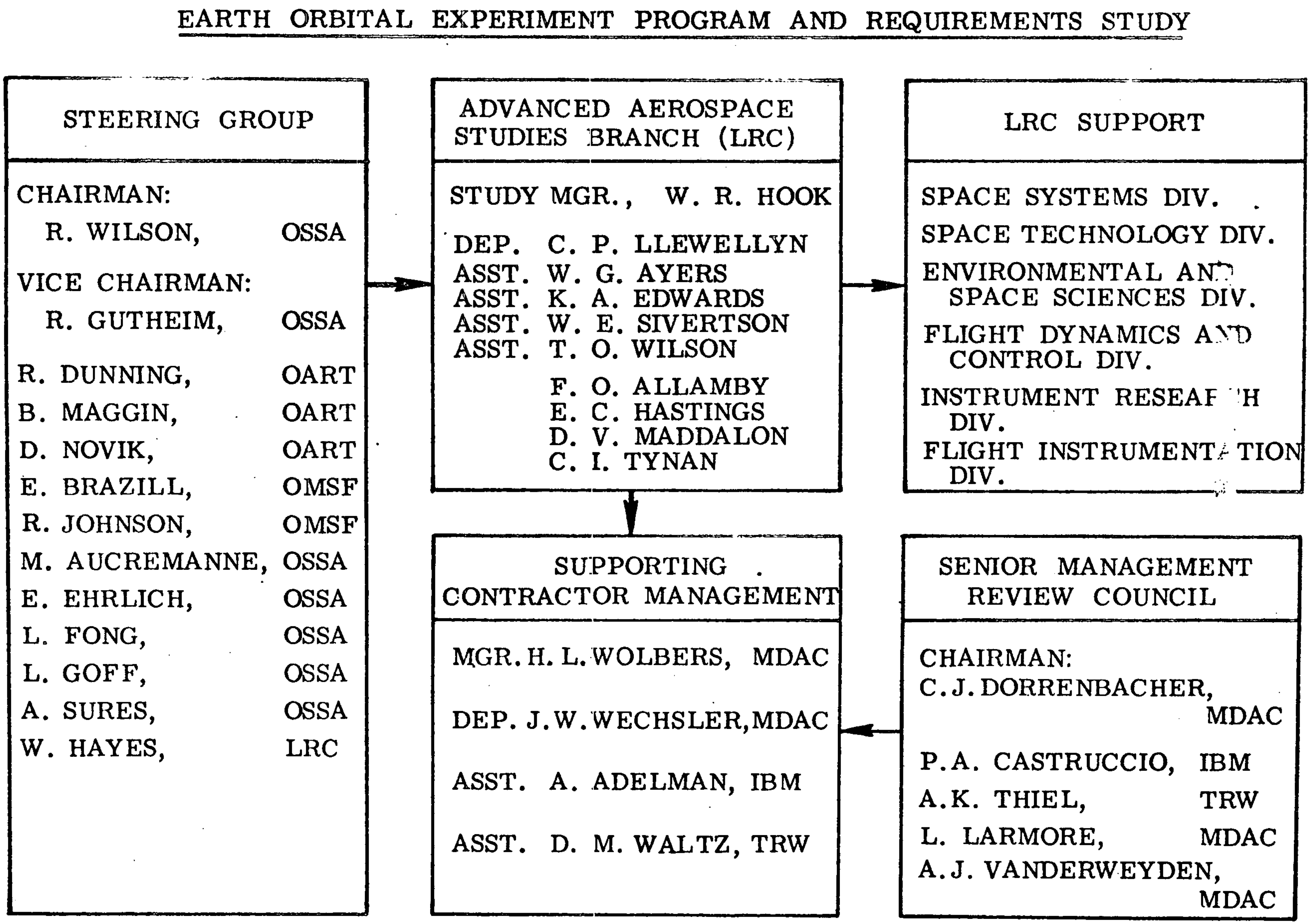


Figure 2. - Study Team.

APPENDIX A

ORGANIZED OVERVIEW CHARTS

EARTH OBSERVATIONS

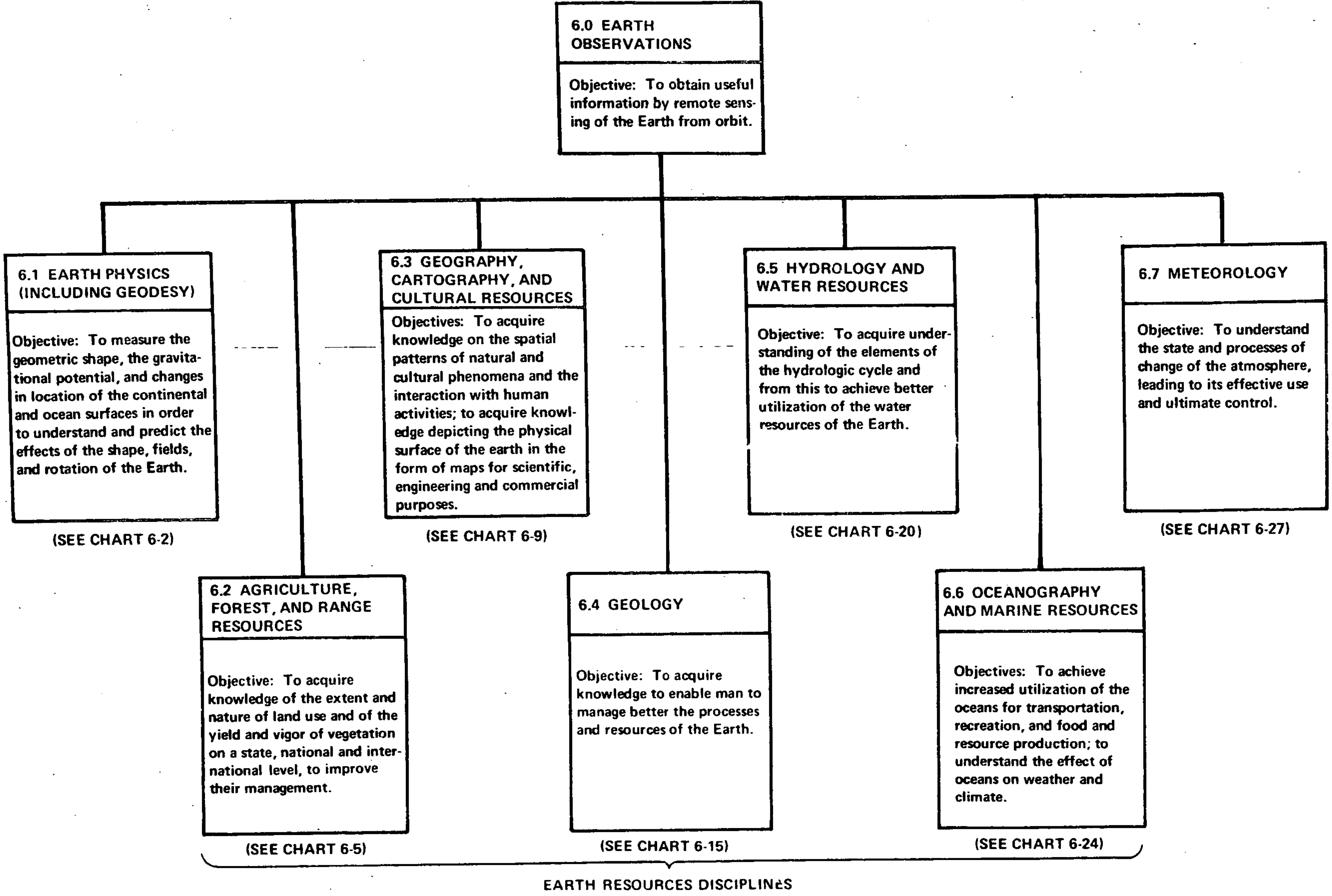
Appendix A
INTRODUCTION

The organized overview method of analysis is described in Section 2, in general terms as well as specific detail for each of the six study disciplines. The organized overview charts derived in each of these disciplines are presented in this Appendix, as follows:

Manned Spaceflight Capability	Charts 1-1 through 1-90
Space Biology	Charts 2-1 through 2-14
Space Astronomy	Charts 3-1 through 3-42
Space Physics	Charts 4-1 through 4-17
Communications and Navigation	Charts 5-1 through 5-9
Earth Observations	Charts 6-1 through 6-29

Critical issues referred to at the lower levels of these charts are found in Tables 1 through 6 Appendix B.

Chart 6-1. Overall Organized Overview for Earth Observations



6.0 EARTH OBSERVATIONS

Objective: To obtain useful information by remote sensing of the Earth from orbit.

6.1 EARTH PHYSICS (INCLUDING GEODESY)

Objective: To measure the geometric shape, the gravitational potential, and changes in location of the continental and ocean surfaces in order to understand and predict the effects of the shape, fields, and rotation of the Earth.

(SEE CHART 6-2)

6.2 AGRICULTURE, FOREST, AND RANGE RESOURCES

Objective: To acquire knowledge of the extent and nature of land use and of the yield and vigor of vegetation on a state, national and international level, to improve their management.

(SEE CHART 6-5)

6.3 GEOGRAPHY, CARTOGRAPHY, AND CULTURAL RESOURCES

Objectives: To acquire knowledge on the spatial patterns of natural and cultural phenomena and the interaction with human activities; to acquire knowledge depicting the physical surface of the earth in the form of maps for scientific, engineering and commercial purposes.

(SEE CHART 6-9)

6.4 GEOLOGY

Objective: To acquire knowledge to enable man to manage better the processes and resources of the Earth.

(SEE CHART 6-15)

6.5 HYDROLOGY AND WATER RESOURCES

Objective: To acquire understanding of the elements of the hydrologic cycle and from this to achieve better utilization of the water resources of the Earth.

(SEE CHART 6-20)

6.6 OCEANOGRAPHY AND MARINE RESOURCES

Objectives: To achieve increased utilization of the oceans for transportation, recreation, and food and resource production; to understand the effect of oceans on weather and climate.

(SEE CHART 6-24)

6.7 METEOROLOGY

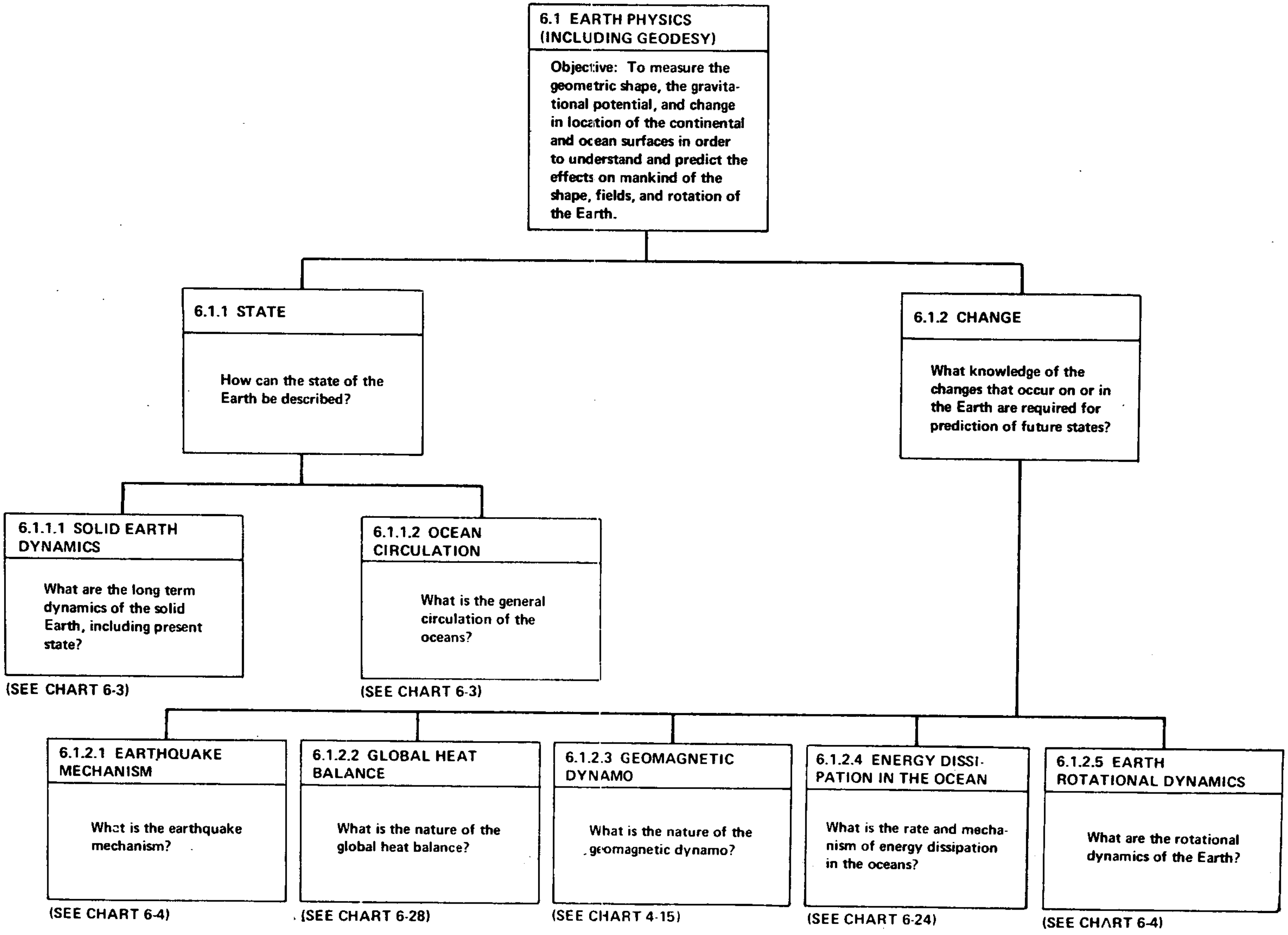
Objective: To understand the state and processes of change of the atmosphere, leading to its effective use and ultimate control.

(SEE CHART 6-27)

EARTH RESOURCES DISCIPLINES

Chart 6-2. Organized Overview for Earth Physics

(SEE CHART 6-1)



6.1 EARTH PHYSICS (INCLUDING GEODESY)

Objective: To measure the geometric shape, the gravitational potential, and change in location of the continental and ocean surfaces in order to understand and predict the effects on mankind of the shape, fields, and rotation of the Earth.

6.1.1 STATE

How can the state of the Earth be described?

6.1.2 CHANGE

What knowledge of the changes that occur on or in the Earth are required for prediction of future states?

6.1.1.1 SOLID EARTH DYNAMICS

What are the long term dynamics of the solid Earth, including present state?

(SEE CHART 6-3)

6.1.1.2 OCEAN CIRCULATION

What is the general circulation of the oceans?

(SEE CHART 6-3)

6.1.2.1 EARTHQUAKE MECHANISM

What is the earthquake mechanism?

(SEE CHART 6-4)

6.1.2.2 GLOBAL HEAT BALANCE

What is the nature of the global heat balance?

(SEE CHART 6-28)

6.1.2.3 GEOMAGNETIC DYNAMO

What is the nature of the geomagnetic dynamo?

(SEE CHART 4-15)

6.1.2.4 ENERGY DISSIPATION IN THE OCEAN

What is the rate and mechanism of energy dissipation in the oceans?

(SEE CHART 6-24)

6.1.2.5 EARTH ROTATIONAL DYNAMICS

What are the rotational dynamics of the Earth?

(SEE CHART 6-4)

Chart 6-3. Earth Physics - Solid Earth Dynamics and Ocean Circulation

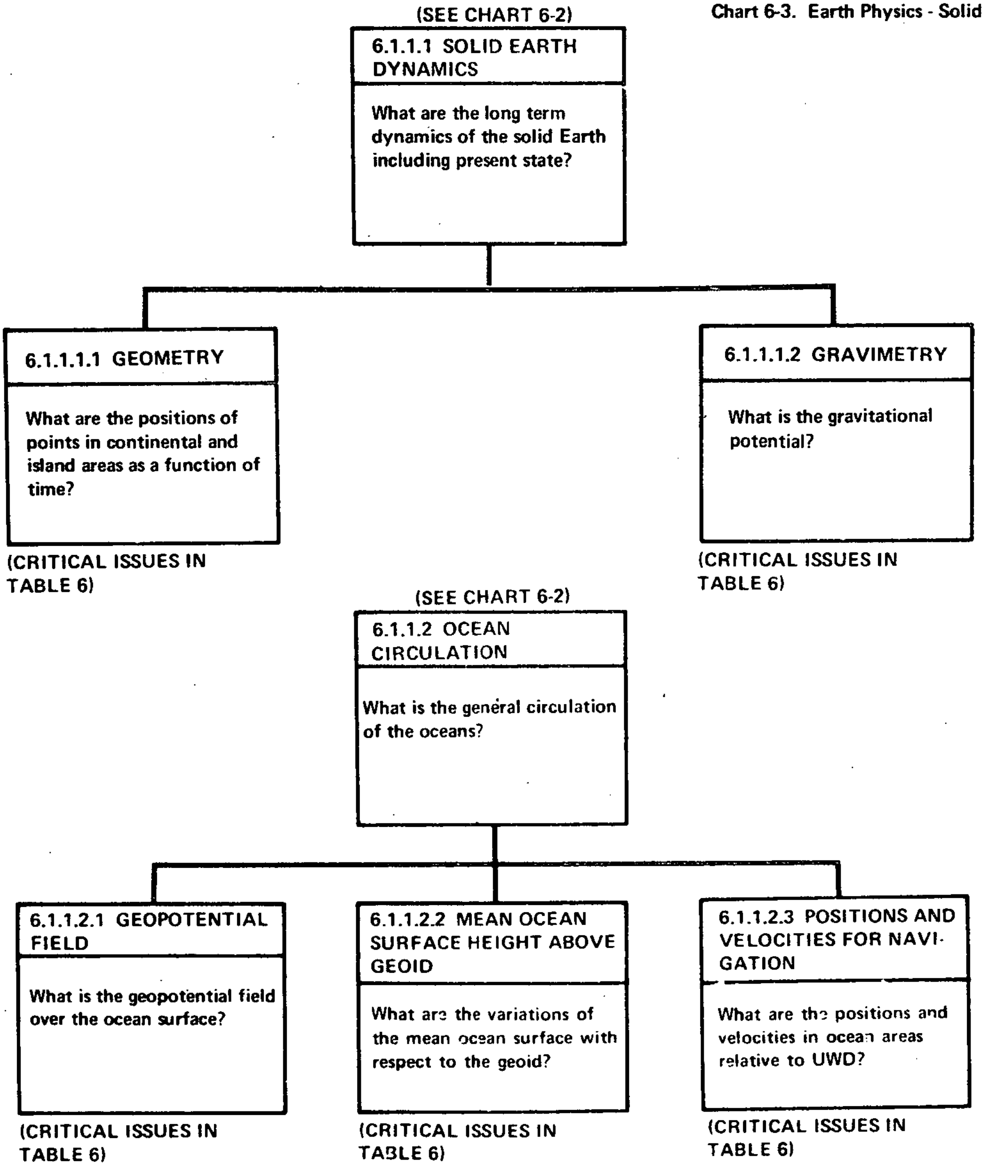
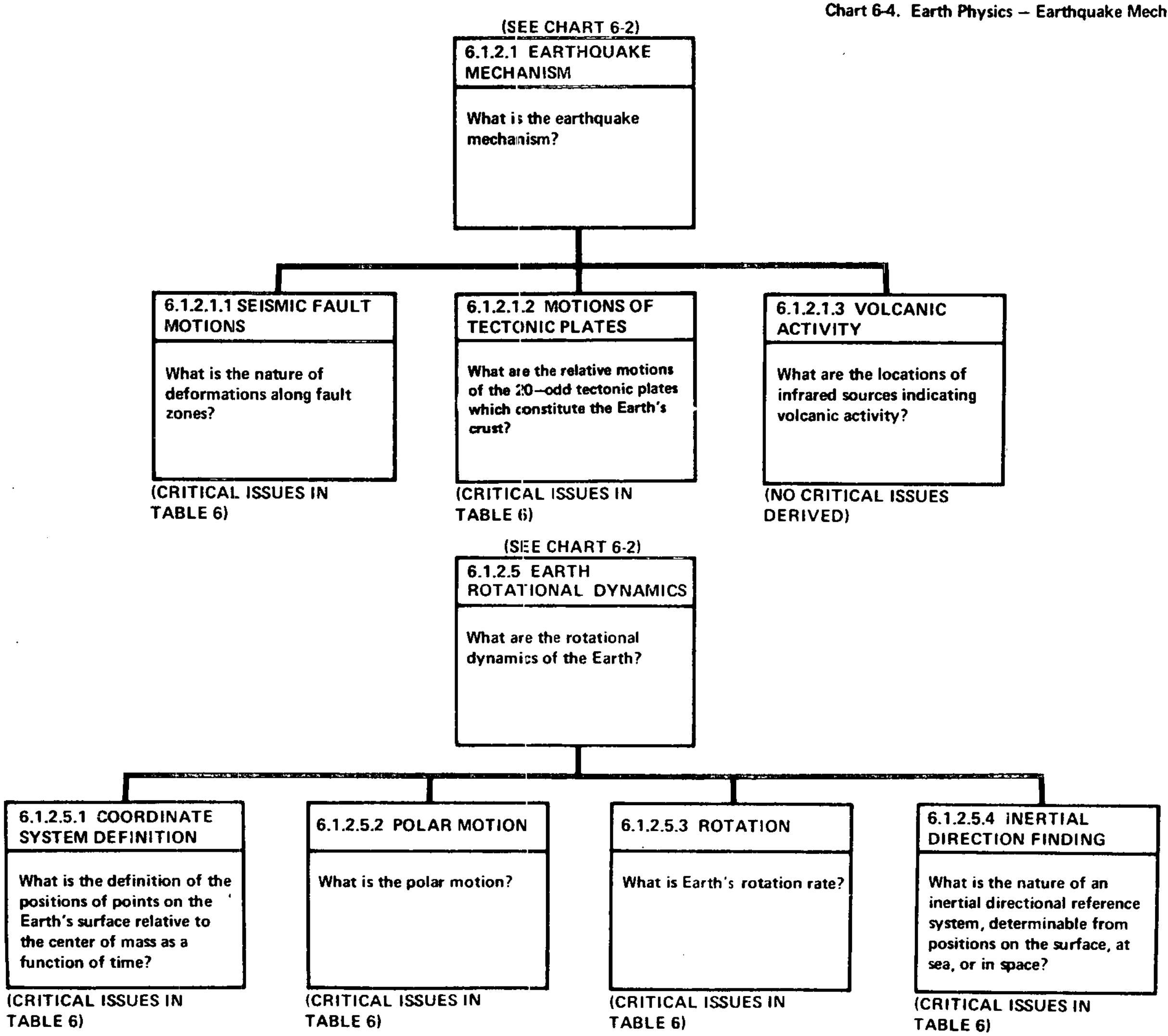


Chart 6-4. Earth Physics – Earthquake Mechanism and Earth Rotational Dynamics



(SEE CHART 6-2)

6.1.2.1 EARTHQUAKE MECHANISM

What is the earthquake mechanism?

6.1.2.1.1 SEISMIC FAULT MOTIONS

What is the nature of deformations along fault zones?

(CRITICAL ISSUES IN TABLE 6)

6.1.2.1.2 MOTIONS OF TECTONIC PLATES

What are the relative motions of the 20–odd tectonic plates which constitute the Earth's crust?

(CRITICAL ISSUES IN TABLE 6)

6.1.2.1.3 VOLCANIC ACTIVITY

What are the locations of infrared sources indicating volcanic activity?

(NO CRITICAL ISSUES DERIVED)

(SEE CHART 6-2)

6.1.2.5 EARTH ROTATIONAL DYNAMICS

What are the rotational dynamics of the Earth?

6.1.2.5.1 COORDINATE SYSTEM DEFINITION

What is the definition of the positions of points on the Earth's surface relative to the center of mass as a function of time?

(CRITICAL ISSUES IN TABLE 6)

6.1.2.5.2 POLAR MOTION

What is the polar motion?

(CRITICAL ISSUES IN TABLE 6)

6.1.2.5.3 ROTATION

What is Earth's rotation rate?

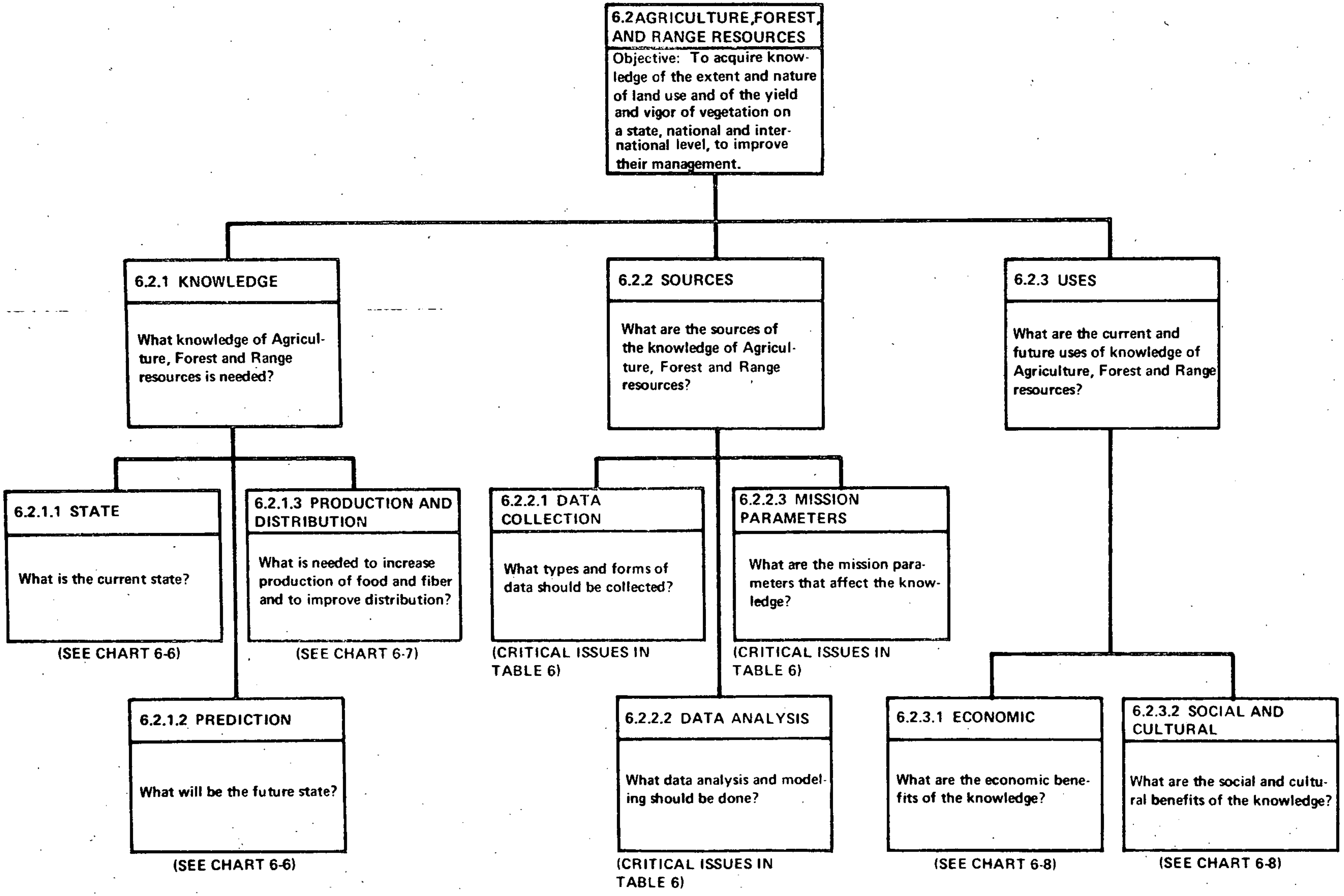
(CRITICAL ISSUES IN TABLE 6)

6.1.2.5.4 INERTIAL DIRECTION FINDING

What is the nature of an inertial directional reference system, determinable from positions on the surface, at sea, or in space?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-5. Organized Overview for Agriculture, Forest, and Range Resources



(SEE CHART 6-1)

6.2 AGRICULTURE, FOREST, AND RANGE RESOURCES

Objective: To acquire knowledge of the extent and nature of land use and of the yield and vigor of vegetation on a state, national and international level, to improve their management.

6.2.1 KNOWLEDGE

What knowledge of Agriculture, Forest and Range resources is needed?

6.2.1.1 STATE

What is the current state?

(SEE CHART 6-6)

6.2.1.2 PREDICTION

What will be the future state?

(SEE CHART 6-6)

6.2.1.3 PRODUCTION AND DISTRIBUTION

What is needed to increase production of food and fiber and to improve distribution?

(SEE CHART 6-7)

6.2.2 SOURCES

What are the sources of the knowledge of Agriculture, Forest and Range resources?

6.2.2.1 DATA COLLECTION

What types and forms of data should be collected?

(CRITICAL ISSUES IN TABLE 6)

6.2.2.2 DATA ANALYSIS

What data analysis and modeling should be done?

(CRITICAL ISSUES IN TABLE 6)

6.2.2.3 MISSION PARAMETERS

What are the mission parameters that affect the knowledge?

(CRITICAL ISSUES IN TABLE 6)

6.2.3 USES

What are the current and future uses of knowledge of Agriculture, Forest and Range resources?

6.2.3.1 ECONOMIC

What are the economic benefits of the knowledge?

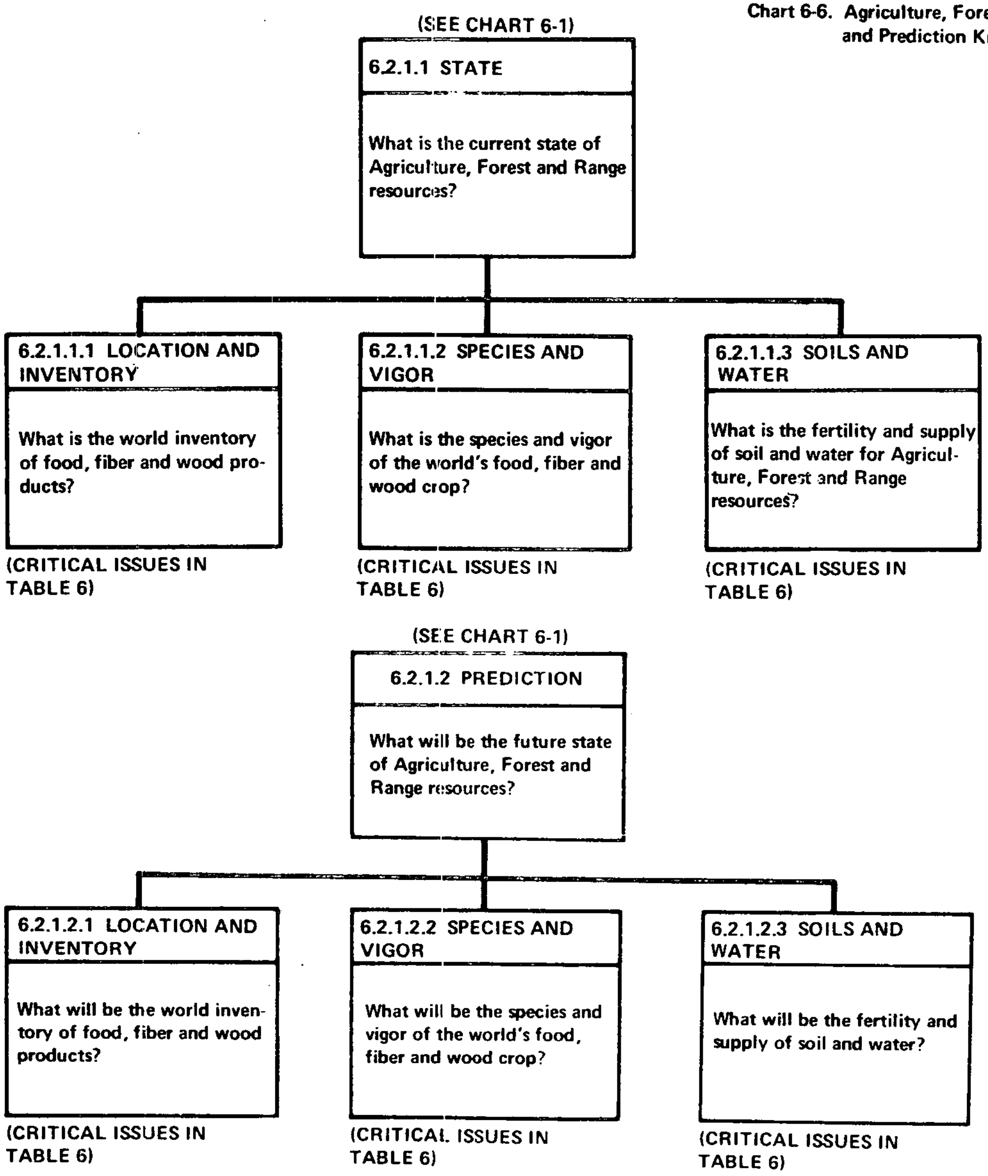
(SEE CHART 6-8)

6.2.3.2 SOCIAL AND CULTURAL

What are the social and cultural benefits of the knowledge?

(SEE CHART 6-8)

Chart 6-6. Agriculture, Forest, and Range Resources – State and Prediction Knowledge



(SEE CHART 6-1)

6.2.1.1 STATE

What is the current state of Agriculture, Forest and Range resources?

6.2.1.1.1 LOCATION AND INVENTORY

What is the world inventory of food, fiber and wood products?

(CRITICAL ISSUES IN TABLE 6)

6.2.1.1.2 SPECIES AND VIGOR

What is the species and vigor of the world's food, fiber and wood crop?

(CRITICAL ISSUES IN TABLE 6)

6.2.1.1.3 SOILS AND WATER

What is the fertility and supply of soil and water for Agriculture, Forest and Range resources?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-1)

6.2.1.2 PREDICTION

What will be the future state of Agriculture, Forest and Range resources?

6.2.1.2.1 LOCATION AND INVENTORY

What will be the world inventory of food, fiber and wood products?

(CRITICAL ISSUES IN TABLE 6)

6.2.1.2.2 SPECIES AND VIGOR

What will be the species and vigor of the world's food, fiber and wood crop?

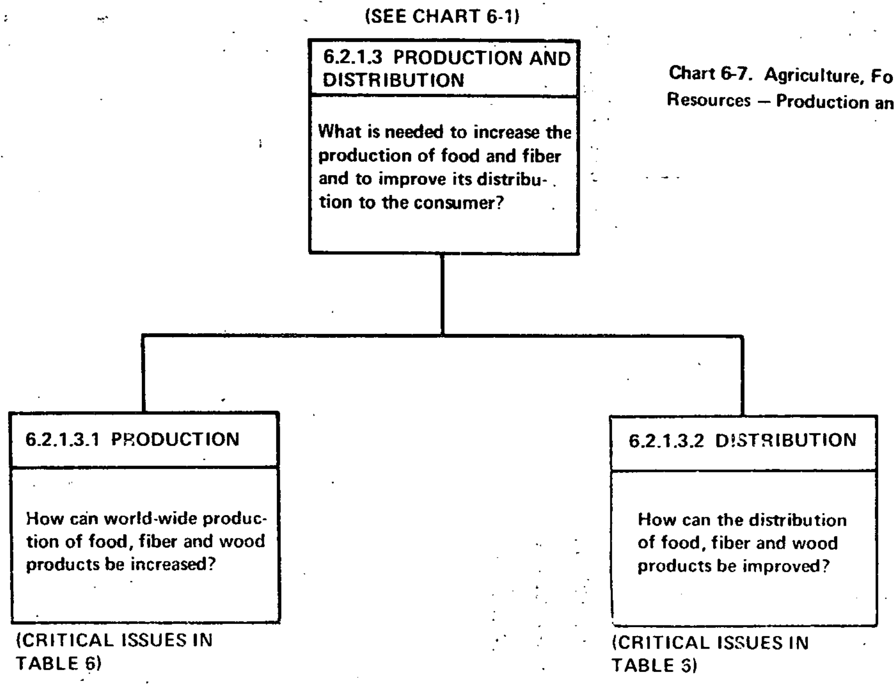
(CRITICAL ISSUES IN TABLE 6)

6.2.1.2.3 SOILS AND WATER

What will be the fertility and supply of soil and water?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-7. Agriculture, Forest, and Range Resources – Production and Distribution Knowledge



(SEE CHART 6-1)

6.2.1.3 PRODUCTION AND DISTRIBUTION

What is needed to increase the production of food and fiber and to improve its distribution to the consumer?

6.2.1.3.1 PRODUCTION

How can world-wide production of food, fiber and wood products be increased?

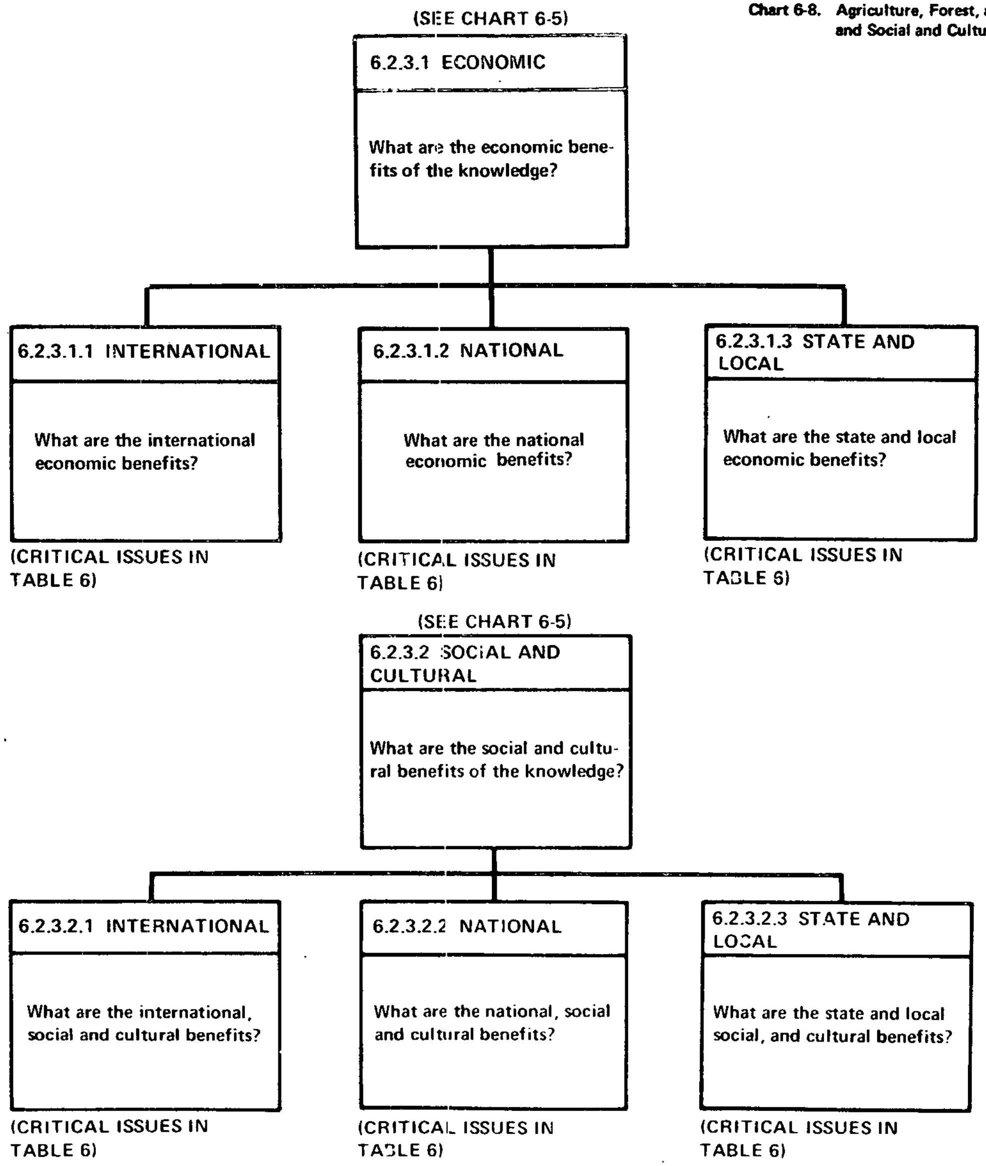
(CRITICAL ISSUES IN TABLE 6)

6.2.1.3.2 DISTRIBUTION

How can the distribution of food, fiber and wood products be improved?

(CRITICAL ISSUES IN TABLE 3)

Chart 6-8. Agriculture, Forest, and Range Resources – Economic and Social and Cultural Uses



(SEE CHART 6-5)

6.2.3.1 ECONOMIC

What are the economic benefits of the knowledge?

6.2.3.1.1 INTERNATIONAL

What are the international economic benefits?

(CRITICAL ISSUES IN TABLE 6)

6.2.3.1.2 NATIONAL

What are the national economic benefits?

(CRITICAL ISSUES IN TABLE 6)

6.2.3.1.3 STATE AND LOCAL

What are the state and local economic benefits?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-5)

6.2.3.2 SOCIAL AND CULTURAL

What are the social and cultural benefits of the knowledge?

6.2.3.2.1 INTERNATIONAL

What are the international, social and cultural benefits?

(CRITICAL ISSUES IN TABLE 6)

6.2.3.2.2 NATIONAL

What are the national, social and cultural benefits?

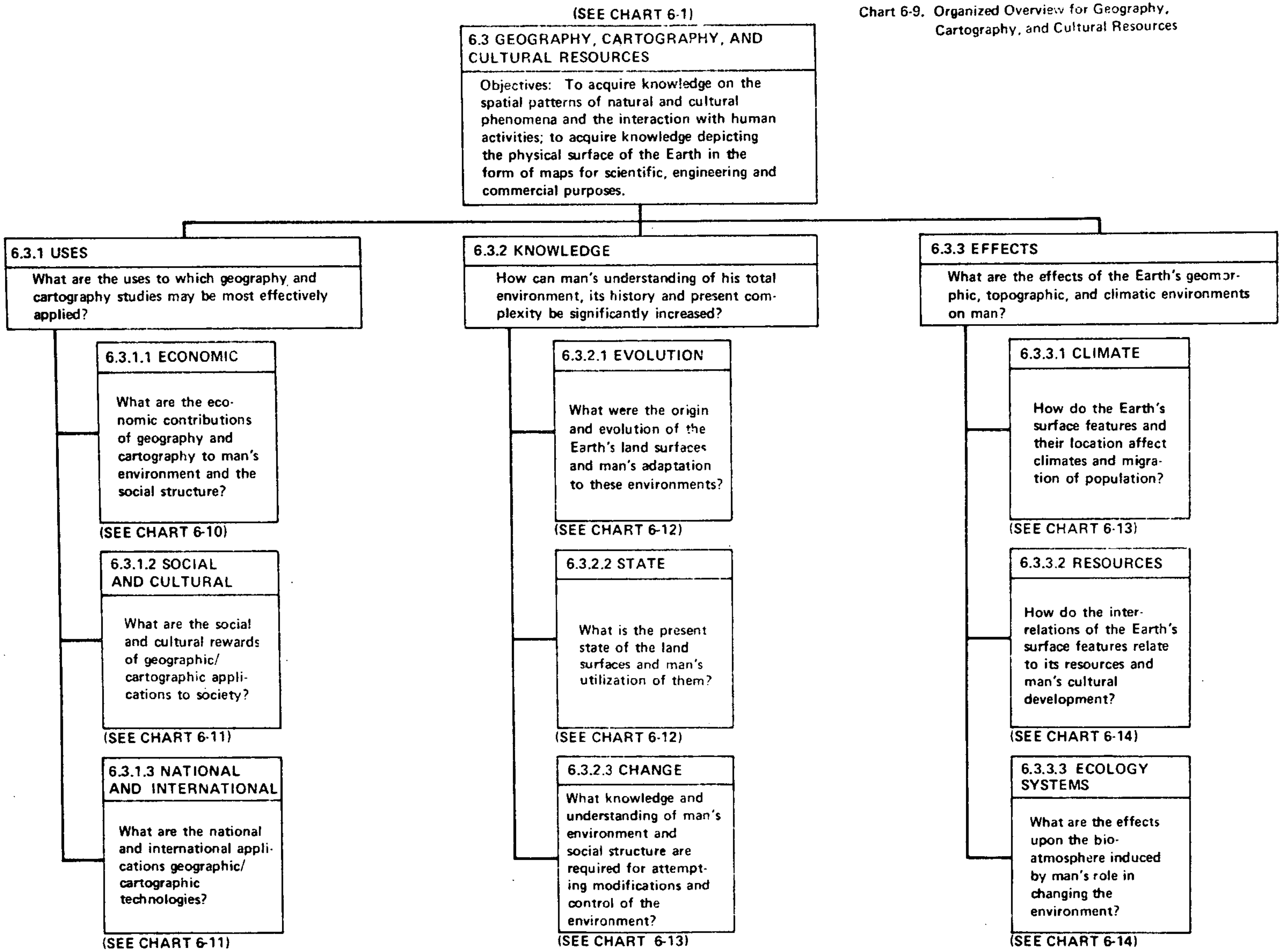
(CRITICAL ISSUES IN TABLE 6)

6.2.3.2.3 STATE AND LOCAL

What are the state and local social, and cultural benefits?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-9. Organized Overview for Geography, Cartography, and Cultural Resources



(SEE CHART 6-1)

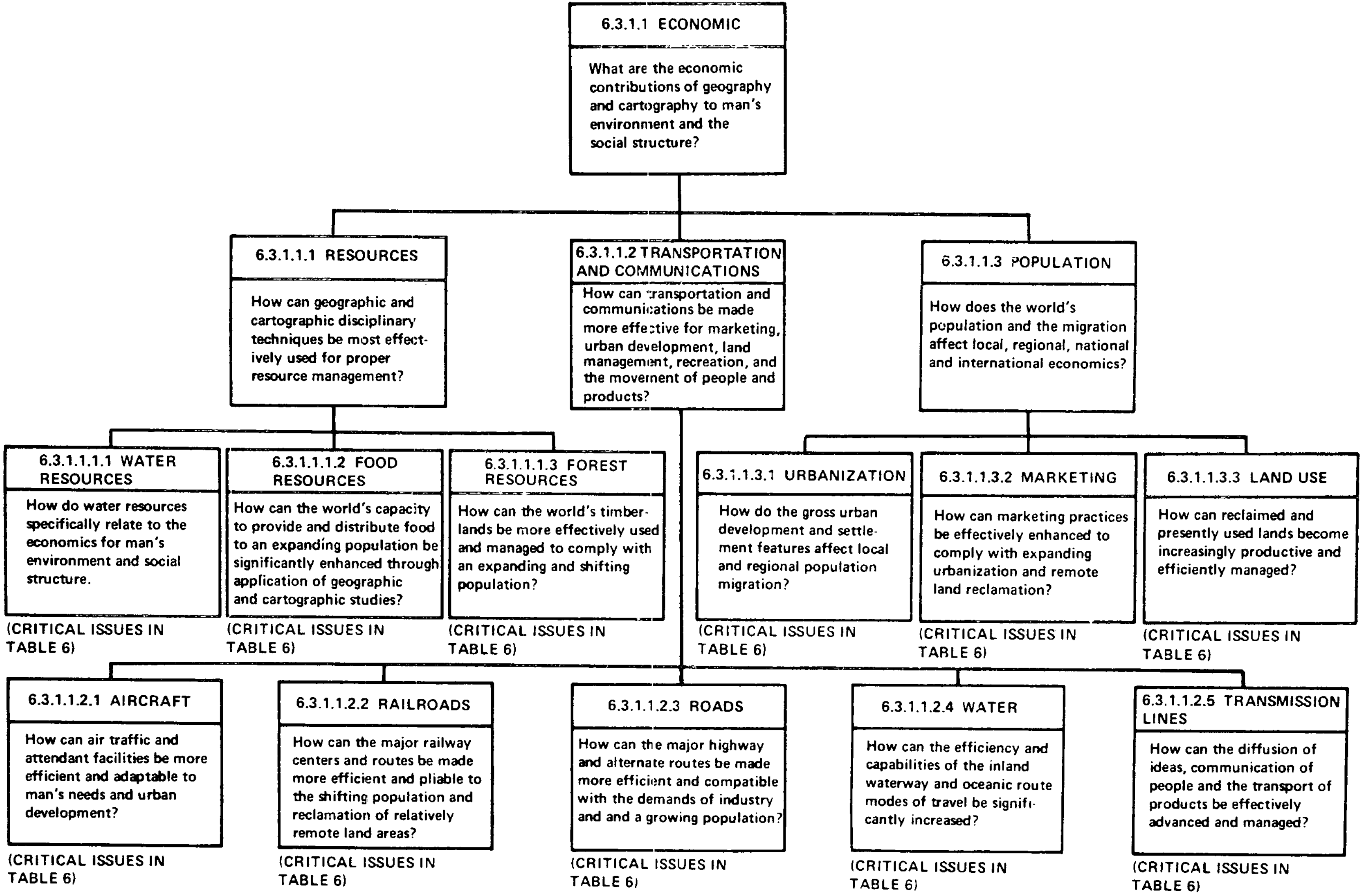
6.3 GEOGRAPHY, CARTOGRAPHY, AND CULTURAL RESOURCES

Objectives: To acquire knowledge on the spatial patterns of natural and cultural phenomena and the interaction with human activities; to acquire knowledge depicting the physical surface of the Earth in the form of maps for scientific, engineering and commercial purposes.

- **6.3.1 USES** — What are the uses to which geography and cartography studies may be most effectively applied?
  - **6.3.1.1 ECONOMIC** — What are the economic contributions of geography and cartography to man's environment and the social structure? (SEE CHART 6-10)
  - **6.3.1.2 SOCIAL AND CULTURAL** — What are the social and cultural rewards of geographic/cartographic applications to society? (SEE CHART 6-11)
  - **6.3.1.3 NATIONAL AND INTERNATIONAL** — What are the national and international applications geographic/cartographic technologies? (SEE CHART 6-11)
- **6.3.2 KNOWLEDGE** — How can man's understanding of his total environment, its history and present complexity be significantly increased?
  - **6.3.2.1 EVOLUTION** — What were the origin and evolution of the Earth's land surfaces and man's adaptation to these environments? (SEE CHART 6-12)
  - **6.3.2.2 STATE** — What is the present state of the land surfaces and man's utilization of them? (SEE CHART 6-12)
  - **6.3.2.3 CHANGE** — What knowledge and understanding of man's environment and social structure are required for attempting modifications and control of the environment? (SEE CHART 6-13)
- **6.3.3 EFFECTS** — What are the effects of the Earth's geomorphic, topographic, and climatic environments on man?
  - **6.3.3.1 CLIMATE** — How do the Earth's surface features and their location affect climates and migration of population? (SEE CHART 6-13)
  - **6.3.3.2 RESOURCES** — How do the interrelations of the Earth's surface features relate to its resources and man's cultural development? (SEE CHART 6-14)
  - **6.3.3.3 ECOLOGY SYSTEMS** — What are the effects upon the bio-atmosphere induced by man's role in changing the environment? (SEE CHART 6-14)

Chart 6-10. Geography, Cartography, and Cultural Resources – Economic Uses

(SEE CHART 6-9)



6.3.1.1 ECONOMIC

What are the economic contributions of geography and cartography to man's environment and the social structure?

6.3.1.1.1 RESOURCES

How can geographic and cartographic disciplinary techniques be most effectively used for proper resource management?

6.3.1.1.1.1 WATER RESOURCES

How do water resources specifically relate to the economics for man's environment and social structure.

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.1.2 FOOD RESOURCES

How can the world's capacity to provide and distribute food to an expanding population be significantly enhanced through application of geographic and cartographic studies?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.1.3 FOREST RESOURCES

How can the world's timberlands be more effectively used and managed to comply with an expanding and shifting population?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.2 TRANSPORTATION AND COMMUNICATIONS

How can transportation and communications be made more effective for marketing, urban development, land management, recreation, and the movement of people and products?

6.3.1.1.2.1 AIRCRAFT

How can air traffic and attendant facilities be more efficient and adaptable to man's needs and urban development?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.2.2 RAILROADS

How can the major railway centers and routes be made more efficient and pliable to the shifting population and reclamation of relatively remote land areas?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.2.3 ROADS

How can the major highway and alternate routes be made more efficient and compatible with the demands of industry and and a growing population?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.2.4 WATER

How can the efficiency and capabilities of the inland waterway and oceanic route modes of travel be significantly increased?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.2.5 TRANSMISSION LINES

How can the diffusion of ideas, communication of people and the transport of products be effectively advanced and managed?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.3 POPULATION

How does the world's population and the migration affect local, regional, national and international economics?

6.3.1.1.3.1 URBANIZATION

How do the gross urban development and settlement features affect local and regional population migration?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.3.2 MARKETING

How can marketing practices be effectively enhanced to comply with expanding urbanization and remote land reclamation?

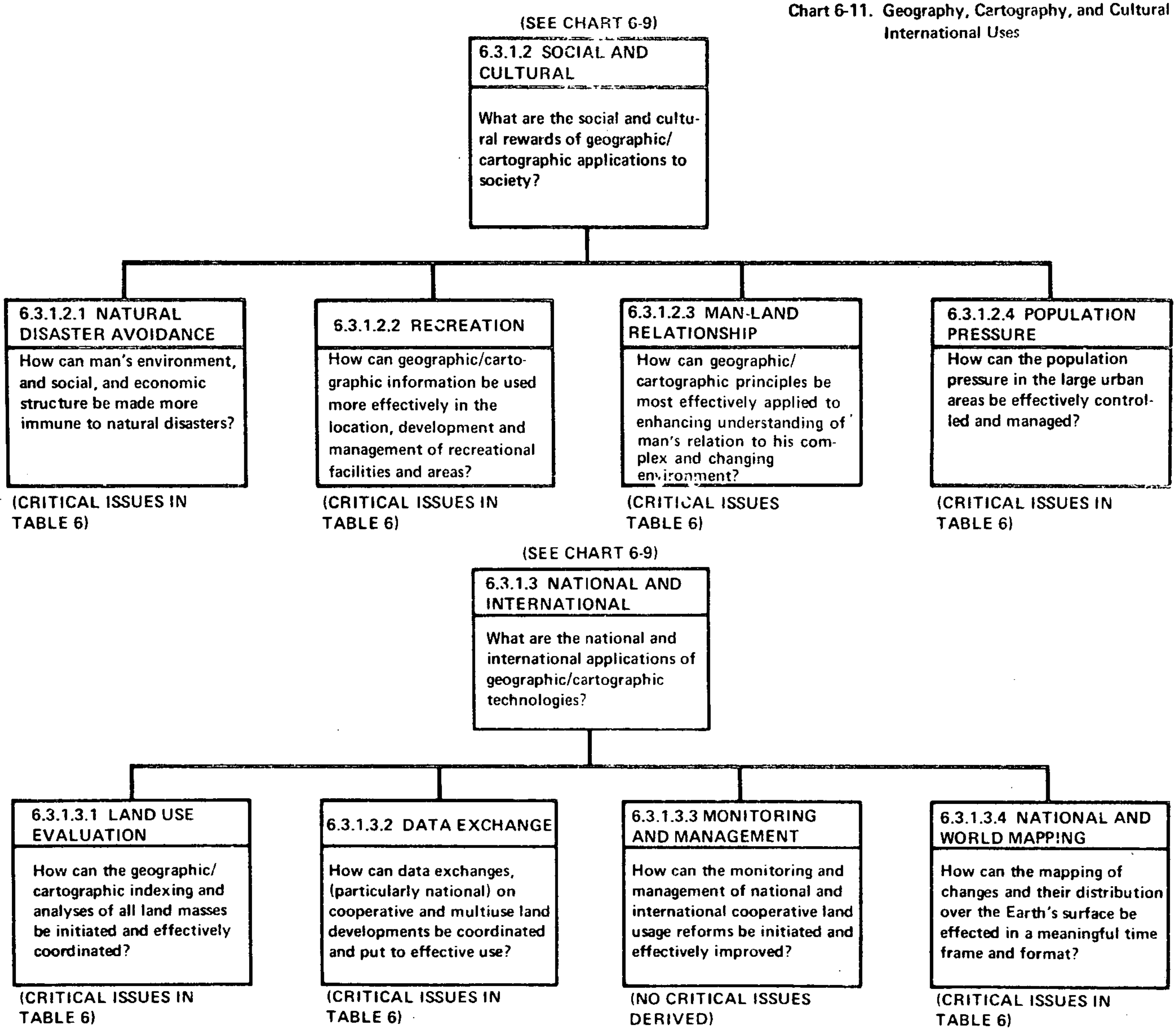
(CRITICAL ISSUES IN TABLE 6)

6.3.1.1.3.3 LAND USE

How can reclaimed and presently used lands become increasingly productive and efficiently managed?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-11. Geography, Cartography, and Cultural Resources -- and International Uses



(SEE CHART 6-9)

6.3.1.2 SOCIAL AND CULTURAL

What are the social and cultural rewards of geographic/cartographic applications to society?

6.3.1.2.1 NATURAL DISASTER AVOIDANCE

How can man's environment, and social, and economic structure be made more immune to natural disasters?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.2.2 RECREATION

How can geographic/cartographic information be used more effectively in the location, development and management of recreational facilities and areas?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.2.3 MAN-LAND RELATIONSHIP

How can geographic/cartographic principles be most effectively applied to enhancing understanding of man's relation to his complex and changing environment?

(CRITICAL ISSUES TABLE 6)

6.3.1.2.4 POPULATION PRESSURE

How can the population pressure in the large urban areas be effectively controlled and managed?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-9)

6.3.1.3 NATIONAL AND INTERNATIONAL

What are the national and international applications of geographic/cartographic technologies?

6.3.1.3.1 LAND USE EVALUATION

How can the geographic/cartographic indexing and analyses of all land masses be initiated and effectively coordinated?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.3.2 DATA EXCHANGE

How can data exchanges, (particularly national) on cooperative and multiuse land developments be coordinated and put to effective use?

(CRITICAL ISSUES IN TABLE 6)

6.3.1.3.3 MONITORING AND MANAGEMENT

How can the monitoring and management of national and international cooperative land usage reforms be initiated and effectively improved?

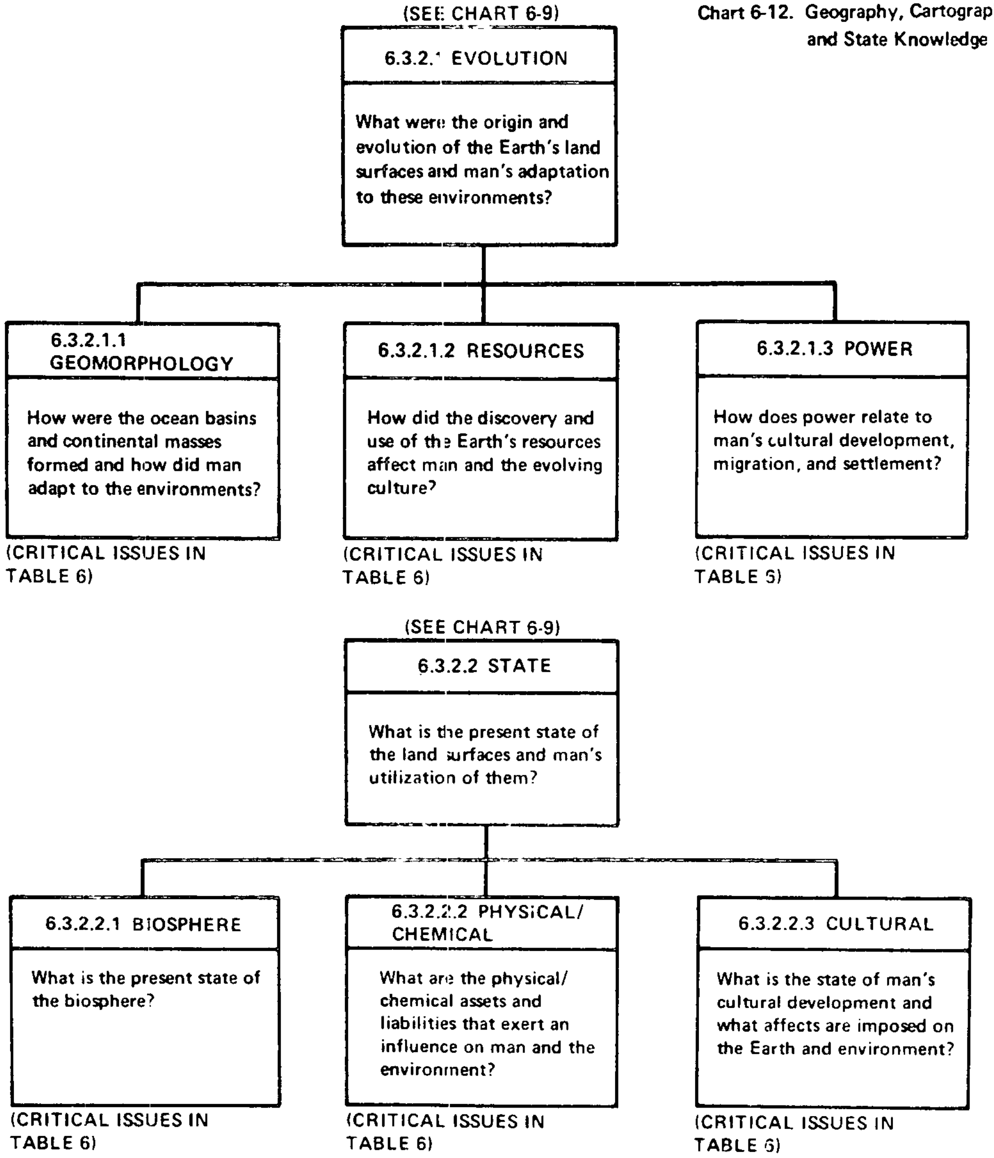
(NO CRITICAL ISSUES DERIVED)

6.3.1.3.4 NATIONAL AND WORLD MAPPING

How can the mapping of changes and their distribution over the Earth's surface be effected in a meaningful time frame and format?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-12. Geography, Cartography, and Cultural Resources – Evolution and State Knowledge



(SEE CHART 6-9)

6.3.2.1 EVOLUTION

What were the origin and evolution of the Earth's land surfaces and man's adaptation to these environments?

6.3.2.1.1 GEOMORPHOLOGY

How were the ocean basins and continental masses formed and how did man adapt to the environments?

(CRITICAL ISSUES IN TABLE 6)

6.3.2.1.2 RESOURCES

How did the discovery and use of the Earth's resources affect man and the evolving culture?

(CRITICAL ISSUES IN TABLE 6)

6.3.2.1.3 POWER

How does power relate to man's cultural development, migration, and settlement?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-9)

6.3.2.2 STATE

What is the present state of the land surfaces and man's utilization of them?

6.3.2.2.1 BIOSPHERE

What is the present state of the biosphere?

(CRITICAL ISSUES IN TABLE 6)

6.3.2.2.2 PHYSICAL/ CHEMICAL

What are the physical/ chemical assets and liabilities that exert an influence on man and the environment?

(CRITICAL ISSUES IN TABLE 6)

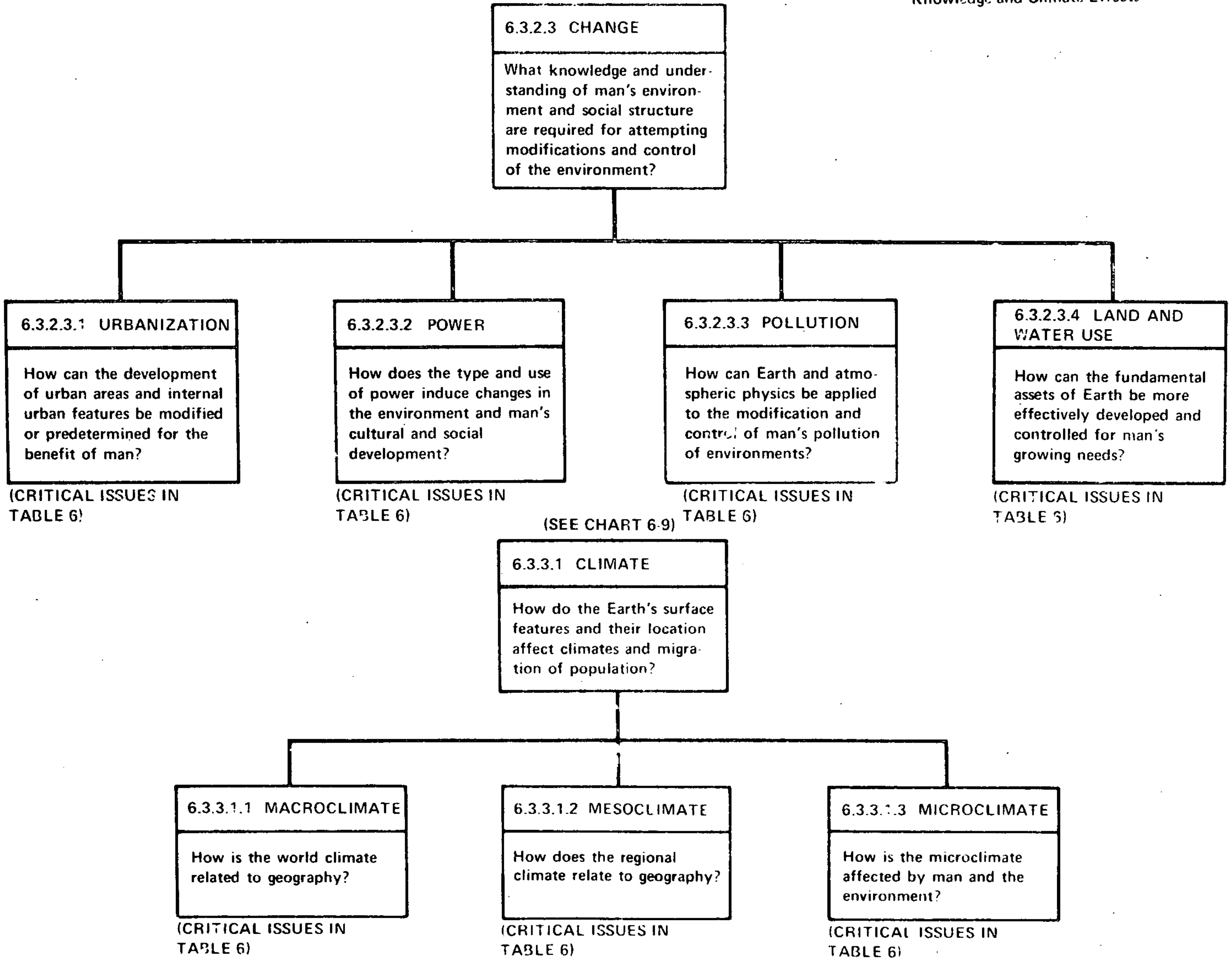
6.3.2.2.3 CULTURAL

What is the state of man's cultural development and what affects are imposed on the Earth and environment?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-13. Geography, Cartography, and Cultural Resources -- Change Knowledge and Climate Effects

(SEE CHART 6-9)



6.3.2.3 CHANGE

What knowledge and understanding of man's environment and social structure are required for attempting modifications and control of the environment?

6.3.2.3.1 URBANIZATION

How can the development of urban areas and internal urban features be modified or predetermined for the benefit of man?

(CRITICAL ISSUES IN TABLE 6)

6.3.2.3.2 POWER

How does the type and use of power induce changes in the environment and man's cultural and social development?

(CRITICAL ISSUES IN TABLE 6)

6.3.2.3.3 POLLUTION

How can Earth and atmospheric physics be applied to the modification and control of man's pollution of environments?

(CRITICAL ISSUES IN TABLE 6)

6.3.2.3.4 LAND AND WATER USE

How can the fundamental assets of Earth be more effectively developed and controlled for man's growing needs?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-9)

6.3.3.1 CLIMATE

How do the Earth's surface features and their location affect climates and migration of population?

6.3.3.1.1 MACROCLIMATE

How is the world climate related to geography?

(CRITICAL ISSUES IN TABLE 6)

6.3.3.1.2 MESOCLIMATE

How does the regional climate relate to geography?

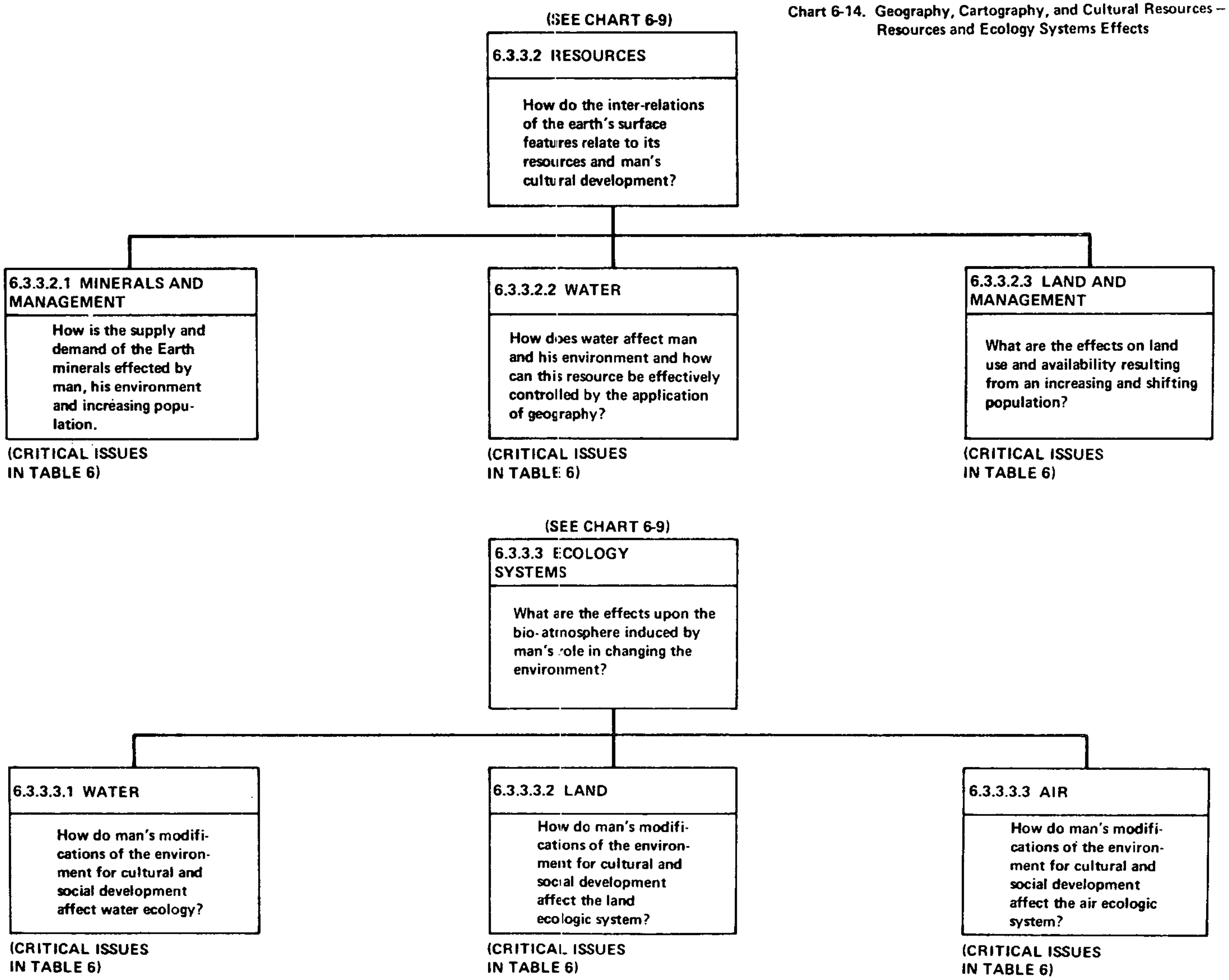
(CRITICAL ISSUES IN TABLE 6)

6.3.3.1.3 MICROCLIMATE

How is the microclimate affected by man and the environment?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-14. Geography, Cartography, and Cultural Resources – Resources and Ecology Systems Effects



(SEE CHART 6-9)

6.3.3.2 RESOURCES

How do the inter-relations of the earth's surface features relate to its resources and man's cultural development?

6.3.3.2.1 MINERALS AND MANAGEMENT

How is the supply and demand of the Earth minerals effected by man, his environment and increasing population.

(CRITICAL ISSUES IN TABLE 6)

6.3.3.2.2 WATER

How does water affect man and his environment and how can this resource be effectively controlled by the application of geography?

(CRITICAL ISSUES IN TABLE 6)

6.3.3.2.3 LAND AND MANAGEMENT

What are the effects on land use and availability resulting from an increasing and shifting population?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-9)

6.3.3.3 ECOLOGY SYSTEMS

What are the effects upon the bio-atmosphere induced by man's role in changing the environment?

6.3.3.3.1 WATER

How do man's modifications of the environment for cultural and social development affect water ecology?

(CRITICAL ISSUES IN TABLE 6)

6.3.3.3.2 LAND

How do man's modifications of the environment for cultural and social development affect the land ecologic system?

(CRITICAL ISSUES IN TABLE 6)

6.3.3.3.3 AIR

How do man's modifications of the environment for cultural and social development affect the air ecologic system?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-15. Organized Overview for Geology

(SEE CHART 6-1)

6.4 GEOLOGY

Objective: To acquire knowledge to enable man to manage better the processes and resources of the Earth.

6.4.1 USES

What are the present and foreseeable potential uses of the Earth's crust and its contained resources?

- **6.4.1.1 ECONOMIC**

  What are the economic uses of the Earth's surface, crust, and subcrustal constituents?

  (SEE CHART 6-16)

- **6.4.1.2 SOCIAL AND CULTURAL**

  What are the social and cultural uses of the Earth surface crust and subcrustal constituents and environments?

  (SEE CHART 6-16)

6.4.2 KNOWLEDGE

How can man's understanding of the Earth and its processes, mineral resources, and their management be increased?

- **6.4.2.1 EVOLUTION**

  What was the origin and evolution of the Earth's crustal configuration?

  (SEE CHART 6-17)

- **6.4.2.2 STATE**

  What is the present state of the Earth's crust?

  (SEE CHART 6-17)

- **6.4.2.3 CHANGE**

  What knowledge of the changes that have and are occurring in the Earth's crust is required for prediction and possible control of future state of the crust.

  (SEE CHART 6-18)

6.4.3 EFFECTS

What are the effects of the Earth's crustal composition, dynamics, and morphology on man?

- **6.4.3.1 WEATHER AND CLIMATE**

  How does the Earth surface morphology and configuration affect weather and climate.

  (SEE CHART 6-18)

- **6.4.3.2 GLOBAL DYNAMICS**

  How does the Earth's geomorphology and configuration affect total global dynamics?

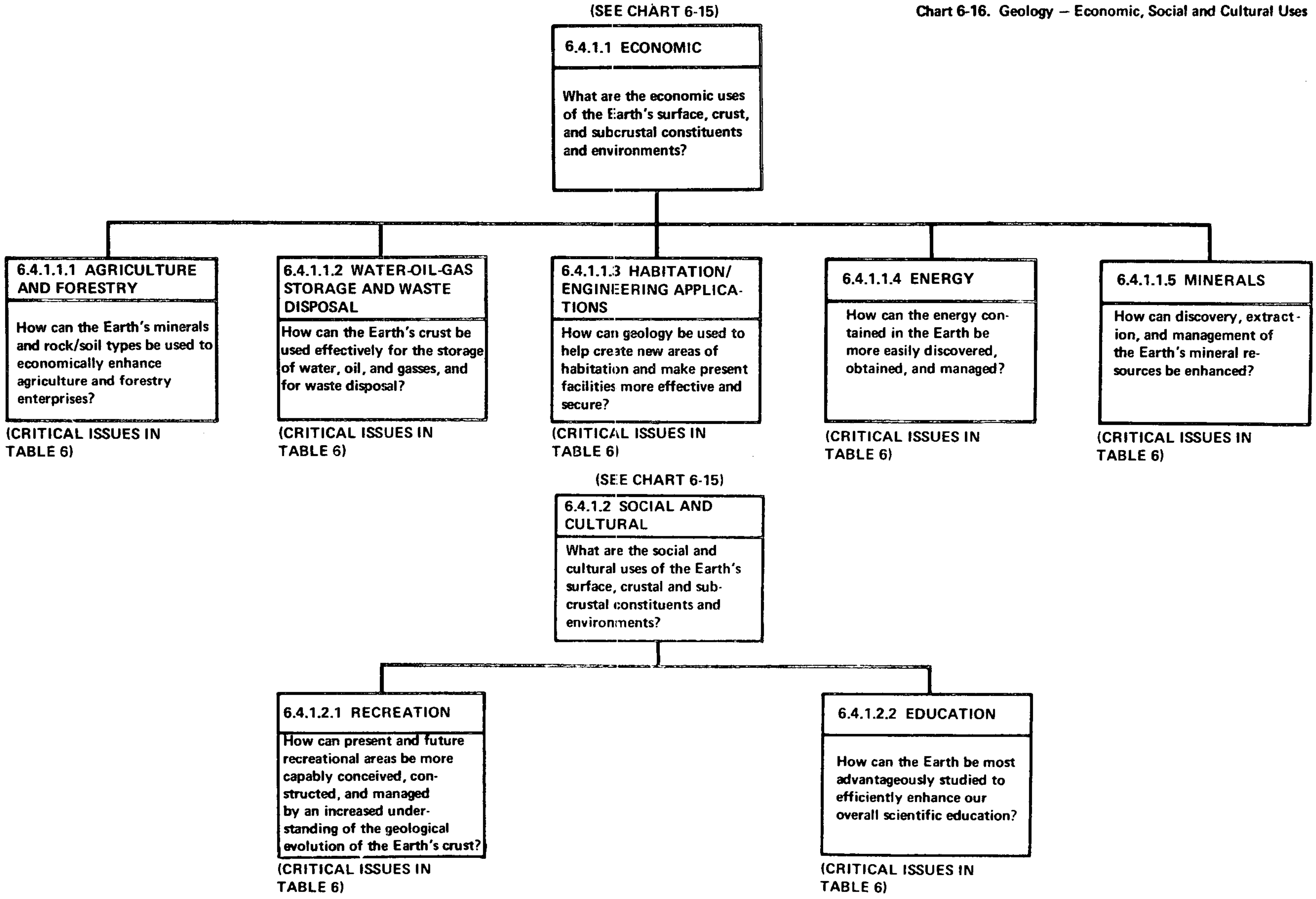
  (SEE CHART 6-19)

- **6.4.3.3 BIOTA**

  How does the Earth's surface constituents and environments affect the biota?

  (SEE CHART 6-19)

Chart 6-16. Geology – Economic, Social and Cultural Uses



(SEE CHART 6-15)

6.4.1.1 ECONOMIC

What are the economic uses of the Earth's surface, crust, and subcrustal constituents and environments?

6.4.1.1.1 AGRICULTURE AND FORESTRY

How can the Earth's minerals and rock/soil types be used to economically enhance agriculture and forestry enterprises?

(CRITICAL ISSUES IN TABLE 6)

6.4.1.1.2 WATER-OIL-GAS STORAGE AND WASTE DISPOSAL

How can the Earth's crust be used effectively for the storage of water, oil, and gasses, and for waste disposal?

(CRITICAL ISSUES IN TABLE 6)

6.4.1.1.3 HABITATION/ ENGINEERING APPLICATIONS

How can geology be used to help create new areas of habitation and make present facilities more effective and secure?

(CRITICAL ISSUES IN TABLE 6)

6.4.1.1.4 ENERGY

How can the energy contained in the Earth be more easily discovered, obtained, and managed?

(CRITICAL ISSUES IN TABLE 6)

6.4.1.1.5 MINERALS

How can discovery, extraction, and management of the Earth's mineral resources be enhanced?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-15)

6.4.1.2 SOCIAL AND CULTURAL

What are the social and cultural uses of the Earth's surface, crustal and subcrustal constituents and environments?

6.4.1.2.1 RECREATION

How can present and future recreational areas be more capably conceived, constructed, and managed by an increased understanding of the geological evolution of the Earth's crust?

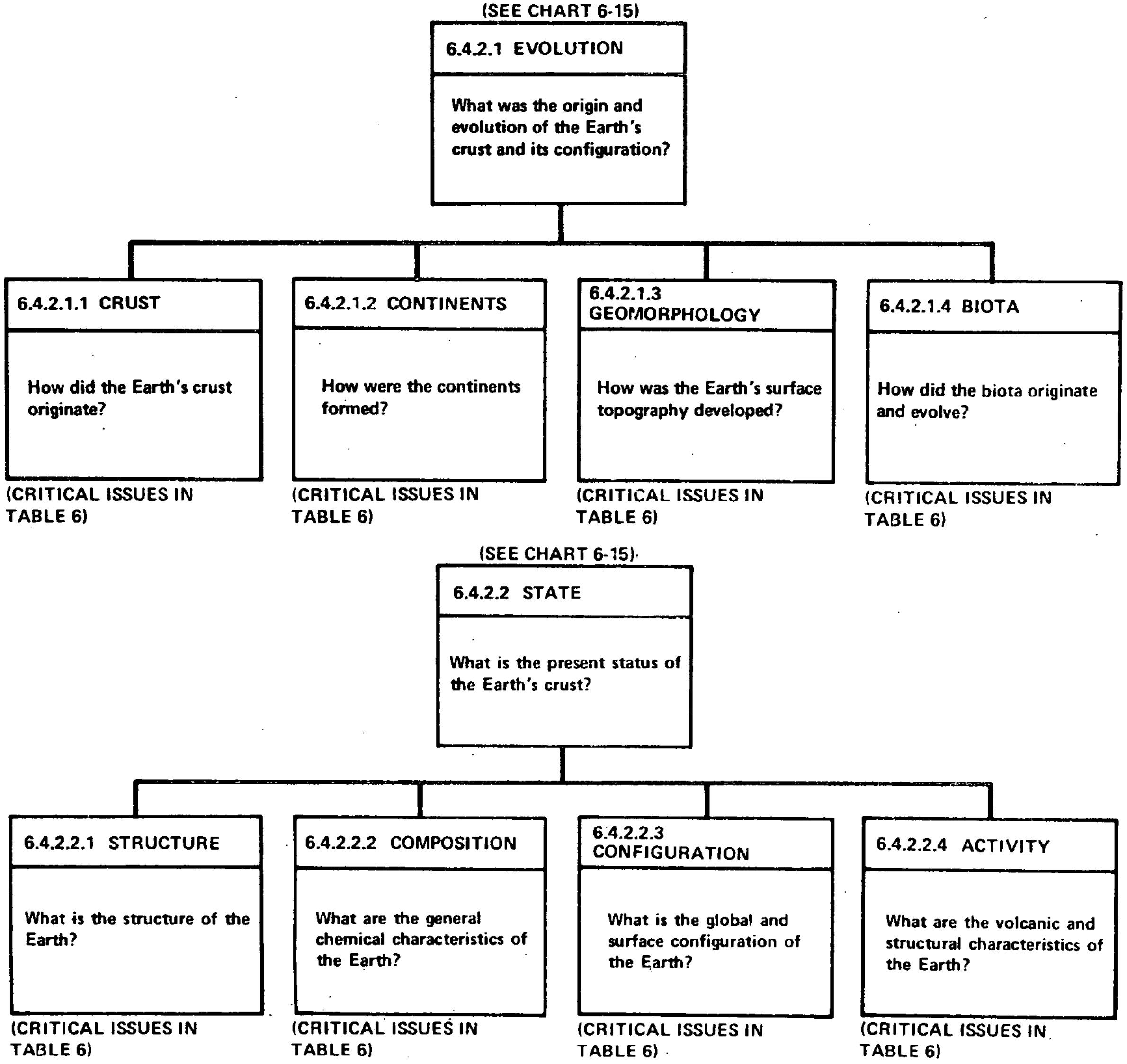
(CRITICAL ISSUES IN TABLE 6)

6.4.1.2.2 EDUCATION

How can the Earth be most advantageously studied to efficiently enhance our overall scientific education?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-17. Geology – Evolution and State Knowledge



(SEE CHART 6-15)

6.4.2.1 EVOLUTION

What was the origin and evolution of the Earth's crust and its configuration?

6.4.2.1.1 CRUST

How did the Earth's crust originate?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.1.2 CONTINENTS

How were the continents formed?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.1.3 GEOMORPHOLOGY

How was the Earth's surface topography developed?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.1.4 BIOTA

How did the biota originate and evolve?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-15)

6.4.2.2 STATE

What is the present status of the Earth's crust?

6.4.2.2.1 STRUCTURE

What is the structure of the Earth?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.2.2 COMPOSITION

What are the general chemical characteristics of the Earth?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.2.3 CONFIGURATION

What is the global and surface configuration of the Earth?

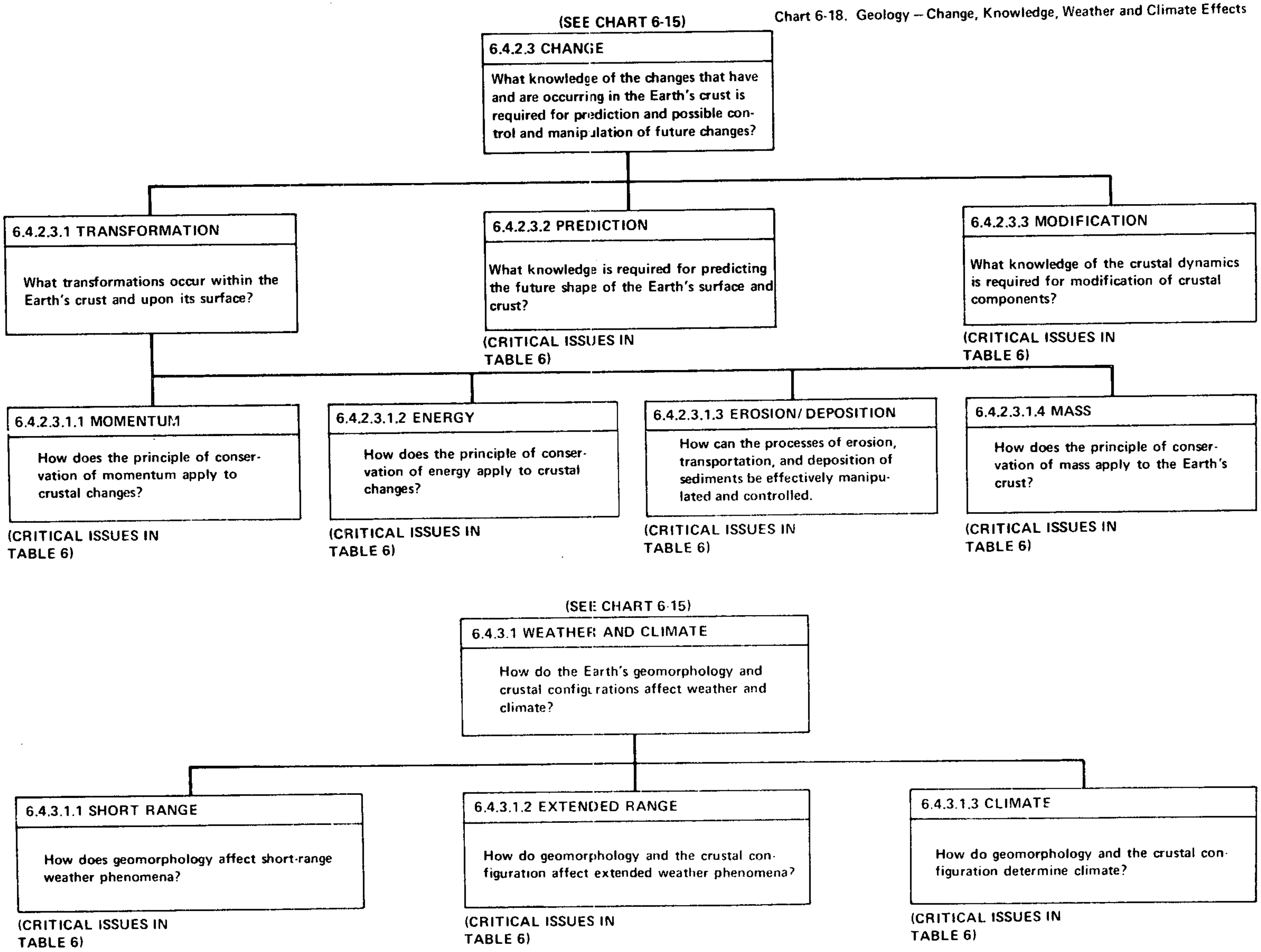
(CRITICAL ISSUES IN TABLE 6)

6.4.2.2.4 ACTIVITY

What are the volcanic and structural characteristics of the Earth?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-18. Geology – Change, Knowledge, Weather and Climate Effects



(SEE CHART 6-15)

6.4.2.3 CHANGE

What knowledge of the changes that have and are occurring in the Earth's crust is required for prediction and possible control and manipulation of future changes?

6.4.2.3.1 TRANSFORMATION

What transformations occur within the Earth's crust and upon its surface?

6.4.2.3.2 PREDICTION

What knowledge is required for predicting the future shape of the Earth's surface and crust?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.3.3 MODIFICATION

What knowledge of the crustal dynamics is required for modification of crustal components?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.3.1.1 MOMENTUM

How does the principle of conservation of momentum apply to crustal changes?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.3.1.2 ENERGY

How does the principle of conservation of energy apply to crustal changes?

(CRITICAL ISSUES IN TABLE 6)

6.4.2.3.1.3 EROSION/DEPOSITION

How can the processes of erosion, transportation, and deposition of sediments be effectively manipulated and controlled.

(CRITICAL ISSUES IN TABLE 6)

6.4.2.3.1.4 MASS

How does the principle of conservation of mass apply to the Earth's crust?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-15)

6.4.3.1 WEATHER AND CLIMATE

How do the Earth's geomorphology and crustal configurations affect weather and climate?

6.4.3.1.1 SHORT RANGE

How does geomorphology affect short-range weather phenomena?

(CRITICAL ISSUES IN TABLE 6)

6.4.3.1.2 EXTENDED RANGE

How do geomorphology and the crustal configuration affect extended weather phenomena?

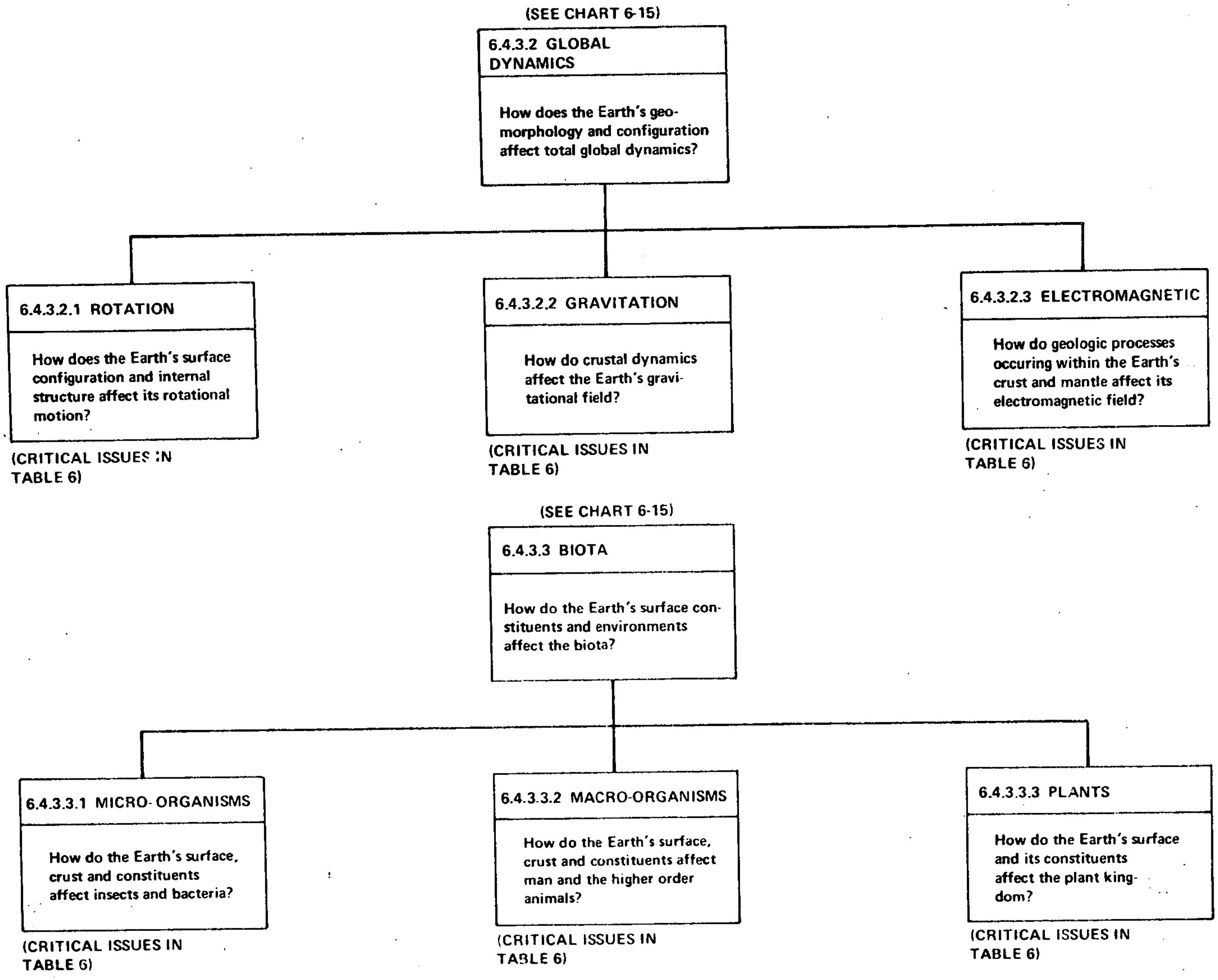
(CRITICAL ISSUES IN TABLE 6)

6.4.3.1.3 CLIMATE

How do geomorphology and the crustal configuration determine climate?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-19. Geology – Global Dynamics Effects and Biota Effects



(SEE CHART 6-15)

6.4.3.2 GLOBAL DYNAMICS

How does the Earth's geomorphology and configuration affect total global dynamics?

6.4.3.2.1 ROTATION

How does the Earth's surface configuration and internal structure affect its rotational motion?

(CRITICAL ISSUES IN TABLE 6)

6.4.3.2.2 GRAVITATION

How do crustal dynamics affect the Earth's gravitational field?

(CRITICAL ISSUES IN TABLE 6)

6.4.3.2.3 ELECTROMAGNETIC

How do geologic processes occuring within the Earth's crust and mantle affect its electromagnetic field?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-15)

6.4.3.3 BIOTA

How do the Earth's surface constituents and environments affect the biota?

6.4.3.3.1 MICRO-ORGANISMS

How do the Earth's surface, crust and constituents affect insects and bacteria?

(CRITICAL ISSUES IN TABLE 6)

6.4.3.3.2 MACRO-ORGANISMS

How do the Earth's surface, crust and constituents affect man and the higher order animals?

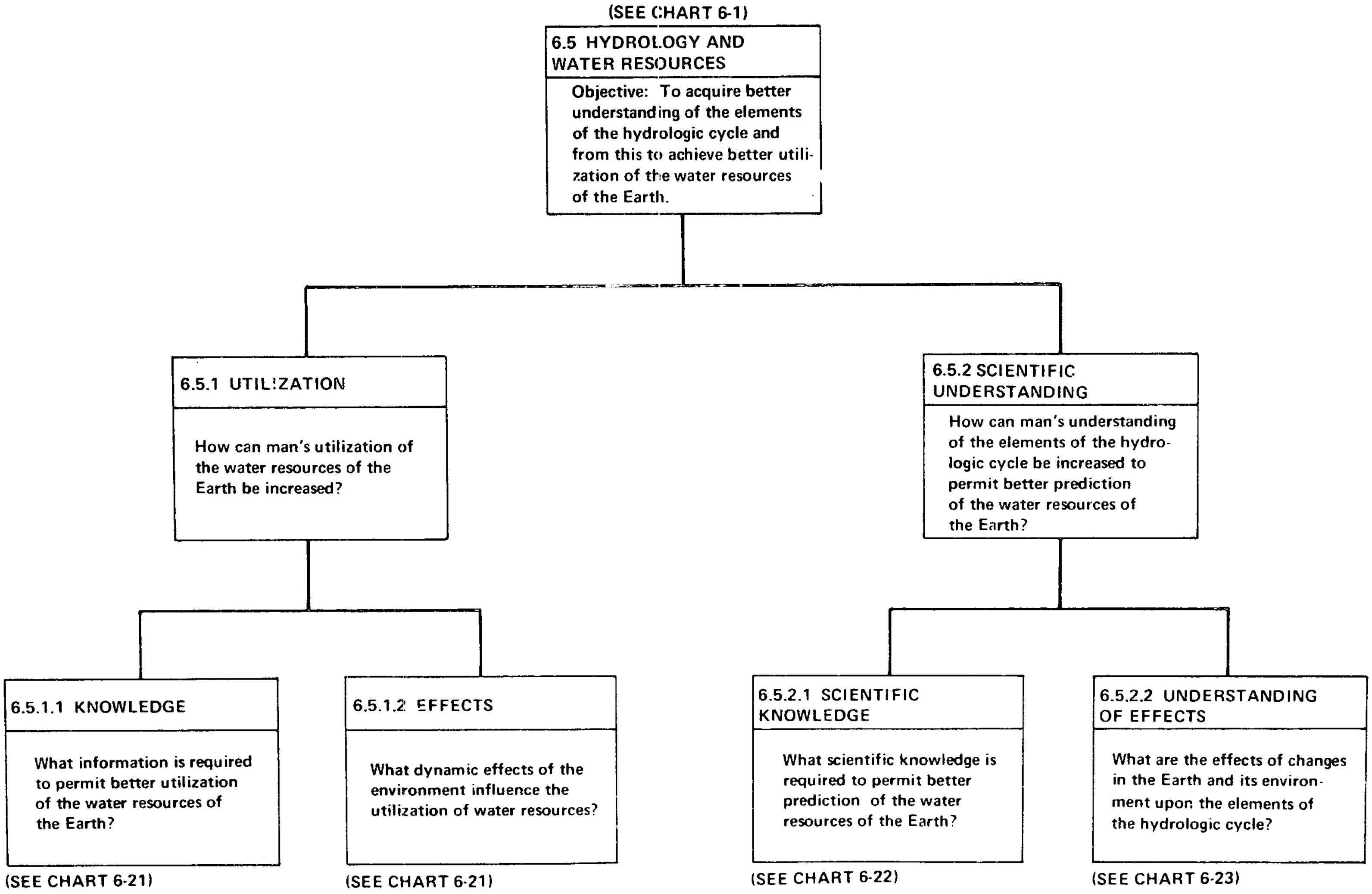
(CRITICAL ISSUES IN TABLE 6)

6.4.3.3.3 PLANTS

How do the Earth's surface and its constituents affect the plant kingdom?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-20. Organized Overview for Hydrology and Water Resources



(SEE CHART 6-1)

6.5 HYDROLOGY AND WATER RESOURCES

Objective: To acquire better understanding of the elements of the hydrologic cycle and from this to achieve better utilization of the water resources of the Earth.

6.5.1 UTILIZATION

How can man's utilization of the water resources of the Earth be increased?

6.5.2 SCIENTIFIC UNDERSTANDING

How can man's understanding of the elements of the hydrologic cycle be increased to permit better prediction of the water resources of the Earth?

6.5.1.1 KNOWLEDGE

What information is required to permit better utilization of the water resources of the Earth?

(SEE CHART 6-21)

6.5.1.2 EFFECTS

What dynamic effects of the environment influence the utilization of water resources?

(SEE CHART 6-21)

6.5.2.1 SCIENTIFIC KNOWLEDGE

What scientific knowledge is required to permit better prediction of the water resources of the Earth?

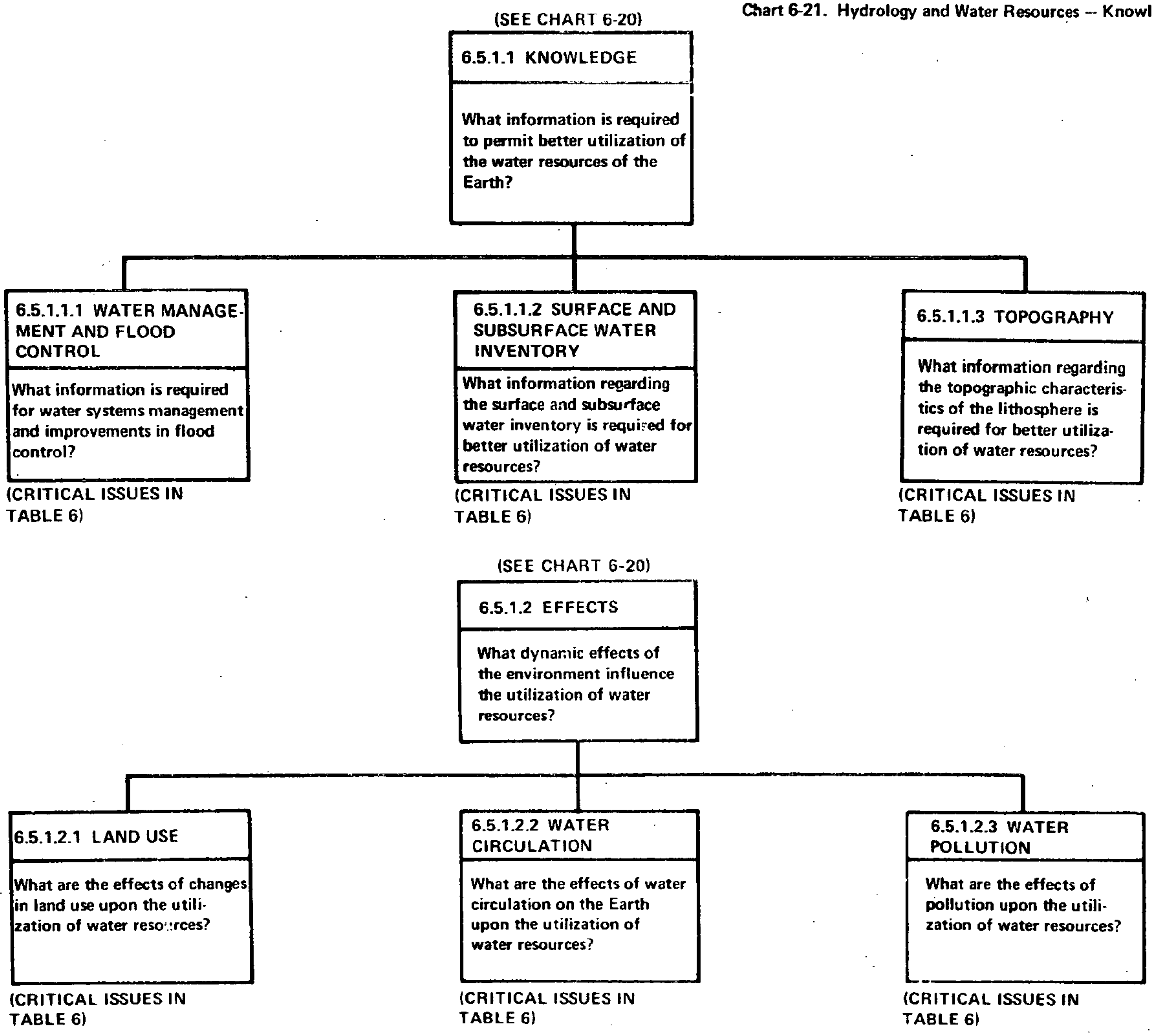
(SEE CHART 6-22)

6.5.2.2 UNDERSTANDING OF EFFECTS

What are the effects of changes in the Earth and its environment upon the elements of the hydrologic cycle?

(SEE CHART 6-23)

Chart 6-21. Hydrology and Water Resources -- Knowledge and Effects of Utilization



(SEE CHART 6-20)

6.5.1.1 KNOWLEDGE

What information is required to permit better utilization of the water resources of the Earth?

6.5.1.1.1 WATER MANAGEMENT AND FLOOD CONTROL

What information is required for water systems management and improvements in flood control?

(CRITICAL ISSUES IN TABLE 6)

6.5.1.1.2 SURFACE AND SUBSURFACE WATER INVENTORY

What information regarding the surface and subsurface water inventory is required for better utilization of water resources?

(CRITICAL ISSUES IN TABLE 6)

6.5.1.1.3 TOPOGRAPHY

What information regarding the topographic characteristics of the lithosphere is required for better utilization of water resources?

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-20)

6.5.1.2 EFFECTS

What dynamic effects of the environment influence the utilization of water resources?

6.5.1.2.1 LAND USE

What are the effects of changes in land use upon the utilization of water resources?

(CRITICAL ISSUES IN TABLE 6)

6.5.1.2.2 WATER CIRCULATION

What are the effects of water circulation on the Earth upon the utilization of water resources?

(CRITICAL ISSUES IN TABLE 6)

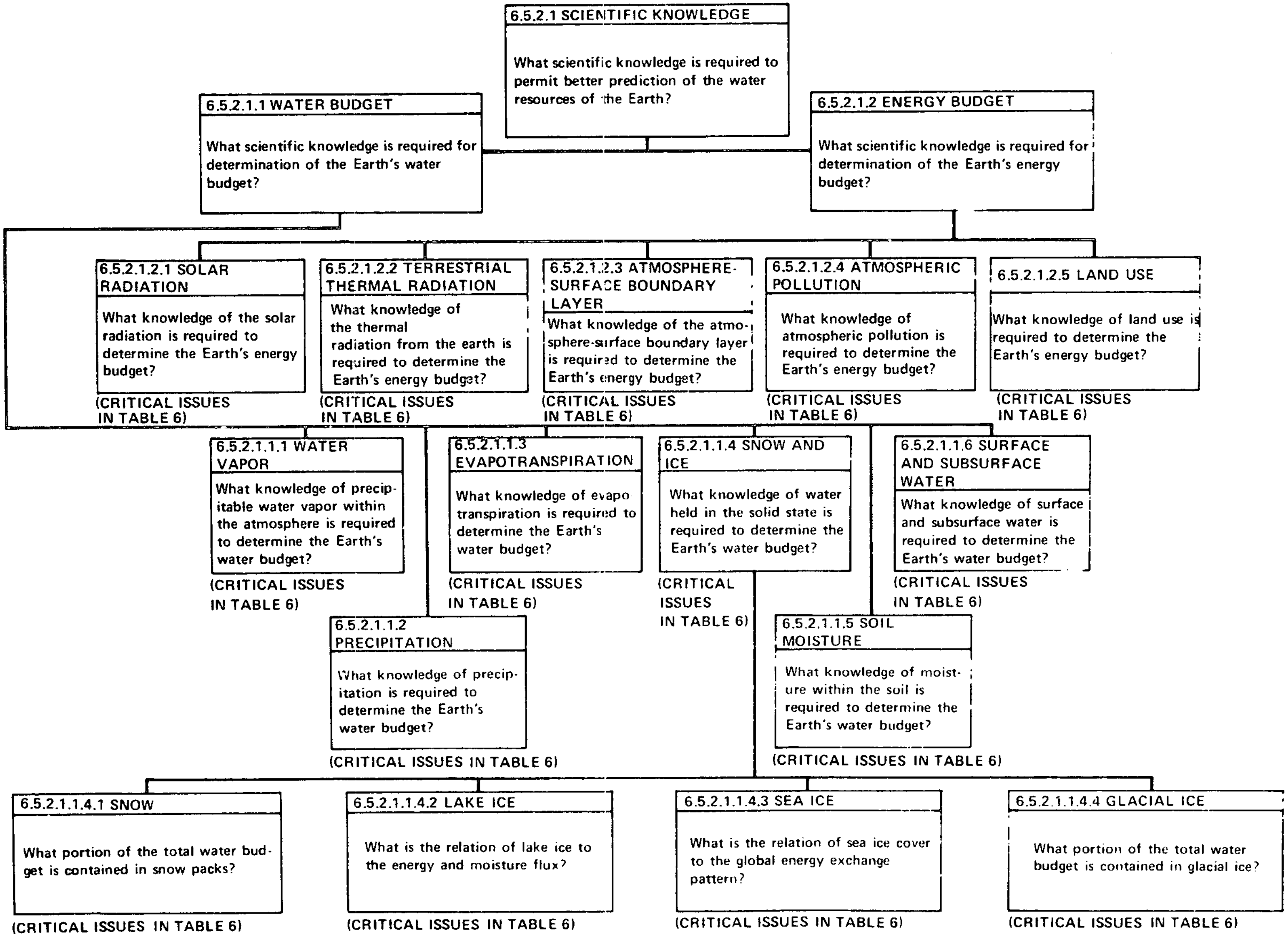
6.5.1.2.3 WATER POLLUTION

What are the effects of pollution upon the utilization of water resources?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-22. Hydrology and Water Resources – Scientific Knowledge

(SEE CHART 6-20)



6.5.2.1 SCIENTIFIC KNOWLEDGE

What scientific knowledge is required to permit better prediction of the water resources of the Earth?

6.5.2.1.1 WATER BUDGET

What scientific knowledge is required for determination of the Earth's water budget?

6.5.2.1.2 ENERGY BUDGET

What scientific knowledge is required for determination of the Earth's energy budget?

6.5.2.1.2.1 SOLAR RADIATION

What knowledge of the solar radiation is required to determine the Earth's energy budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.2.2 TERRESTRIAL THERMAL RADIATION

What knowledge of the thermal radiation from the earth is required to determine the Earth's energy budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.2.3 ATMOSPHERE-SURFACE BOUNDARY LAYER

What knowledge of the atmosphere-surface boundary layer is required to determine the Earth's energy budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.2.4 ATMOSPHERIC POLLUTION

What knowledge of atmospheric pollution is required to determine the Earth's energy budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.2.5 LAND USE

What knowledge of land use is required to determine the Earth's energy budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.1 WATER VAPOR

What knowledge of precipitable water vapor within the atmosphere is required to determine the Earth's water budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.2 PRECIPITATION

What knowledge of precipitation is required to determine the Earth's water budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.3 EVAPOTRANSPIRATION

What knowledge of evapotranspiration is required to determine the Earth's water budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.4 SNOW AND ICE

What knowledge of water held in the solid state is required to determine the Earth's water budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.5 SOIL MOISTURE

What knowledge of moisture within the soil is required to determine the Earth's water budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.6 SURFACE AND SUBSURFACE WATER

What knowledge of surface and subsurface water is required to determine the Earth's water budget?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.4.1 SNOW

What portion of the total water budget is contained in snow packs?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.4.2 LAKE ICE

What is the relation of lake ice to the energy and moisture flux?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.4.3 SEA ICE

What is the relation of sea ice cover to the global energy exchange pattern?

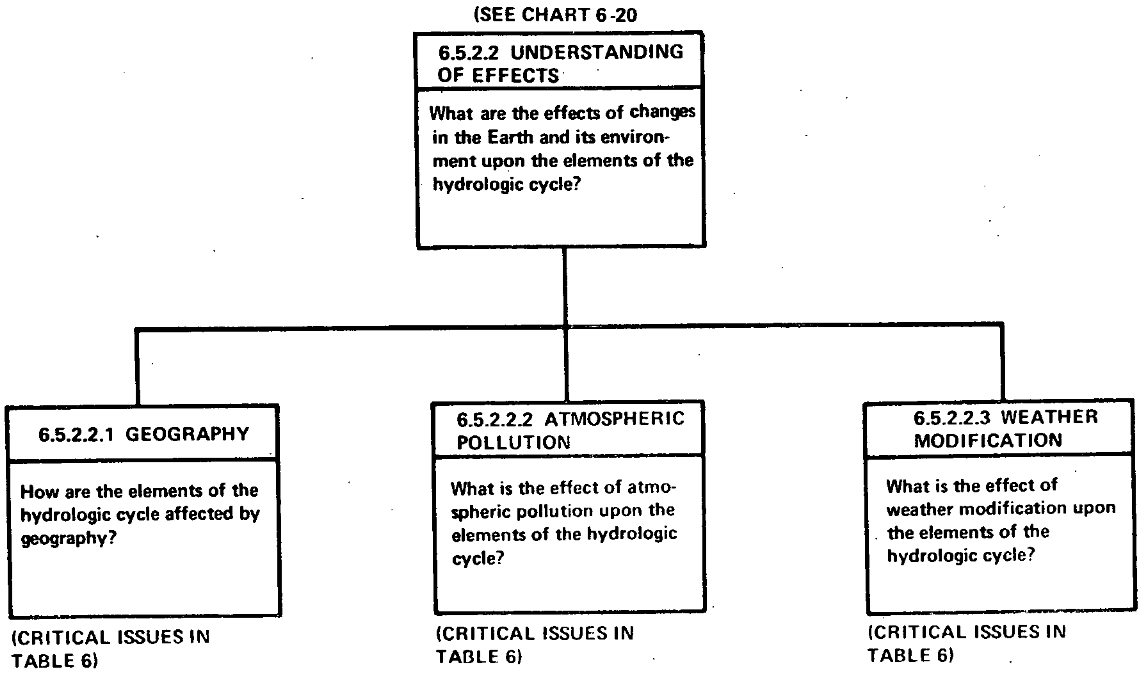
(CRITICAL ISSUES IN TABLE 6)

6.5.2.1.1.4.4 GLACIAL ICE

What portion of the total water budget is contained in glacial ice?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-23. Hydrology and Water Resources – Understanding of Effects



(SEE CHART 6-20

6.5.2.2 UNDERSTANDING OF EFFECTS

What are the effects of changes in the Earth and its environment upon the elements of the hydrologic cycle?

6.5.2.2.1 GEOGRAPHY

How are the elements of the hydrologic cycle affected by geography?

(CRITICAL ISSUES IN TABLE 6)

6.5.2.2.2 ATMOSPHERIC POLLUTION

What is the effect of atmospheric pollution upon the elements of the hydrologic cycle?

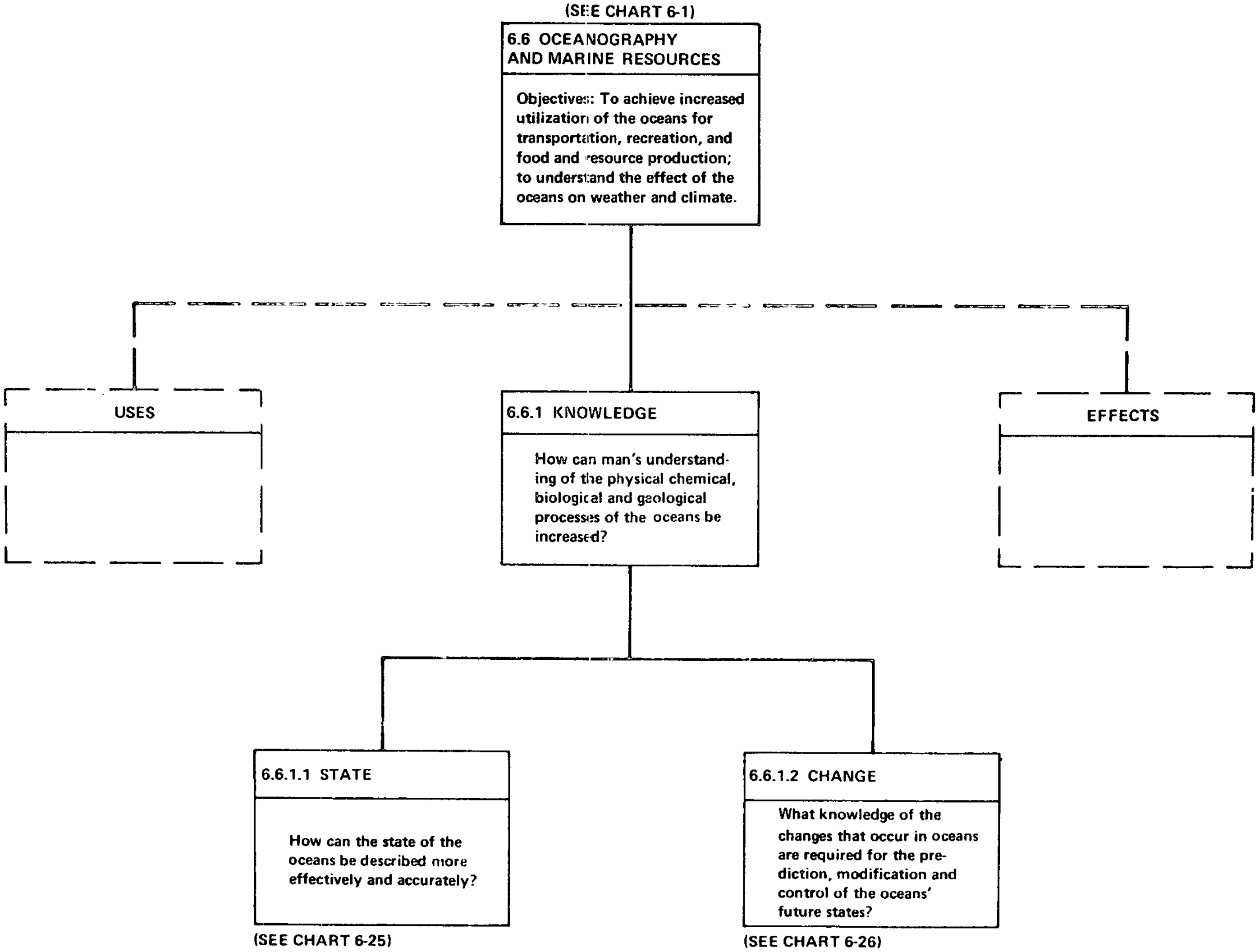
(CRITICAL ISSUES IN TABLE 6)

6.5.2.2.3 WEATHER MODIFICATION

What is the effect of weather modification upon the elements of the hydrologic cycle?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-24. Organized Overview for Oceanography and Marine Resources



(SEE CHART 6-1)

6.6 OCEANOGRAPHY AND MARINE RESOURCES

Objectives: To achieve increased utilization of the oceans for transportation, recreation, and food and resource production; to understand the effect of the oceans on weather and climate.

USES

6.6.1 KNOWLEDGE

How can man's understanding of the physical chemical, biological and geological processes of the oceans be increased?

EFFECTS

6.6.1.1 STATE

How can the state of the oceans be described more effectively and accurately?

(SEE CHART 6-25)

6.6.1.2 CHANGE

What knowledge of the changes that occur in oceans are required for the prediction, modification and control of the oceans' future states?

(SEE CHART 6-26)

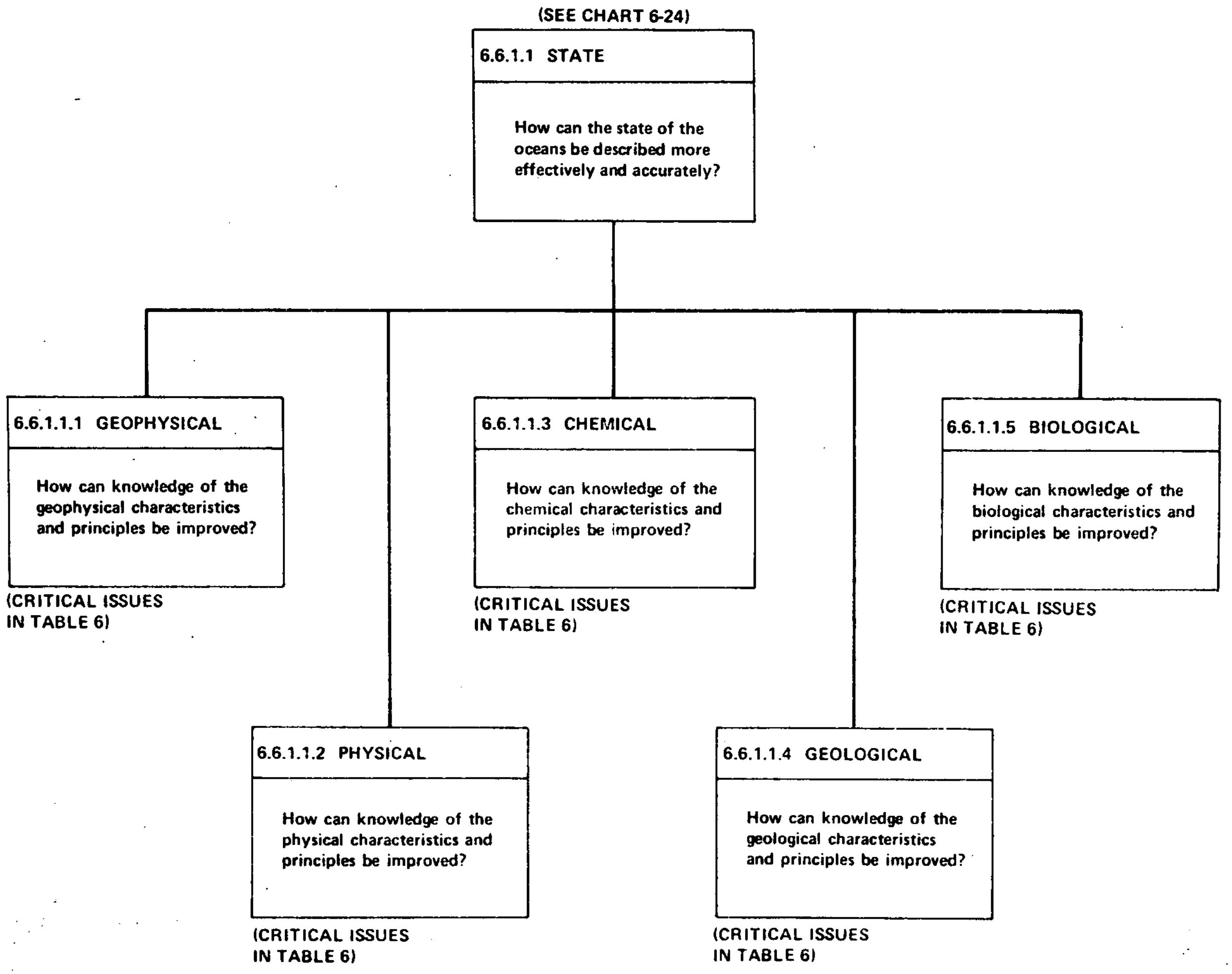


Chart 6-25. Oceanography and Marine Resources – Knowledge of State

(SEE CHART 6-24)

6.6.1.1 STATE

How can the state of the oceans be described more effectively and accurately?

6.6.1.1.1 GEOPHYSICAL

How can knowledge of the geophysical characteristics and principles be improved?

(CRITICAL ISSUES IN TABLE 6)

6.6.1.1.2 PHYSICAL

How can knowledge of the physical characteristics and principles be improved?

(CRITICAL ISSUES IN TABLE 6)

6.6.1.1.3 CHEMICAL

How can knowledge of the chemical characteristics and principles be improved?

(CRITICAL ISSUES IN TABLE 6)

6.6.1.1.4 GEOLOGICAL

How can knowledge of the geological characteristics and principles be improved?

(CRITICAL ISSUES IN TABLE 6)

6.6.1.1.5 BIOLOGICAL

How can knowledge of the biological characteristics and principles be improved?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-26. Oceanography and Marine Resources – Knowledge of Change

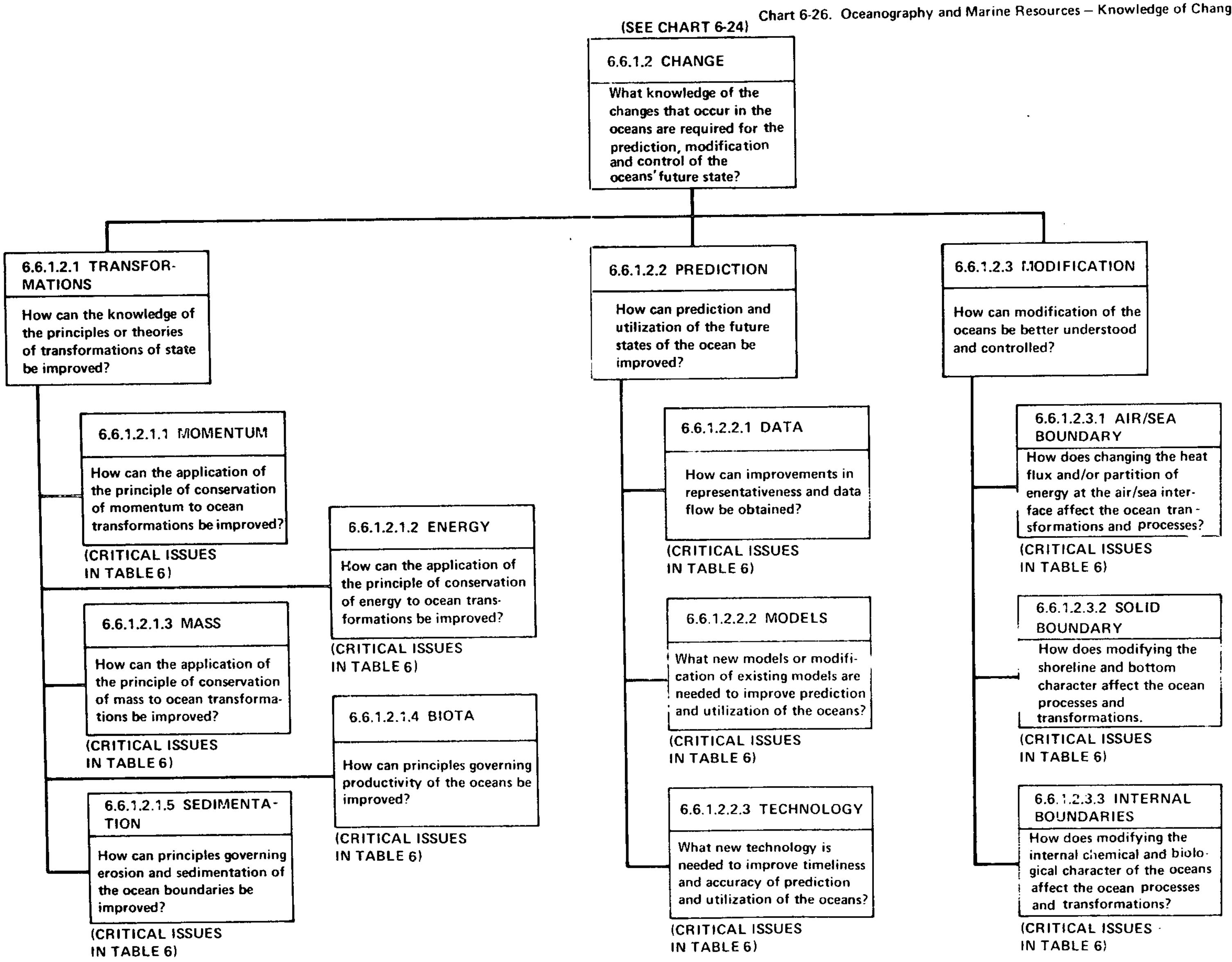


Chart 6-27. Organized Overview for Meteorology

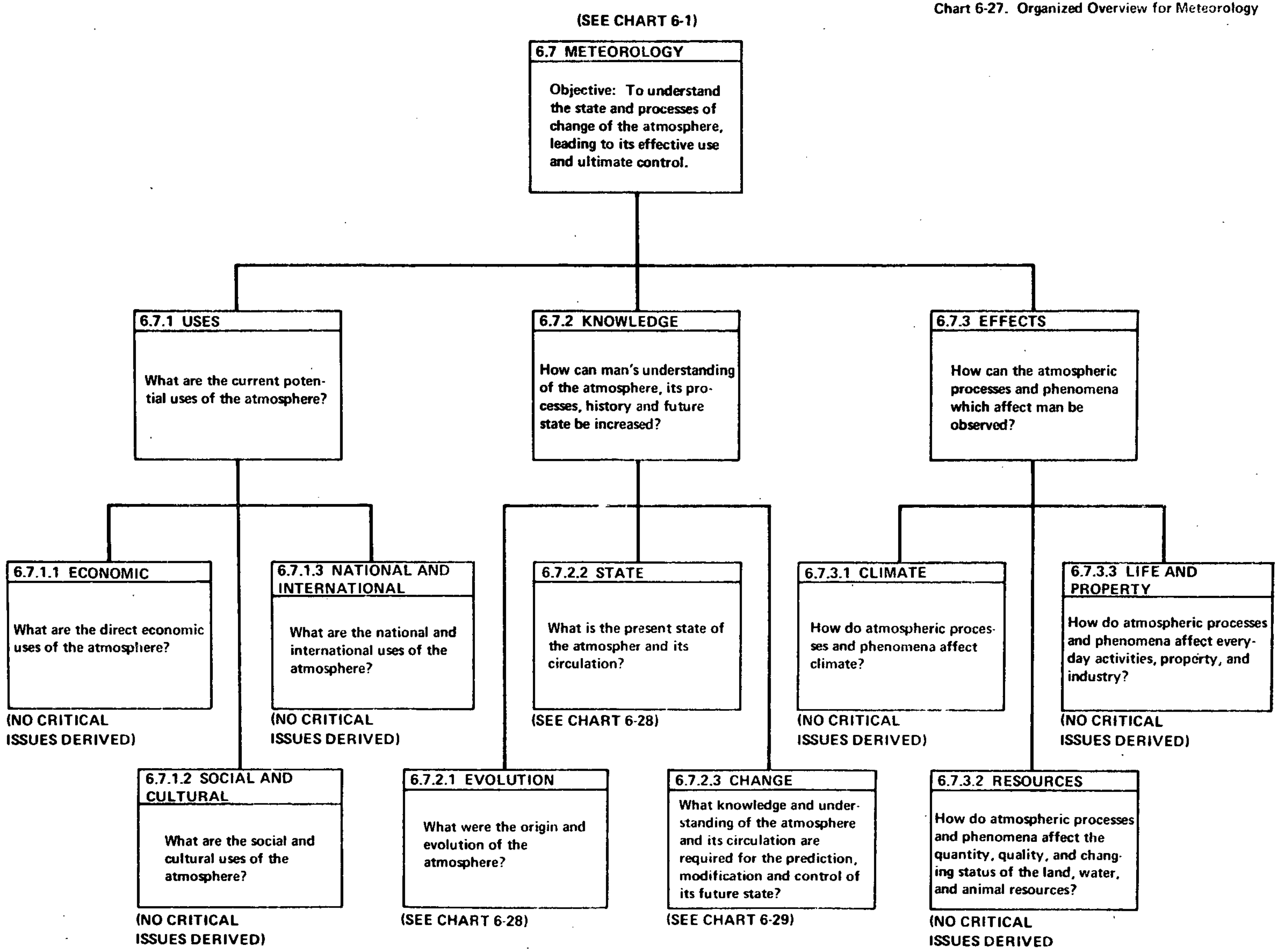
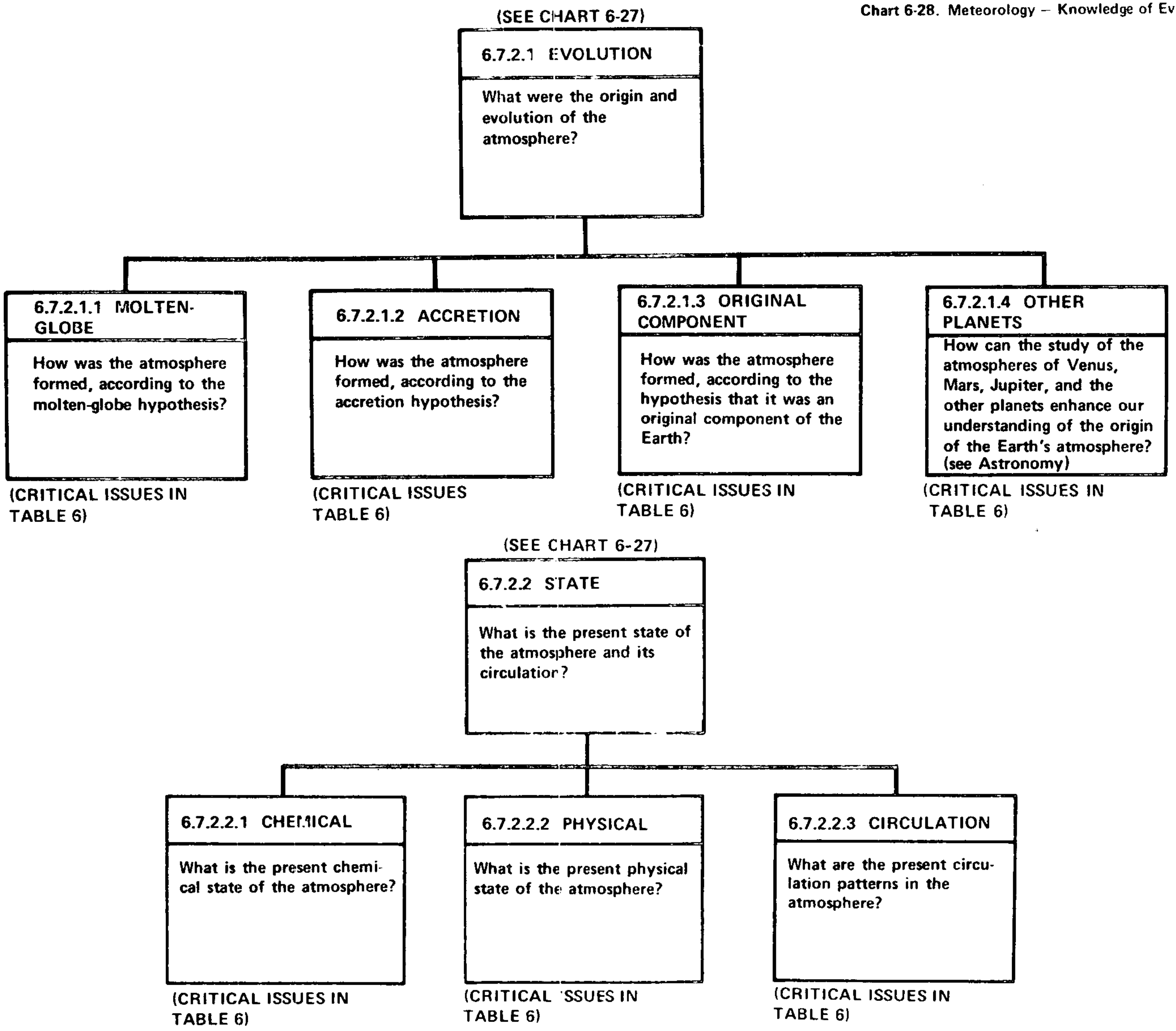


Chart 6-28. Meteorology – Knowledge of Evolution and State



(SEE CHART 6-27)

6.7.2.1 EVOLUTION

What were the origin and evolution of the atmosphere?

6.7.2.1.1 MOLTEN-GLOBE

How was the atmosphere formed, according to the molten-globe hypothesis?

(CRITICAL ISSUES IN TABLE 6)

6.7.2.1.2 ACCRETION

How was the atmosphere formed, according to the accretion hypothesis?

(CRITICAL ISSUES TABLE 6)

6.7.2.1.3 ORIGINAL COMPONENT

How was the atmosphere formed, according to the hypothesis that it was an original component of the Earth?

(CRITICAL ISSUES IN TABLE 6)

6.7.2.1.4 OTHER PLANETS

How can the study of the atmospheres of Venus, Mars, Jupiter, and the other planets enhance our understanding of the origin of the Earth's atmosphere? (see Astronomy)

(CRITICAL ISSUES IN TABLE 6)

(SEE CHART 6-27)

6.7.2.2 STATE

What is the present state of the atmosphere and its circulation?

6.7.2.2.1 CHEMICAL

What is the present chemical state of the atmosphere?

(CRITICAL ISSUES IN TABLE 6)

6.7.2.2.2 PHYSICAL

What is the present physical state of the atmosphere?

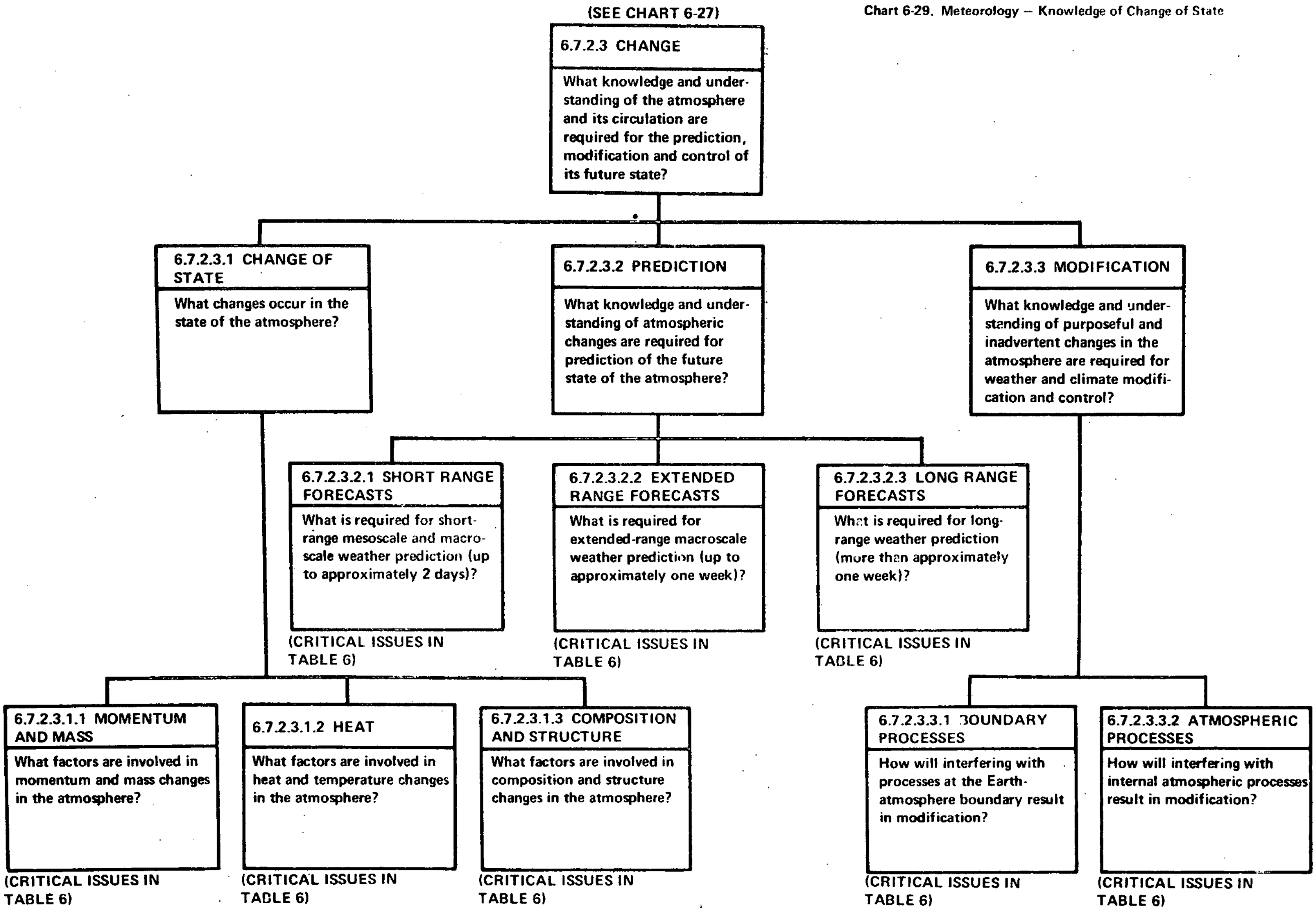
(CRITICAL ISSUES IN TABLE 6)

6.7.2.2.3 CIRCULATION

What are the present circulation patterns in the atmosphere?

(CRITICAL ISSUES IN TABLE 6)

Chart 6-29. Meteorology – Knowledge of Change of State



APPENDIX B

CRITICAL ISSUES

EARTH OBSERVATIONS

Appendix B

INTRODUCTION

This appendix presents the series of 3, 800 critical issues that comprise the principal result of the organized overview analysis of objectives for the six scientific and technical disciplines. The organized overview is described in Section 2 and graphically displayed in the charts contained in Appendix A.

In order to maintain the traceable indexing system carried through the charts shown in Appendix A, the numbers are repeated as major headings in Appendix B. Each critical issue thereby retains identity with the objectives and subobjectives from which it was derived.

The results of further analysis of the critical issues during the latter phases of the study are combined with the tabulation in this appendix by entering a code in the margin of the page, specifying the eventual disposition action. Table B-1 explains the code used for this assignment of critical issues.

In using Table B-1 to trace out the disposition, it is helpful to note that the principal consideration is whether or not the critical issue is addressed in at least one research cluster. In cases where this has occurred, the identifying serial number of the research cluster is used as the code. The alternative (2-letter) codes refer to categorical assignments of critical issues not included in the research cluster descriptions.

A summary of the disposition of the 3, 800 critical issues in the six disciplines, according to the coding protocol of Table B-1, is presented in Table B-2.

Gaps in the sequence of critical issue numbers in Appendix B represent scientific and technical areas that were considered in the study but for which no critical issues were derived.

Table B-1

CODE FOR DISPOSITION OF CRITICAL ISSUES

X-AB-YY	Addressed in Research Cluster No. X-AB The first number (X) indicates the scientific or technical discipline, i. e., 1 - Manned Spaceflight Capability 2 - Space Biology 3 - Space Astronomy 4 - Space Physics 5 - Communications and Navigation 6 - Earth Observations The one- or two-letter code (AB) indicates the subdiscipline area, e. g., BR - Behavioral Research PP - Plasma Physics Laboratory A/F - Agriculture, Forest, and Range Resources The final number (YY) is a sequence number within the subdiscipline. Thus, 4-PP-3 is the third research cluster in the Plasma Physics Laboratory subdiscipline of the Space Physics discipline.
PS	Eliminated by Preliminary Screening Critical issue considered to be essentially peripheral to the scope of Earth orbital research. These issues were included in the report for the ideas that they might stimulate, but were not analyzed further.
NS	Eliminated: Not an Earth Orbital Research Candidate Critical issue judged to be more appropriate to research based elsewhere—terrestrial, sub-orbital, interplanetary trajectories, extraterrestrial bodies, etc.—after considering the advantages and disadvantages of various orbits and of the space environment.
UM	Eliminated: Not a Manned Earth Orbital Research Candidate Critical issue judged to be better suited to automated spacecraft than to manned Earth orbital research facilities, due either to the inability of man to contribute meaningfully to the research or to detrimental effects of man's presence.

Table B-1

CODE FOR DISPOSITION OF CRITICAL ISSUES (Continued)

OP	Eliminated: Covered in Ongoing Programs Critical issue whose research requirements are expected to be satisfied from the results of programs already in progress or firmly planned.
AC	Deferred, Due to Requirements for Advanced Concepts Critical issue for which no experimental approach is currently available, or for which advanced study or advanced ground-based developments should precede further programmatic analysis.
MS, SB, SA, SP, CN, or EO	Principally Concerned with Another Discipline Critical issue included in the organized overview analysis of a given discipline for the sake of completeness, but which is actually more germain to another discipline (indicated by symbol) and is analyzed further in that discipline.

Table B-2

DISPOSITION OF CRITICAL ISSUES

Discipline Code	Manned Spaceflight Capability	Space Biology	Space Astronomy	Space Physics	Communications and Navigation	Earth Observations	Totals
In Research Cluster Cluster (X-AB-YY)	785	361	154	154	90	439	1,983
Preliminary Screening (PS)	330	0	155	15	0	36	536
Not Earth Orbital (NS)	187	0	240	49	81	137	694
Not Manned Earth Orbital (UM)	0	0	21	23	0	35	79
Covered in Ongoing Programs (OP)	72	0	0	0	14	1	87
Requires Advanced Concepts (AC)	81	2	156	0	122	9	370
Referred to Another Discipline (MS, SB, etc.)	13	0	26	3	8	1	51
Totals	1,468	363	752	244	315	658	3,800

Table 6

EARTH OBSERVATIONS CRITICAL ISSUES

6.1 EARTH PHYSICS (INCLUDING GEODESY)

6.1.1 STATE

6.1.1.1 Solid Earth Dynamics

6.1.1.1.1 Geometry

.1 What are positions of points in various local datums relative to United World Datum to ±10m? UM

.2 What are positions of tracking stations to ±5m on UWD? UM

.3 What are positions of deep space tracking stations to ±1m longitude and ±0.5m with respect to spin axis? UM

.4 What are the relative positions of points in at least 3 tectonic plates (various datums) to ±15cm? UM

.5 What are positions of points in each of the 20-odd large tectonic plates constituting the crust relative to each other to ±2cm from laser ranging and by very long baseline interferometry? UM

.6 What are the photographic characteristics of the Earth to ±500m? 6-EP-1

.7 What are the positions of ground beacons to ±1m? UM

6.1.1.1.2 Gravimetry

.1 What is the best-fit potential model for the Earth, including harmonic terms down to a half wavelength of 400km? UM

.2 What is the best-fit potential model for the Earth, including harmonic terms down to a half wavelength of 100km? UM

6.1.1.2 Ocean Circulation

6.1.1.2.1 Geopotential Field

.1 What is the best-fit potential model for the Earth, including harmonic terms down to a half wavelength of 250km? UM

.2 What is the best-fit potential model for the Earth, including harmonic terms down to a half wavelength of 100km? UM

.3 What are the improvements needed in potential theory to relate satellite measures to the geoid level? UM

.4 What are the gravimetric measurements by satellites or ships, necessary to support 10cm requirements in radar altimeters? UM

6.1.1.2.2 Mean Ocean Surface Height Above Geoid

.1 What are the variations of the mean ocean surface from the geoid to ±1m? UM

.2 What are the variations of the mean ocean surface from the geoid to ±10 cm? UM

.3 What is the model for representing and predicting variations of the mean ocean surface, including known tidal and current effects? NS

6.1.1.2.3 Positions and Velocities for Navigation

.1 What are ship locations relative to UWD to ±100m in position and 5cm/sec in velocity? UM

.2 What are float locations relative to UWD to ±2km? UM

6.1.2 CHANGE

6.1.2.1 Earthquake Mechanism

6.1.2.1.1 Seismic Fault Motions

.1 What are position changes along fault zones to ±15cm (by 1974) inferred from laser tracking and VLBI supplemented by detailed ground survey? 6-G-3

.2 What are position changes along fault zones to ±2cm? NS

6.1.2.1.2 Motions of Tectonic Plates

.1 What are tectonic motions to ±15cm for at least 3 plates? NS

.2 What are tectonic motions to ±2cm for 3 to 5 points on each of 20-odd plates? NS

6.1.2.1.3 Volcanic Activity

.1 What are the locations of incipient volcanic activity? 6-EP-2, 6-G-3

6.1.2.2 Global Heat Balance

.1 What is the global heat balance within the Earth's crust? 6-M-6

6.1.2.3 Geomagnetic Dynamo

.1 What are the geomagnetic dynamo characteristics of the Earth and how do they change with time? SP

6.1.2.4 Energy Dissipation in the Ocean

.1 What are the energy dissipation mechanisms in the ocean? 6-O-2

6.1.2.5 Earth Rotational Dynamics

6.1.2.5.1 Coordinate System Definition

.1 What are the geocentric locations of laser tracking sites to ±15cm? UM

.2 What are relative positions of VLBI stations to ±15cm? UM

.3 What are relative positions of laser and VLBI sites to ±2cm? UM

6.1.2.5.2 Polar Motion

.1 What is the location of the pole to an accuracy of 15 to 50cm? UM

.2 What is the location of the pole to an accuracy to 3 to 20cm? UM

6.1.2.5.3 Rotation

.1 What is the length of the day to ±2.5msec.? UM

.2 What is the length of the day to ±1msec.? UM

6.1.2.5.4 Inertial Direction Finding

.1 What are directions of radio sources to 0".005? UM

.2 What are directions of radio sources to 0".001? UM

6.2 AGRICULTURE, FOREST, AND RANGE RESOURCES

6.2.1 KNOWLEDGE

6.2.1.1 State

6.2.1.1.1 Location and Inventory

.1 What is the location and acreage of food and fiber crops? 6-A/F-1

.2 What is the location and acreage of grazing and browsing land? 6-A/F-1

.3 What is the location and acreage of commercial timber forests? 6-A/F-1

.4 What is the location and number of livestock? AC

.5 What is the location and number of game animals and birds? AC

.6 What is the location and acreage of fallow or soil improvement land? 6-A/F-1

.7 What is the location and acreage of harvested crop and forest land? 6-A/F-1

.8 What is the location and acreage of noxious weed infested land? 6-A/F-1

.9 What is the location and acreage of forest land that is pastured? 6-A/F-1

.10 What is the location, type and extent of storm damage? 6-A/F-4

.11 What is the location, direction and rate of movement of forest fires? 6-A/F-5

6.2.1.1.2 Species and Vigor

.1 What are the species of food crops and fiber crops? 6-A/F-3

.2 What are the species of trees? 6-A/F-3

.3 What is the palatability of forage on grazing and browsing lands? 6-A/F-3

.4 What are the species of livestock? AC

.5 What are the species of game animals and birds? AC

.6	What is the species of weeds and phreatophytes?	6-A/F-3
.7	What is the location, type and extent of beneficial and harmful insect infestation of vegetation?	6-A/F-4
.8	What is the location, type and extent of disease?	6-A/F-4
.9	What is the location, type and numbers of beneficial and harmful insects in the soil?	6-A/F-4
.10	What is the location, type and amount of beneficial and harmful organisms in the soil?	6-A/F-2,-4
.11	What is the age of orchards, vineyards and forests?	6-A/F-1,-4
.12	What is the flammability index of forest and range lands?	6-A/F-5

6.2.1.1.3 Soils and Water

.1	What is the fertility of the soil?	6-A/F-2,-4 6-G-1
.2	What is the salinity of the soil?	6-A/F-2,-4 6-G-1
.3	What is the moisture content, porosity and permeability of the soil?	6-A/F-2,-4 6-H-5
.4	What is the organic material content of the soil?	6-A/F-2,-4
.5	What is the incursion of brackish water in ground and surface water?	6-A/F-2,-4
.6	What is the location and extent of soil types?	6-A/F-2 6-G-1

6.2.1.2 Prediction

6.2.1.2.1 Location and Inventory

.1	What basic sensor and signature research should be done?	6-A/F-1,-3,-4
.2	What are the changes in acreage of cultivated, forest and wild lands?	6-A/F-1,-4
.3	What are the changes in numbers and distribution of livestock?	6-A/F-1
.4	What are the changes in numbers and location of game animals and birds?	AC
.5	What is the potential in board feet of timber lands?	6-A/F-4
.6	What is the location and extent of erosion, siltation and pollution?	6-A/F-4

6.2.1.2.2 Species and Vigor

.1	What is the signature of the species of food, fiber and wood crops?	6-A/F-3
.2	What is the signature of livestock and wild life?	6-A/F-3
.3	What is the signature of the unique ecological systems?	6-A/F-3,-4
.4	What is the yield forecasts for major food, fiber and forage crops?	6-A/F-4
.5	What is the state of vigor of crops, forests and range?	6-A/F-4
.6	Where are crops, forests or range under stress?	6-A/F-4
.7	What is the location and cause of major crop failure?	6-A/F-4
.8	What is the location and extent of insect or disease infestation?	6-A/F-4

6. 2. 1. 2. 3 Soils and Water

.1	What is the signature of brackish water or soil?	6-A/F-2, 6-G-1
.2	What are the sources of pollution?	6-A/F-1, 6-H-4, 6-M-5
.3	What are the distribution mechanisms of pollution?	6-A/F-1,6-H-4,6-M-5
.4	What is the location and amount of ground water?	6-A/F-2,-4 6-H-6
.5	What are the nutrient deficiencies of the soil?	6-A/F-4
.6	What are the organism deficiencies of the soil?	6-A/F-4
.7	What are the seasonal changes in snow packs and glaciers?	6-H-4
.8	Where are fertilizers being used?	6-A/F-2,-4 6-G-1

6. 2. 1. 3 Production and Distribution

6. 2. 1. 3. 1 Production

.1	What is the location and acreage of potentially arable land?	6-A/F-1
.2	Where should intensive land management be applied or improved?	6-AF-1
.3	Where should better timber cutting and logging methods be used?	6-A/F-1,-5
.4	Where should forest fire detection and fighting methods be improved?	6-AF-5
.5	Where should more land be converted to cultivation?	6-A/F-1
.6	Where should pesticides be used?	6-A/F-4
.7	Where should conservation practices be improved?	6-A/F-1,-4
.8	What is the ecological balance in wildlife and forest land?	AC
.9	Which countries currently have undeveloped forest and rangeland resources?	6-A/F-1
.10	Where is better conversion of forage into meat products needed?	6-A/F-1

6. 2. 1. 3. 2 Distribution

.1	What are the location and type of transportation routes?	6-A/F-1
.2	What are the potential access routes to resources that are difficult to reach?	6-A/F-1
.3	Where and by whom are the food and timber resources consumed?	6-A/F-1
.4	What is the weather along distribution routes?	6-M-6
.5	What is the climate of distribution areas?	6-M-6

6. 2. 2 SOURCES

6. 2. 2. 1 Data Collection

.1	What new instrumentation and measurement techniques are needed?	6-A/F-1,2,3,4,5
.2	What is the better form of data collection--statistics or maps?	6-AF-1,-3,-4

.3	What is the best size sampling unit for area classification?	6-A/F-1
.4	What is the effect of cloud obscuration?	6-A/F-1
.5	How effectively can an astronaut recognize and track a resource?	6-A/F-3
.6	How effectively can an astronaut work with a PI on the ground?	6-A/F-1,-3,-4,-5
.7	Can large structures, e.g., antennas, be erected in space?	6-A/F-1,2,3,4,5
.8	Can man perform calibration, repairs and maintenance of sensors in space?	6-A/F-1,2,3,4,5
.9	What sensor modification can and should be done in space?	6-A/F-1,2,3,4,5

6.2.2.2 Data Analyses

.1	What models are needed and what should be their inputs?	6-A/F-2,-3,-4
.2	What is the better form of data presentation--statistics or maps?	6-A/F-1,-3,-4
.3	What is the degree of usefulness of data that has marginal resolution?	6-A/F-2,-3,-4
.4	What is the cost of data collected from space compared to air and ground?	6-A/F-1,-4
.5	How can man's capabilities be combined in real time analysis, evaluation and decision making?	6-A/F-1,2,3,4,5
.6	How much data reduction should be done in space?	6-A/F-1,2,3,4,5
.7	What is the value of visual observation and verbal comment by the astronaut?	6-A/F-1,2,3,4,5
.8	What are the specific environmental factors affecting the interpretation of sensor data?	6-A/F-1,2,3,4,5

6.2.2.3 Mission Parameters

.1	What is the effect of cloud obscuration?	6-A/F-1
.2	What is the effect of illumination intensity and angle?	6-A/F-1,-2,-3
.3	What is the effect of season?	6-A/F-1,2,3,4,5
.4	What is the effect of orbit altitude and slant range?	6-A/F-1,2,3,4,5
.5	What is the effect of orbit inclination?	6-A/F-1,2,3,4,5
.6	What coordination with ground truth sites and aircraft underflights is needed?	6-A/F-2,-3,-4
.7	Can perennially clouded-over resources be observed through occasional breaks in the clouds?	6-A/F-1

6.2.3 USES

6.2.3.1 Economic

6.2.3.1.1 International

.1	Which countries are importing/exporting food or fiber?	6-A/F-1
.2	Which countries could be combined into common markets?	6-A/F-1

.3 Which countries have undeveloped agricultural, forest, range or wild resources? 6-A/F-1

.4 Where are new large dams or irrigation projects needed? 6-A/F-1

6.2.3.1.2 National

.1 Where will current data on supply and demand improve market efficiency? 6-A/F-1

.2 Where should intensive land management be applied? 6-A/F-4

.3 Where should land be entered or removed from cultivation? 6-A/F-1

.4 Where is better conversion of forage into meat products needed? 6-A/F-1

.5 Where are dams or irrigation projects needed? 6-A/F-1,-4

.6 What are the market implications of storm, drought and disease? 6-A/F-1,-4

6.2.3.1.3 State and Local

.1 Where can tax revenue from resources be increased? 6-A/F-1,-4

.2 Where can damaged timber or grain be salvaged? 6-A/F-4

.3 What is the ownership of specific forest, range and wild lands? 6-A/F-1

.4 What is the economic worth of the knowledge? 6-A/F-4

.5 What is the condition and economic value of the grain or wood in a stand? 6-A/F-4

.6 Where is soil exhaustion or overgrazing occurring? 6-A/F-2,-4, 6-G-1

6.2.3.2 Social and Cultural

6.2.3.2.1 International

.1 What are the natural food production and consumption areas? 6-A/F-1

.2 What information or training is needed by developing countries? 6-A/F-1

.3 What international cooperation in data acquisition and application is needed? 6-A/F-1,-5

.4 Where should migratory wild life sanctuaries be established? 6-A/F-1

6.2.3.2.2 National

.1 What are the recreation potentialities of forest, water and wild areas? 6-A/F-1

.2 Where should green belts or wilderness areas be established? 6-A/F-1

.3 Where should new cities be placed? 6-A/F-1

.4 What are the ecological effects of dams and irrigation projects? 6-A/F-1,-2

.5 Where is pollution or overuse endangering the recreational use of water or forest areas? 6-A/F-4

.6 Where should wild life sanctuaries and game preserves be established? 6-A/F-1

6.2.3.2.3 State and Local

.1	Where will future expansion of urban into rural areas occur?	6-A/F-1
.2	Where is pollutant emission in excess of standards?	6-H-1,6-M-5
.3	Where is regional development planning needed?	6-A/F-1
.4	Where is noncompliance with minimum land management practices occurring?	6-A/F-1
.5	Where should conservation practices be improved?	6-A/F-2,-4

6.3 GEOGRAPHY, CARTOGRAPHY, AND CULTURAL RESOURCES

6.3.1 USES

6.3.1.1 Economic

6.3.1.1.1 Resources

6.3.1.1.1.1 Water Resources

.1	How can the natural water supplies of remote wildlands, marshes, and other bird/animal sanctuaries be monitored?	6-G/C-1, 6-H-7
.2	How can natural snow and watershed capacities be increased and the runoff controlled and monitored?	6-G/C-1, 6-H-7
.3	How can topography be used more effectively for the generation of electrical power and control of silting of major dam and reservior systems?	6-G/C-1, 6-H-7
.4	How can potential irrigation water be located and possibly transferred to remote and reclaimed land areas?	6-G/C-1 6-H-3,7
.5	How can the distribution and rate of use of water supplies be monitored and presented in map form?	6-G/C-1, 6-H-3

6.3.1.1.1.2 Food Resources

.1	What aspects of geography and cartography may be applied to the analyses of remote lands for food resources applications?	6-G/C-1 6-A/F-1
.2	How may remote lands be located; categorized, indexed, and displayed in map form?	6-G/C-1 6-A/F-1
.3	How can land in the higher lattitudes be used more effectively for food reserves?	6-G/C-1 6-A/F-1,-2

6.3.1.1.1.3 Forest Resources

.1	How can geography be applied to the utilization or remote stands of timber?	6-G/C-1, 6-A/F-1,-5
.2	How can the location and configuration of remote timberlands be categorized, indexed and displayed in map form?	6-G/C-1, 6-A/F-1,-5
.3	How may geography and cartography be applied to more efficient monitoring and management of timberlands?	6-G/C-1, 6-A/F-1,-5

6.3.1.1.2 Transportation and Communications

6.3.1.1.2.1 Aircraft

.1	How can urban land areas be more effectively used for airport and maintenance facilities?	6-G/C-1
.2	How can the hazards of air traffic be more effectively controlled in the urban areas?	NS
.3	How can the offensive noise problem be controlled during flight into and out of urban areas?	NS
.4	Can air terminals be more efficiently or remotely located and satisfy the demands of the business society?	6-G/C-1, 6-A/F-1
.5	How can access and egress be more effectively implemented in the design of internal urban terminals?	6-G/C-1

6.3.1.1.2.2 Railroads

.1	What aspects of geography/cartography can be applied to more efficient routing of existing and future railroads?	6-G/C-1
.2	What changes in the mode and techniques of rail travel could effectively enhance the efficiency?	NS
.3	How can monitoring of population movement and land use be used effectively for the location of railroad connections?	6-G/C-1, 6-A/F-1
.4	How may the development of railroad demands be monitored and portrayed?	6-G/C-1

6.3.1.1.2.3 Roads

.1	What aspects of geography/cartography can be applied to more efficient routing of existing and future highways and internal urban accesses?	6-G/C-1 6-A/F-1
.2	How can geography be applied to the location of road materials and how may the sources be indexed and displayed?	6-G/C-1
.3	How can the most efficient types of roads be associated with geographic constraints and types of use?	NS
.4	How can the development of internal urban roads be efficiently monitored?	6-G/C-1

6.3.1.1.2.4 Water

.1	What aspects of naval architecture can be directed toward the construction of subsurface highspeed cargo ships?	NS
.2	How might inland short water bodies be adapted to air terminals?	6-G/C-1, 6-H-3
.3	How can natural river systems be more expeditiously exploited as transport media, and how can these systems be effectively monitored, managed and controlled?	6-G/C-1, 6-H-7

6.3.1.1.2.5 Transmission Lines

6.3.1.1.2.5.1 Pipelines--How can pipelines be adapted to function under severe climatic conditions and to provide transport for solids?

.1 How can pipelines be more efficiently routed and dependent upon local surface gradients? 6-G/C-1

.2 How can pipelines be adapted to the high latitudes for the transport of liquids? NS

.3 What aspects of pipeline transmission techniques could be applied to the transport of grains and/or other solids? NS

6.3.1.1.2.5.2 Power--How can the transmission of power and information carrying waves be significantly advanced and effectively deployed and managed for the expanding population?

.1 How can laser technology be applied to the transmission of sound? NS

.2 How can power be transmitted with greater efficiency? NS

.3 How can the capacity of the various carriers be significantly increased? NS

.4 How can power, phone, and other lines be eliminated from the urban environment? 6-G/C-1

6.3.1.1.3 Population

6.3.1.1.3.1 Urbanization

.1 What significant impact does expanding urbanization have on the condemnation of usable agriculture and forest lands? 6-G/C-1, 6-A/F-1

.2 How significant is the cement to land ratio of an expanding community on the erosion cycle and how might it be controlled? 6-G/C-1, 6-H-2

.3 How can the economics of urbanization be significantly increased? NS

.4 How may expanding communities be most advantageously monitored? 6-G/C-1, 6-A/F-1

.5 How can optimum community configurations be predicted? 6-G/C-1

6.3.1.1.3.2 Marketing

.1 What aspects of marketing are significantly affected by an expanding community and by settlement of new communities? NS

.2 How can marketing techniques keep abreast of population migration? NS

.3 How can mapping techniques be applied to the specific requirements of marketing? 6-A/F-1

6.3.1.1.3.3 Land Use

.1 What aspects of geography can be applied to the selection of potentially usable land areas? 6-G/C-1, 6-A/F-1

.2 How can unused lands be located, categorized, and indexed for specific uses? 6-G/C-1, 6-A/F-1

.3 How can cartographic techniques best be applied to all phases of land use from urban development to internationally controlled or monitored lands? 6-G/C-1, 6-A/F-1

6.3.1.2 Social and Cultural

6.3.1.2.1 Natural Disaster Avoidance

.1 How can the natural distribution of the Earth's surface features be related to the occurrence of natural destructive forces? 6-G/C-1, 6-A/F-5 6-G-3,6-H-2

.2 What aspectsof river dynamics can be explored to aid in the effective control of flood condition discharge? 6-G/C-1 6-H-2,-7

.3 How can abnormally high water conditions in the coastal environment be controlled for sustained periods? 6-O-4

.4 How can disaster avoidance and management procedures be identified and initiated? 6-A/F-5, 6-G-3,6-H-2

6.3.1.2.2 Recreation

.1 How can internal urban cultural and recreational facilities be created in rapidly expanding/deteriorating population centers? 6-G/C-1

.2 How can the results of cultural achievement be more effectively applied to recreational facilities? NS

.3 How can geographic relations be more effectively used for recreational pursuits? 6-G/C-1, 6-A/F-1

6.3.1.2.3 Man-Land Relationship

.1 How can changing seasonal crop conditions be more efficiently dealt with by application of Geographic principles? 6-A/F-1

.2 What and how are ecological trends being influenced by man's presence and cultural development? 6-A/F-1,-4

.3 What is the rate of environmental change and how can this be measured meaningfully? 6-G/C-1, 6-A/F-1

.4 How can population and traffic statistics be used for cultural studies? 6-G/C-1

6.3.1.2.4 Population Pressure

.1 How can the problem of population density be controlled and/or modified in urban areas? 6-G/C-1, 6-A/F-1

.2 How can birth control education and program participation be effectively implemented in appropriate societies? NS

.3 How can the world food supply be effectively distributed to areas of need and how can the distribution be more efficiently managed in heavily populated urban areas? 6-G/C-1, 6-A/F-1

.4 How can the migration and distribution of urban population be monitored? 6-G/C-1, 6-A/F-1

6.3.1.3 National-International

6.3.1.3.1 Land Use Evaluation

.1 How can the major geographic land areas of the world be identified, classified for use? 6-G/C-1, 6-A/F-1

.2 How can the most appropriate use of specific land areas be determined? 6-G/C-1 6-A/F-1

.3 How should land areas be made more accessible to population centers? NS

.4 How can land use on a world time and crop requirement be initiated for a world food exchange market? NS

6.3.1.3.2 Data Exchange

.1 What data can be exchanged in support of international crop management for input to world food market? NS

.2 What data can be exchanged for precisely determining NS

Available lands
Transportation facilities
Crop/forest inventories
Population migrations
Population expansion

.3 What data can be exchanged in support of detailed and all inclusive surface mapping? NS

6.3.1.3.4 National and World Mapping

.1 How can the mapping of dynamic features and processes be accomplished? What is the time frame? 6-G/C-1, 6-A/F-1, 6-EP-1, 6-H-3,-7 6-M-6

.2 What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.: 6-G/C-1, 6-A/F-1, 6-EP-1, 6-H-3,-7 6-M-6

Land use
Crop-timber
Hydrologic
Political
Population migration
Urban development
Economic
Climatic
Physical/chemical
Cultural

. 3 How can maps displaying time variant entities be effectively produced and distributed for use? 6-G/C-1, 6-A/F-1, 6-EP-1, 6-H-3,-7, 6-M-6

6. 3. 2 KNOWLEDGE

6. 3. 2. 1 Evolution

6. 3. 2. 1. 1 Geomorphology

. 1 How was the Earth's surface topography developed? 6-G/C-1 6-G-1,-6

. 2 What Earth features prompted settlement of population groups? 6-G/C-1, 6-G-1,-6

. 3 What effect did river systems have on the land and man's cultural development? 6-G-6, 6-H-7

. 4 What restrictions or pressures did climate impose on societies and what were the reactions? NS

6. 3. 2. 1. 2 Resources

. 1 What aspects of man's physical-chemical environment have necessitated or induced changes? NS

. 2 What requirements/constraints has the animal kingdom imposed on the development of man and the environment? NS

. 3 How did cultivation of crops effect the evolution and migrations of man and how has this progressed relative to population increase and land use? NS

. 4 What effects did minerals have on the development of man's cultural and social societies? NS

6. 3. 2. 1. 3 Power

. 1 What impact did controlled inanimate power have on the changes of man's culture and migration? NS

. 2 How was the social structure advanced by power applied to resources and production? NS

. 3 How did the development of power affect urban development? NS

. 4 What effect is the expanding population and elevating culture having on power sources and their applications? NS

6. 3. 2. 2 State

6. 3. 2. 2. 1 Biosphere

. 1 What is the ratio of unused to used land and the rate of change of this ratio? 6-G/C-1 6-A/F-1

. 2 What percentage of unused lands is considered usable for cultivation? 6-A/F-1,-2 6-G-1

. 3 How has man changed the natural vegetation? 6-A/F-1

. 4 What factors have dictated the major crops, the location and amounts of the crops? 6-A/F-1,-2,-3

.5 What is the present ratio of specific crops to world population and the rate of change of this ratio? 6-A/F-1

.6 What influence is exerted on the biosphere by the insect world? NS

.7 What is the present ratio of livestock to world population and the rate of change of this ratio? 6-A/F-3

6.3.2.2.2 Physical/Chemical

.1 What pollutants are evident in the atmosphere and in what percentage? What is their rate of change? 6-M-5

.2 What general aspects of man's progress induce pollution and changes in topography and river systems? 6-M-5, 6-H-1,6-O-1

.3 What is the relative importance of the coastline environment to man, river and mountain/plains environments? NS

.4 To what extent has man adjusted to latitude restrictions on the environment? NS

.5 What is the ratio of mineral availability to demand, oil, fresh water, etc? NS

.6 To what extent and to what scales is the physical surface of man's environment depicted? 6-G/C-1, 6-A/F-1

.7 How can the most important factors contributing to man's adaptation to a changing environment be depicted in map form? NS

6.3.2.2.3 Cultural

.1 What is the ratio of expansion of transportation facilities to the expanding population, (a) roads, (b) railroads, (c) waterways, (d) airlines/airports? 6-G/C-1

.2 What influence of community development is imposed by each mode of transportation? 6-G/C-1

.3 What relation exists between population movement and transportation facilities? 6-G/C-1

.4 What is the pattern of population migration and its rate of change? 6-G/C-1

.5 What is the rate of development in new communities? 6-G/C-1, 6-A/F-1

.6 What is the rate of expansion of existing populations, (a) countries, (b) states, (c) counties, (d) cities, (e) towns? 6-G/C-1, 6-A/F-1

.7 How can man's cultural development be more adequately assessed and displayed? NS

.8 What factors of man's environment are the greatest deterrent to community expansion? NS

.9 What are the cement/soil/cultivation ratios of major urban developments? 6-G/C-1

6. 3. 2. 3 Change

6. 3. 2. 3. 1 Urbanization

. 1 How do the various modes of transportation effect physical changes on the environment and population movement? 6-G/C-1

. 2 What are the relative demands placed on the modes of transportation and how may effective control be enhanced? NS

. 3 What aspects of transportation can be most efficiently modified and controlled, (a) type of power, (b) type of conveyor, (c) location of transportation, (d) frequency, etc? NS

. 4 How can industrial development in urban areas be related to the total community? NS

. 5 How can pollution and waste from large population centers be effectively controlled? 6-H-1, 6-M-5,6-O-1

. 6 What aspects of urbanization impose the greatest restraints to orderly development? NS

6. 3. 2. 3. 2 Power

. 1 What inovations in the industrial power supply could significantly change the environment? NS

. 2 How could microclimates be created and controlled by man? 6-M-1

. 3 How could solar radiation be effectively controlled for man's needs? 6-M-1,-6

. 4 What effect would be produced on the ecology of coastal areas supporting atomic power stations? 6-O-2,-4

6. 3. 2. 3. 3 Pollution

. 1 How can pollution from industrial expansion be controlled, i. e., atmospheric/hydrologic? 6-H-1, 6-M-5,6-O-1

. 2 How is pollution related to the Earth's topography and climate? 6-H-1, 6-M-5,6-O-1

. 3 How can waste disposal in large populated centers be significantly reduced or how can the rate of disposal be increased? 6-G/C-1 6-A/F-1

. 4 How is pollution affecting the coastal ecological environment? 6-O-1,-6

6. 3. 2. 3. 4. Land and Water Use

. 1 How can areas of drought and flood be more effectively controlled? 6-H2,-3, -5,-7

. 2 How can vast forest regions be continuously monitored for fire and how can protection against fire be advanced and controlled? 6-A/F-5

. 3 How can the hazards of pesticides and herbicides to the soil, rivers, and standing bodies of water be eliminated or controlled? 6-A/F-4, 6-H-1

. 4 How can tillable lands be worked more efficiently and how can new marginal lands become domesticated? NS

. 5 How can man best be educated to the problems of an ascending culture and the price for the industrial requirements to attain advanced cultural and social societies? NS

6. 3. 3 EFFECTS

6. 3. 3. 1 Climate

6. 3. 3. 1. 1 Macroclimate

. 1 How does the global heat balance affect world climate? 6-M-1, 6-O-2

. 2 How does the positioning of continents and oceans affect the major circulation? NS

. 3 What aspects of man's ascending culture could affect world climate? NS

6. 3. 3. 1. 2 Mesoclimate

. 1 How does the regional heat balance affect regional climates? 6-M-1, 6-O-2

. 2 How do mountain chains and plains provinces affect regional and local climates? NS

. 3 At what rate is man adapting to latitude constraints on land use and settlement? NS

. 4 How do man's activities affect the long term climate pattern? 6-M-1,-5, 6-O-1,-2

6. 3. 3. 1. 3 Microclimate

. 1 How does the local heat balance affect local climates and can this be controlled? 6-M-1, 6-O-2

. 2 How does man's modification of the environment affect local climate? 6-M-1,-5 6-O-1,-2

. 3 How do great population centers affect local climates? 6-M-1,-5 6-O-1,-2

6. 3. 3. 2 Resources

6. 3. 3. 2. 1 Minerals and Management

. 1 How are the world mineral and petroleum inventories effected by the increasing and shifting population? NS

. 2 What effects do the Earth's mineral resources have on man's control of the environment and social structure? NS

. 3 What constraints are imposed upon cultural advancement, population increase, and migration by available minerals and oil? NS

. 4 How do man's migration and settlement patterns exert an influence on mineral resources? NS

. 5 How can the supply of strategic and necessary minerals be effectively managed for man's increasing needs? NS

6.3.3.2.2 Water

.1 How do man's migration and settlement exert an influence on water resources? NS

.2 Do water resources influence man's present cultural development? NS

.3 What is the rate of depletion of natural water supplies in areas of population pressure? 6-H-3,-4,-7

.4 What is the effect of man's cultural development on surface water bodies? 6-H-1,-3

.5 How can urban development be related to available water supplies? 6-G/C-1

.6 How can urban water supplies be increased or effectively controlled? NS

6.3.3.2.3 Land and Management

.1 How will the expanding population affect the decisions on tillable versus urban development land? 6-G/C-1, 6-A/F-1

.2 How can land in the higher latitudes be used effectively? NS

.3 What effect is exerted by man and his environment on land usage? 6-A/F-1

.4 How do settlement patterns relate to land use? 6-A/F-1

.5 What are the effects of urban development on erosion of the land? 6-A/F-1, 6-H-7

6.3.3.3 Ecology

6.3.3.3.1 Water

.1 What effect is exerted on the coastal and inland water body ecologic environments by industrial warm water waste? 6-O-1,-6

.2 What effect do river/dam systems have on the biosphere? 6-G/C-1, 6-H-1

.3 How are pollutants derived from population increase and the cultural and social advancement of man affecting the water ecologic system? 6-H-1

6.3.3.3.2 Land

.1 What effect is exerted on micro-macro organisms by expanded land use and pollution by man? 6-A/F-4

.2 What effects do herbicides/insecticides have on natural vegetation and soils? 6-A/F-4

.3 To what extent do man's modifications of the environment for expansion affect the land and ecologic system? 6-A/F-1,-4

6.3.3.3.3 Air

.1 How are all ecologic systems affected by atmospheric pollution? 6-M-5, 6-A/F-4

.2 What aspects of population increase and migration most affect the airborne ecology? 6-M-5

.3 What effect is exerted on the air ecologic system by the pollution of water and soil? 6-M-5, 6-A/F-4

6.4 GEOLOGY

6.4.1 USES

6.4.1.1 Economic

6.4.1.1.1 Agriculture and Forestry

.1 How can specific rock/soil types be detected, identified, classified, and put to productive use? 6-G-1, 6-A/F-2

6.4.1.1.2 Water-Oil-Gas, Storage and Waste Disposal

.1 How can natural caverns, porous and permeable formations, and aquifers be detected and identified? 6-G-2

.2 How can areas of thick detrital-fill be detected and evaluated? 6-G-1

.3 How can the Earth's crust be used to store or condition waste products? 6-G-2

6.4.1.1.3 Habitation/Engineering Applications

.1 How can present and future areas of interest be more effectively protected from geologic processes such as earthquakes, volcanic erruptions, landslides, erosion/transportation/deposition, and subsidence. 6-G-3

.2 How can dam sites for flood control and other controlling structures sites be identified? 6-G-3, 6-H-7

6.4.1.1.4 Energy

.1 How can geothermal sources of energy (e. g., igneous, hydrothermal) be detected and identified? 6-G-4

.2 How can geothermal sources of energy be predicted? NS

6.4.1.1.5 Minerals

.1 How can areas of potential mineral deposits be located and identified? 6-G-5

.2 How can potential source areas of petroleum and/or natural gas be located and identified? 6-G-5

6.4.1.2 Social and Cultural

6.4.1.2.1 Recreation

.1 How can the location and proper construction of new park and recreational areas be significantly enhanced? NS

6.4.1.2.2 Education

.1 How can educational and scientific expenditions and field trips be aided by space observations and data? NS

.2 How can the use of satellites and sensor packages for education and research be initiated and/or improved? PS

.3 How can the study of geologic processes and land forms be used to improve our understanding of subaqueous and subglacial features? NS

.4 How can the motion of major ice flows be used to study the plastic flow of rock masses? NS

.5 How can mutual data exchanges on cooperative and multiuser programs be coordinated? NS

.6 What information can be exchanged in support of geologic mapping on a global scale? NS

.7 What information can be exchanged in support of international geophysical programs? NS

6.4.2 KNOWLEDGE

6.4.2.1 Evolution

6.4.2.1.1 Crust

.1 Did the Earth's crust originate from a molten state? NS

.2 Did the Earth's crust originate from gaseous condensation and the infall of planetesimal matter? NS

6.4.2.1.2 Continents

.1 Did the continents evolve from eruption of subcrustal material? NS

.2 Did the continents evolve from the molten state? NS

.3 How does the geosyncline affect continents? NS

6.4.2.1.3 Geomorphology

.1 Did the Earth's initial topography develop as a result of a shrinking Earth-expanding Earth? NS

.2 Did the topography develop from eruptions of material from within the Earth? NS

.3 Did the topography develop from tectonic forces? NS

.4 Did the topography develop from erosive action-water, wind, etc. ? NS

6.4.2.1.4 Biota

.1 Did the Biota originate from spores from outer space? NS

.2 Did the Biota originate from within the world ocean? NS

.3 Did the Biota originate on land? NS

6.4.2.2 State

6.4.2.2.1 Structure

.1	Is the Earth a homogeneous accumulation of matter?	6-G-6
.2	Is the Earth a heterogeneous accumulation of matter?	6-G-6
.3	Is the Earth composed of readily identifiable masses?	6-G-6
.4	Is the Earth structure one of orderly and continuous concentric masses, contrasting but concentric masses, continuous, but not concentric masses?	NS
.5	What land forms can be related to dynamic processes?	6-G-6
.6	How can structures be identified by vegetation?	6-G-1, 6-A/F-2,-3

6.4.2.2.2 Composition

.1	What chemical characteristics affect the physical nature of the Earth?	NS
.2	What chemicals contribute to pollution?	NS

6.4.2.2.3 Configuration

.1	What is the shape of the earth?	OP
.2	What are the positions of land masses, polar ice sheets, and ocean basins?	6-G-6,6-G/C-1,6-H-4, 6-O-6,6-EP-1
.3	Are positions of land masses fixed or moving?	NS
.4	If moving, at what rate and direction?	NS

6.4.2.2.4 Activity

.1	What regions of the crustal mass are experiencing isostatic readjustment?	6-G-6
.2	What tectonic and volcanic belts are active?	6-G-3,-6, 6-EP-2
.3	What evidence is there that the continents are drifting?	6-G/C-1, 6-EP-1,6-O-6
.4	What evidence is there of sea floor spreading?	6-G/C-1, 6-EP-1,6-O-6

6.4.2.3 Change

6.4.2.3.1 Transformation

6.4.2.3.1.1 Momentum

.1	Is Earth spin constant or variable?	UM
.2	Is Earth revolution constant or variable?	UM
.3	What is the effect of precession of equinoxes on crustal processes?	UM
.4	What is the effect of lunar cycle on Earth tides?	6-O-4

6.4.2.3.1.2 Energy

.1 How does radiation transfer of energy affect the Earth's crust? NS

.2 How does heat loss through vulcanism affect the Earth's crust, through tectonic evolution? NS

.3 How do crustal convection currents affect the energy change within the crust? NS

.4 How does heat exchange at the Earth/sea boundary affect energy changes in the crust? NS

.5 How do metamorphism and atomic disintegration affect the energy changes within the crust? NS

.6 How can the Curie point be obtained? NS

.7 How does the water/ice ratio affect the energy budget? 6-H-4

6.4.2.3.1.3 Erosion/Deposition

.1 How does erosion of mountain chains affect crustal stability? NS

.2 How do the processes of erosion and deposition affect the crustal dynamics? NS

.3 How does the Earth's rotation affect eroding agents? NS

.4 How do sedimentary basins affect crustal stability? NS

6.4.2.3.1.4 Mass

.1 How does the principle of conservation of mass apply to the Earth's crust? NS

.2 How do dynamic geologic processes affect the mass of the Earth? NS

.3 How does planetesimal matter affect the mass of the Earth? NS

.4 How do metamorphic processes affect mass changes within the crust? NS

.5 How do crustal convection currents affect the mass distribution of the crust? NS

6.4.2.3.2 Prediction

.1 What knowledge and understanding of crustal dynamics, physics, and chemistry, are required for predicting the future state of the crust? NS

.2 What is the rate of heat loss from the Earth's crust (en toto)? 6-M-1, 6-O-2

.3 What phenomena trigger widespread glacial activity. What are rates of change of mountain and continental glaciers? 6-H-4

.4 What is the rate of growth of the Earth's crust? NS

.5 What is the relative rate of drift of the continents? 6-G/C-1 6-EP-1,6-O-6

.6 What is the rate of compression/elastic rebound of the Earth's crust? NS

.7 What are the rates of relative movements of the Earth's major fault systems? 6-G/C-1, 6-EP-1

.8 What are the rates of sedimentation in major basin of deposition? 6-G-6

.9 What are the rates of sea floor spreading? 6-G/C-1, 6-EP-1,6-O-6

6.4.2.3.3 Modification

.1 What are the physical characteristics of the Earth's crust and mantle? 6-G-1,-6

.2 What are the rates of crustal warping, positive and negative? NS

.3 What are the rates of flow of the major river systems? 6-H-7

.4 What geologic features could be modified to serve the needs of man? 6-G-6

.5 How could select geologic features be modified to serve man better? 6-G-6

.6 How could some geologic processes be augmented, stalemated or controlled for the betterment of mankind? 6-G-6

6.4.3 EFFECTS

6.4.3.1 Weather and Climate

6.4.3.1.1 Short Range

.1 What causes glaciation? 6-M-1, 6-H-4

.2 Are we entering interglacial epoch or is the glacial cycle completed? 6-M-1, 6-H-4

6.4.3.1.2 Extended Range

.1 How do ocean basins, continental masses control weather? 6-M-1,-6

.2 How does the radiant temperature of the Earth contribute to to the control of weather? 6-M-1,-6, 6-O-2

6.4.3.1.3 Climate

.1 How do mountain chains affect local and regional climates? 6-M-6

.2 How do plains provinces affect local and regional climates? 6-M-6

.3 How do large geothermal anomalies affect local climates? 6-M-6

.4 How do large population centers affect climate? 6-M-6

.5 How long has the Earth possessed seasonal weather variations? NS

6.4.3.2 Global Dynamics

6.4.3.2.1 Rotation

.1 What effects do mountains chains have on the Earth's rotation? PS

.2 What effect does the Earth's internal structure have on its rotation? PS

.3 What effect does rotation of the Earth have on crustal and sub-crustal tectonics? PS

.4 What effect does erosion-transportation and deposition of sediment have on the Earth's rotation? PS

6.4.3.2.2 Gravitation

.1 How do drifting continents affect the Earth's gravity field? UM

.2 How do erosion, transportation and deposition of sediments as large coastal delta developments affect Earth gravity gradients? NS

.3 How do continental-size features affect the Earth's gravity field? UM

.4 How do mountain roots affect the Earth's gravity field? NS

.5 How do areas of concentration of minerals (metallic-nonmetallic) affect gravity gradient? NS

.6 How do large scale structures; i.e., salt domes, major folds, etc., affect the Earth's gravity gradients? NS

.7 How does plastic flow (convection currents) affect the Earth's gravity field? NS

6.4.3.2.3 Electromagnetic

.1 How do major crustal lineaments affect the electromagnetic field? NS

.2 How does the subcrustal plastic flow of rock masses affect the electromagnetic field? NS

.3 How do drifting continents affect the electromagnetic field? NS

.4 How do areas of concentration of minerals (metals) affect the electromagnetic field? NS

.5 How do magnetohydrodynamic phenomena affect Earth's magnetic field? Solar winds? AC

.6 At what rate do migrating pole fluctuations change? AC

.7 How do continental-size features affect the Earth's magnetic field? NS

6.4.3.3 Biota

6.4.3.3.1 Micro-Organisms

.1 What effects would large-scale volcanic eruptions have on Micro-Organisms? NS

.2 What effects would increased glacial activity have on Micro-Organisms? NS

.3 What are the effects of migrating magnetic poles on Micro-Organisms? NS

.4 What are the effects of migrating geographic poles on Micro-Organisms? NS

6.4.3.3.2 Macro-Organisms

.1 What effects would large-scale volcanic eruptions have on Macro-Organisms? NS

.2 What effects would increased glacial activity have on Macro-Organisms? NS

.3 What are the effects of migrating magnetic poles on Macro-Organisms? NS

.4 What are the effects of migrating geographic poles on Macro-organisms? NS

6.4.3.3.3 Plants

.1 What effects would large-scale volcanic eruptions have on plants? 6-A/F-4

.2 What effects would increased glacial activity have on plants? 6-A/F-4, 6-H-4

.3 What are the effects of migrating magnetic poles on plants? NS

.4 What are the effects of migrating geographic poles on plants? NS

6.5 HYDROLOGY AND WATER RESOURCES

6.5.1 UTILIZATION

6.5.1.1 Knowledge

6.5.1.1.1 Water Management and Flood Control

.1 What synoptic data is required for flood forecasting and water-resource systems management? 6-H-2

.2 How can reliable information on the concentration of storm flows be obtained? 6-H-2

.3 How can real-time communication of ground-based hydrologic data be accomplished? 6-H-2

.4 What is the velocity and discharge of streamflows? PS

.5 What is the level and movement of groundwater? 6-H-6

.6	What is the areal extent of precipitation?	6-H-5
.7	How can the runoff from snowpack be predicted?	6-H-4
.8	What is the effect of water use policies of different states upon long-term water availability?	PS
.9	What is the relative cost of land communication lines versus remote platforms for hydrologic data collection?	PS

6.5.1.1.2 Surface and Subsurface Water Inventory

.1	How can a synoptic inventory of the surface area and geographic location of the world's major lakes and reservoirs be obtained?	6-H-3
.2	How can a synoptic inventory of the world's snow and ice cover be obtained on a perennial and annual basis?	6-H-4
.3	What is the area extent and albedo of snowpacks and the lower limits of snowlines?	6-H-4
.4	What is the areal extent of ice in estuaries, rivers, lakes, and glaciers?	6-H-4
.5	How can the location and extent of underground water sources be identified?	6-H-6
.6	How can soil moisture be measured?	6-H-5
.7	What is the depth and water content of snow?	6-H-4
.8	What is the location of large icebergs which can be used as a source of fresh water?	6-H-4, 6-O-4

6.5.1.1.3 Topography

.1	What is the topography, geologic structure, and soil cover in underdeveloped regions of the world?	6-H-7, 6G/C-1, 6-G-1
.2	What are the hyrdologic features of coastal regions and large inland lakes?	6-H-7, 6-O-6
.3	What are the geomorphological characteristics of river basins?	6-H-7
.4	How can the best routing for canals and artificial waterways be determined?	6-H-7

6.5.1.2 Effects

6.5.1.2.1 Land Use

.1	How can land-use mapping and classification be improved?	6-A/F-1, 6G/C-1
.2	What is the extent of diversion of water for user requirements?	6-H-3, 6-A/F-1
.3	What is the extent of the loss of water along irrigation canals?	6-H-5
.4	What are the effects of changes in vegetation patterns on the run-off of precipitation?	6-H-5, 6-A/F-3
.5	What are the location where excessive irrigation is increasing the saline content of soil?	6-H-5, 6-A/F-4

6.5.1.2.2 Water Circulation

.1	What are the water circulation patterns in coastal waters, estuaries, and large lakes?	6-H-1,-3, 6-O-5
.2	What are the effects of currents and tidal flows upon harbors and estuaries?	6-O-5

6.5.1.2.3 Water Pollution

.1	What are the chemical and biological characteristics of water and pollutants?	AC
.2	What are the effects of streamflow and wastes upon coastal waters?	6-H-1,-7 6-O-6
.3	What is the extent of saline intrusion in estuaries?	6-H-1
.4	What is the dispersion of visible pollutants in coastal waters, estuaries, large lakes, and reservoirs?	6-H-1
.5	How can the occurrence and extent of algal blooms be determined?	6-H-1
.6	How can oil slicks on the surface of water be identified?	6-H-1
.7	How can the resources of fish and waterfowl be protected?	PS
.8	How can the transportation and deposition of sediment be determined?	6-H-1

6.5.2 SCIENTIFIC UNDERSTANDING

6.5.2.1 Scientific Knowledge

6.5.2.1.1 Water Budget

6.5.2.1.1.1 Water Vapor

.1	How can the amount of precipitable water within the Earth's atmosphere be determined?	6-M-6
.2	What are the temporal variations in the fluxes of water vapor into and out of large drainage basins and lakes, and continental areas?	6-M-6
.3	How can the water vapor content within the atmosphere at the atmosphere--surface interface be determined?	6-M-1,-6
.4	How can the occurrence and horizontal and vertical flow of water vapor over large areas be determined?	6-M-6

6.5.2.1.1.2 Precipitation

.1	How can the global distribution of precipitation be determined on a frequent basis?	6-M-6
.2	How can long-range prediction of precipitation (rain and snow) be improved?	6-M-1,-6

6.5.2.1.1.3 Evapotranspiration

.1 How can reliable information on evaporation of water from the land and ocean be obtained? 6-M-6

.2 What are the evaporation and transpiration losses along major river systems in arid environments? 6-M-6

6.5.2.1.1.4 Snow and Ice

6.5.2.1.1.4.1 Snow

.1 How can the areal extent of snow cover be determined? 6-H-4

.2 How can snow depth and moisture content be determined? 6-H-4

.3 How can free water appearing on the snow surface be sensed? 6-H4

.4 How is the apparent temperature of snow in the microwave region affected by density, depth, liquid water content, and sensible temperature? 6-H-4

6.5.2.1.1.4.2 Lake Ice

.1 What is the distribution of lake ice? 6-H-4

.2 How can the thickness, temperature, and albedo of ice be determined? 6-H-4, 6-M-1

6.5.2.1.1.4.3 Sea Ice

.1 How is sea ice movement related to climatic and ocean current patterns? 6-H-4, 6-O-4

.2 How can anomalies in the sea ice pack be related to climatic or subsurface causes? 6-H-4, 6-O-2

6.5.2.1.1.4.4 Glacial Ice

.1 How can the areal extent of glacial ice be determined? 6-H-4

.2 How can the volume of glacial ice be determined? 6-H-4

6.5.2.1.1.5 Soil Moisture

.1 How can the subsurface moisture content of the soil be determined? PS

.2 What is the global distribution of soil moisture? 6-H-5

6.5.2.1.1.6 Surface and Subsurface Water

.1 How can the water content of lakes and rivers be determined? 6-H-3

.2 What is the water content of subterranean water sources? PS

6.5.2.1.2 Energy Budget

6.5.2.1.2.1 Solar Radiation

.1 What is the global distribution of solar irradiance? UM

.2 What is the global distribution of solar energy reflected from the clouds and surface of the Earth? UM

6.5.2.1.2.2 Terrestrial Thermal Radiation

.1 What is the global distribution of the infrared radiance of the Earth's surface? 6-M-1

.2 What is the diurnal variation in the heat flux of thermal reservoirs beneath the surface of the Earth? NS

.3 How can the diurnal variations in temperature of the surface of the Earth be determined? 6-M-1

6.5.2.1.2.3 Atmosphere-Surface Boundary Layers

.1 What are the characteristics of the boundary layer at the interface between the atmosphere and the Earth's surface? 6-M-1

.2 What is the rate of flow of thermal flux from the Earth into the turbulent atmosphere? 6-M-1

.3 What is the distribution of the horizontal vapor flux over the surface of the Earth? 6-M-6

6.5.2.1.2.4 Atmospheric Pollution

.1 What are the effects of dust and contaminants in the Earth's atmosphere upon the energy budget? 6-M-5

.2 What are the effects of air pollution upon the climate of urban areas? 6-M-5,-6

6.5.2.1.2.5 Land Use

.1 How can seasonal changes in vegetation cover be determined? UM

.2 What are effects of seasonal changes in vegetative cover upon regional energy balance? UM

.3 What are the regional effects of changes in land use on the climate? 6-A/F-1, 6-M-6

.4 Can the characteristics of sand dunes be used to predict the climate in arid regions? 6-M-6

6.5.2.2 Understanding of Effects

6.5.2.2.1 Geography

.1 What is the effect of cultural changes of the surface of the Earth on the elements of the hydrologic cycle? 6-G/C-1, 6-H-5

.2 How is the watershed affected by changes in use of land? 6-H-4,-7, 6-A/F-1

6.5.2.2.2 Atmospheric Pollution

.1 What are the effects of contaminants in the atmosphere on the elements of the hydrologic cycle? 6-M-5

6.5.2.2.3 Weather Modification

.1 What is the effect of cloud seeding experiments on elements of the hydrologic cycle? 6-M-6

6.6 OCEANOGRAPHY AND MARINE RESOURCES

6.6.1 KNOWLEDGE

6.6.1.1 State

6.6.1.1.1 Geophysical

.1 How does the sea surface height vary because of variations in the Earth's gravitational potential? 6-O-4

.2 What is the effect of shielding by the ocean on the depths of penetration of cosmic rays and other radioactive particles? PS

.3 How does the electric and magnetic field potentials vary in the oceans? PS

.4 How do the acoustic properties of the ocean vary? PS

.5 What are the relationships between bottom topography and tsunamis? 6-O-6

6.6.1.1.2 Physical

.1 How are tidal flushing patterns affected by coastline construction? 6-O-6

.2 How are the physical properties affected by ocean pollution? 6-O-1

.3 What are the relationships between energy partition at the ocean surface and atmospheric and ocean characteristics and phenomena? 6-O-2

.4 What are the relationships between distribution of ocean variables on the small scale and ocean turbulence and other motion? 6-O-4,-7

.5 How can knowledge of the bottom topography be improved? 6-O-6

6.6.1.1.3 Chemical

.1 How is the salinity field of the ocean surface affected by precipitation, evaporation and runoff from land? 6-O-5

.2 How does ocean pollution affect electromagnetic emission from the sea surface? 6-O-1,-2

.3 How does ocean pollution affect the chemical reactions and salinity in the oceans? 6-O-1,-5

.4 How does tidal flushing patterns affect salinity and pollution characteristics? 6-O-1,-5

6.6.1.1.4 Geological

.1 How do the volcanological characteristics of the ocean relate to the occurrence of tsunamis? 6-O-6, 6-EP-2

.2 How does aeolian transport affect the composition of sea water and sediments. 6-O-5,-6 6-M-6

.3 What are the erosion and sedimentation characteristics of the coastlines? 6-O-6

.4 What is the relationship between sediment character and physical characteristics? NS

6.6.1.1.5 Biological

.1 What is the population dynamics of the ocean? 6-O-3

.2 How is the productivity of the oceans related to ocean pollution? 6-O-1,-3,-5

.3 How is the population distribution of the biota affected by cloud cover and precipitation? 6-O-3, 6-M-6

.4 How can knowledge of the surface slicks be improved? 6-O-1

6.6.1.2 Change

6.6.1.2.1 Transformations

6.6.1.2.1.1 Momentum

.1 How do the eddy coefficients of the Keynolds stresses vary with static stability, current speeds and current shears? PS

.2 How do boundary stresses affect the momentum changes of ocean volumes? PS

.3 What terms of the equations of motion can be reasonably omitted for various scales of motion? PS

6.6.1.2.1.2 Energy

.1 How is the partition of solar energy at the sea surface affected by the roughness, foaminess, oiliness, etc., of the surface? 6-O-2

.2 How is the emission of microwave and infrared radiation of the sea surface affected by the roughness, foaminess, oiliness, etc., of the surface? 6-O-2

.3 How do the chemical, biological and geological processes affect the energy changes in the ocean? PS

.4 How do the characteristics of the atmosphere at the air-sea boundary affect the heat flux and veritical temperature profile at the ocean boundary layer? PS

.5 What is the rate and mechanism of energy dissipation in the ocean? 6-O-2

6.6.1.2.1.3 Mass

.1 How does the interpretation of motion, salinity and temperature affect the change of pressure with depth? PS

.2 How do the chemical, geological and biological characteristics and processes affect the mass distribution in the ocean? PS

.3 How does the variation of divergence with depth affect the mass distribution and bottom pressure change? PS

.4 How does the mass distribution adjust to the transient ocean currents caused by variations in the wind stress in space and time? PS

.5 How does the mass distribution respond to fluctuations in atmospheric pressure? PS

6.6.1.2.1.4 Biota

.1 How is the nutrient distribution affected by turbulence in the ocean? 6-O-3

.2 How is the productivity modified by short-term variations in the solar radiation that penetrates the ocean boundary? 6-O-2,-3

.3 How is the population dynamics affected by ocean pollution? 6-O-1,-3

.4 How is the biota distribution affected by temperature and salinity changes? 6-O-3

.5 How is the population distribution affected by kelp beds? 6-O-3

.6 How are surface slicks related to population dynamics? 6-O-1,3

6.6.1.2.1.5 Sedimentation

.1 How does turbulence affect the transport of particulate matter? 6-O-6

.2 How do turbidity currents affect the bottom topography of the ocean? 6-O-6

.3 How does the ocean motion affect the equilibrium profiles of the ocean bottom? PS

.4 How do surface films affect the coagulation and transport of aeolean deposits and other particulate matter? PS

.5 How do the biological processes affect the depositional characteristics? 6-O-6

.6 How do the chemical and biological processes affect the exchange of gasses with the atmosphere? PS

6.6.1.2.2 Prediction

6.6.1.2.2.1 Data

.1 How can operational data be separated efficiently from research data? UM

.2 How can operational data be transmitted more quickly and accurately? 6-O-1,2,3,4,5,6,7

.3	How can the representativeness of sea surface data be improved?	6-O-1,2,3, 4,5,6,7
.4	How can the time between data acquisition and processed results to the user be improved?	6-O-1,2,3, 4,5,6,7
.5	What ground truth data is needed to improve data accuracy?	6-O-1,2,3, 4,5,6,7

6.6.1.2.2.2 Models

.1	How can forecasts of the density be improved?	6-O-5
.2	How can forecasts of movements of silt and sand be improved?	6-O-4
.3	How can forecasts of salinity be improved?	6-O-5
.4	How can forecasts of nutrients be improved?	6-O-3
.5	How can forecasts of fish population be improved?	6-O-3
.6	How can forecasts of tides be improved?	6-O-4
.7	How can forecasts of storm surges be improved?	6-O-4
.8	How can forecasts of tidal waves be improved?	6-O-4
.9	How can location of oil deposits be improved?	6-G-5
.10	How can forecasts of icebergs and ice movement be improved?	6-O-4,-5
.11	How can forecasts of rough seas be improved?	6-O-7, 6-M-6
.12	How can forecasts of mean sea surface height be improved?	6-O-4
.13	How can forecasts of ocean currents be improved?	6-O-4
.14	How can forecasts of upwelling be improved?	6-O-3,-4
.15	How can forecasts of diffusion be improved?	6-O-4
.16	How can forecasts of sea surface temperature fields be improved?	6-O-2
.17	How can forecasts of sea temperature with depth be improved?	6-O-2
.18	How can forecasts of mixed layer depths be improved?	6-O-2
.19	How can the location of mineral deposits be improved?	PS
.20	How can forecasts of heavy swell on coasts be improved?	6-O-7, 6-M-6
.21	How can forecasts of convergence zones be improved?	6-O-4

6.6.1.2.2.3 Technology

.1	What oceanographic instruments need further development to improve data needed for prediction?	6-O-1,-2,-3, -4,-5,-6,-7
.2	What improvements in computational facilities are needed?	6-O-1,-2,-3, -4,-5,-6,-7
.3	What improvements in communications are needed?	6-O-1,-2,-3, -4,-5,-6,-7
.4	What improvements in display facilities are needed?	6-O-1,-2,-3, -4,-5,-6,-7

6.6.1.2.3 Modification

6.6.1.2.3.1 Air/Sea Boundary

.1 How much effect does a sea surface film of oil have on evaporation sensible heat flux and gas exchange? 6-O-2

.2 How much effect does an oil film have on the character of wind stress and momentum flux on the ocean surface? 6-O-4

6.6.1.2.3.2 Solid Boundary

.1 How do jetties and land fill affect longshore transport? 6-O-6

.2 How can the ocean bottom be stabilized? PS

6.6.1.2.3.3 Internal Boundaries

.1 How are population dynamics affected by ocean pollution? 6-O-1

.2 How does changing the sea color affect ocean heating and photosynthesis? 6-O-3

.3 How can pollution of the ocean be effectively controlled? 6-O-1

6.7 METEOROLOGY

6.7.2 KNOWLEDGE

6.7.2.1 Evolution

6.7.2.1.1 Molten-Globe

.1 How can the examination of glaciation patterns aid in the understanding of carbonate and carbonaceous deposit formation? PS

.2 How can the systematic study of coal and oil deposits aid in the understanding of carbon dioxide fixation? PS

6.7.2.1.2 Accretion

.1 How can the analysis of micrometeoroids, planetesimals, and other extraterrestrial particles aid in the understanding of the formation of the atmosphere? NS

.2 How can the study and observation of volcanic exhalations add to our knowledge of the origin of the atmosphere? PS

6.7.2.1.3 Original Component

.1 How can the mapping of geologic rhythms advance our understanding of the origin of the atmosphere? NS

.2 How can the study of volcanic activity and magma aid in the understanding of the origin of the atmosphere? NS

.3 How can the survey of limestone and dolomite deposits help the understanding of the origin of the atmosphere? NS

6.7.2.1.4 Other Planets

.1 How can the study of the CO_2 and O_2 components of the atmosphere of Venus help the understanding of the origin of the atmosphere? PS

.2 How can the study of possible photosynthesis, ozone reactions, and oxidation on the surface of Mars help the understanding of the origin of the atmosphere? PS

.3 How can the study of the atmosphere of Jupiter help the understanding of the origin of the atmosphere? PS

6.7.2.2 State

6.7.2.2.1 Chemical

.1 What chemical consitutents are present in the atmosphere? 6-M-2,-3,-5

.2 Where are the chemical constituents located and how do they vary? 6-M-2,-3,-5

.3 What terrestrial and extraterrestrial factors affect the distribution of chemical constituents? 6-M-2,-3,-5

6.7.2.2.2 Physical

.1 What knowledge of the present state of the physical characteristics is required? 6-M-1,-2,-3,-5,-6

.2 What knowledge of the present state of the physical constituents is required? 6-M-1,-2,-3,-5,-6

6.7.2.2.3 Circulation

.1 What factors are involved in the current atmospheric momentum and mass fields? 6-M-1,-2,-3,-5,-6

.2 What factors are involved in the current atmospheric radiation and temperature fields? 6-M-1,-2,-3,-5,-6

.3 What factors are involved in the current atmospheric composition and structure? 6-M-1,-2,-3,-5,-6

6.7.2.3 Change

6.7.2.3.1 Change of State

6.7.2.3.1.1 Momentum and Mass

.1 What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity? 6-M-1,-2,-3,-4,-5,-6

.2 What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity? 6-M-1,-2,-3,-4,-5,-6

.3 What is the effect of the acceleration by the coriolis force on the local time change of horizontal velocity? PS

.4 What is the effect of the acceleration by the frictional force due to internal eddy stresses on the local time change of horizontal velocity? 6-M-6

.5 What is the effect of the acceleration by the frictional force due to boundary layer stresses on the local time change of horizontal velocity? 6-M-6

6.7.2.3.1.2 Heat

.1 What are the effects of the horizontal and vertical advection of temperature on the local time change of temperature? 6-M-1

.2 What is the effect of the transfer of heat by adiabatic processes due to the individual pressure change on the local time change of temperature? 6-M-6

.3 What is the effect of diabatic heating by radiative transfer on the local time change of temperature? 6-M-6

.4 What is the effect of diabatic heating by latent heat release on the local time change of temperature. 6-M-6

.5 What is the effect of diabatic heating by internal eddy heat diffusion on the local time change of temperature? 6-M-6

.6 What is the effect of diabatic heating by boundary layer heat transfer on the local time change of temperature? 6-M-1,-6

6.7.2.3.1.3 Composition and Structure

.1 How is the water vapor field changed by advection and eddy diffusion? 6-M-6

.2 How is the water vapor field changed by evaporation and condensation? 6-M-6

.3 How are the water droplet and ice crystal cloud fields changed by advection and eddy diffusion? 6-M-4,-6

.4 How are the water droplet and ice crystal fields changed by direct condensation, sublimation, and freezing? 6-M-4

.5 How are the water droplet and ice crystal fields changed by collision, coalescence, and colloidal instability? 6-M-4

.6 How is the ozone field changed by horizontal and vertical advection and eddy diffusion? 6-M-6

.7 How is the ozone field changed by photochemical dissociation or reduction and recombination? 6-M-6

.8 How is the hygroscopic aerosol field changed by advection, eddy diffusion, and wind lifting of soil particles? 6-M-5

.9 How is the hygroscopic aerosol field changed by evaporation of sea spray and sea bubbles? 6-M-5

.10 How is the hygroscopic aerosol field changed by condensation scavenging and precipitation washout? 6-M-5

.11 How is the nonhygroscopic aerosol field changed by advection, eddy diffusion, and wind lifting of soil particles? 6-M-5

.12 How is the nonhygroscopic aerosol field changed by percipitation washout? 6-M-5

6.7.2.3.2 Prediction

6.7.2.3.2.1 Short-Range Forecasts

.1 What knowledge is required of the changes in the momentum, temperature and mass fields including local soil heating and radiation? 6-M-1,-2,-3

.2 How can numerical, statistical, empirical or other real time techniques be used? NS

.3 What fast reaction data handling, warning and display facilities are required? NS

.4 How can frequent and detailed local and hemispherical observations of the initial state of the time-dependent atmospheric variables be obtained and used? 6-M-3,-6

6.7.2.3.2.2 Extended Range Forecasts

.1 What knowledge is required of the changes in the momentum temperature and mass fields? 6-M-1,-2,-3

.2 How can high precision numerical, statistical, empirical or other techniques be used? NS

.3 What large scale data handling and display facilities are required? NS

.4 How can global observations of initial state of all the time-dependent atmospheric variables be obtained and used? 6-M-3,-6

6.7.2.3.2.3 Long-Range Forecasts

.1 What knowledge is required of the changes in the momentum, temperature and mass fields. 6-M-1,-2,-3

.2 How can the changes in the state of the ocean be used? 6-M-6

.3 How can advanced numerical, statistical, empirical or other techniques be used? NS

.4 What global scale data handling and display facilities are required? NS

.5 How can global observations of the initial state of the time-dependent atmospheric variables be obtained and used? 6-M-6

.6 How can global observations of the initial state of the time-dependent land and oceanic variables be obtained and used? 6-M-6

6.7.2.3.3 Modification

6.7.2.3.3.1 Boundary Processes

.1 What are the effects of changing the physical characteristics of the surface? 6-M-1,-6

.2 What are the effects of changing the surface albedo and emissivity? 6-M-1,-6

.3 What are the effects of changing the surface evaporation? 6-M-1,-6

.4 What are the effects of modifying the colloidal state of clouds or fog at the boundary? 6-M-1,-4,-6

6.7.2.3.3.2 Atmospheric Processes

.1 What are the effects of changing the latent heat released by condensation and precipitation? 6-M-6

.2 What are the effects of modulating the reflection, absorption, and emission of radiation by the atmosphere or clouds? 6-M-6

.3 What are the effects of changing the aerosol (dust) field in the atmosphere? 6-M-5

.4 What are the effects of modifying the colloidal state of clouds over large areas? 6-M-4,-6

APPENDIX C

RESEARCH CLUSTER DESCRIPTIONS

C-1

EARTH OBSERVATIONS

Appendix C

INTRODUCTION

This Appendix presents the Research Clusters in Earth Observations of the Earth Orbital Experiment Program and Requirements Study. Each Cluster consists of (1) a synopsis; (2) a list (by number and title) of the critical issues addressed by the Research Cluster; (3) a measurement table; (4) an instrument table; and (5) a crew activity matrix. Table C-1 identifies these Research Clusters by number and title for all disciplines.

TABLE C-1

RESEARCH CLUSTERS

MANNED SPACEFLIGHT CAPABILITY

Cluster No.	Title
BIOMEDICINE	
1-BM-4*	Effects of Weightlessness on Circulatory Function
1-BM-5	Radiation, Toxicology, and Medical Problems
1-BM-6	Effects of Weightlessness on Stress Response
1-BM-7	Effects of Weightlessness on the Nervous System
1-BM-8	Effects of Weightlessness on Gastro-intestinal Function
1-BM-10	Body Fluid Analysis
1-BM-12	Studies on Instrumented Animals
1-BM-13	Effects of Weightlessness on Pulmonary Function
1-BM-14	Effects of Weightlessness on Metabolism
1-BM-15	Centrifuge Studies
BEHAVIORAL RESEARCH	
1-BR-1	Sensory, Psychomotor, and Cognitive Behavior (5 parts)
1-BR-1-1	Visual Experiment
1-BR-1-2	Behavior Effects of Acoustic Environment
1-BR-1-3	Psychomotor
1-BR-1-4	Cognitive Capability
1-BR-1-5	Orientation
1-BR-2	Group Dynamics and Personal Adjustment

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*Missing numbers were assigned to clusters that were later combined with others or eliminated.

Cluster No.	Title
1-BR-3	Complex Task Behavior
1-BR-4	Skills Retention
1-BR-6	Performance Measurement
MAN-MACHINE RESEARCH	
1-MM-1	Controls and Displays
1-MM-2	Locomotion and Restraint
1-MM-3	Habitability
1-MM-4	Work/Rest/Sleep Cycles
1-MM-5	Performance Aids
LIFE SUPPORT AND PROTECTIVE SYSTEMS	
1-LS-1	Phase Change and Thermal Processes
1-LS-2	Material Transport Processes
1-LS-3	Atmosphere Supply Processes
1-LS-4	Water Management
1-LS-5	Water Electrolysis
1-LS-6	Food Management and Processes
1-LS-7	Atmosphere Purification Methods
1-LS-8	Life Support Monitoring and Control
1-LS-9	Waste Management
1-LS-10	Heat Transport Equipment
1-LS-11	Crew Equipment and Protective Systems
1-LS-12	Life Support System Maintenance and Repair
ENGINEERING EXPERIMENTS	
1-EE-1	Data Management
1-EE-2	Structures
1-EE-3	Stabilization and Control (3 parts)

Cluster No.	Title
1-EE-3-1	Drift Measurement of Gyroscopic Attitude Controls
1-EE-3-2	Disturbance Torque Measurements
1-EE-3-3	Biowaste Electric Propulsion
1-EE-4	Navigation and Guidance (4 parts)
1-EE-4-1	Onboard Laser Ranging
1-EE-4-2	Interplanetary or Translunar Navigation By Spectroscopic Binary Satellite
1-EE-4-3	Landmark Tracker Orbital Navigation
1-EE-4-4	Navigation/Subsystem Candidate Evaluation
1-EE-5	Communications
OPERATIONS EXPERIMENTS	
1-OE-1	Logistics and Resupply (2 parts)
1-OE-1-1	Space Logistics and Resupply
1-OE-1-2	Emergency and Rescue Operations
1-OE-2	Maintenance, Repair and Retrofit
1-OE-3	Assembly and Deployment
1-OE-4	Module Operations
1-OE-5	Vehicle Support Operations
SPACE BIOLOGY	
VERTEBRATES	
2-VB-1	Preliminary Investigations of Biological Processes, Using Primates and Small Vertebrates
2-VB-2	Intermediate Investigations of Biological Processes, Using Primates and Small Vertebrates
2-VB-3	Advanced Investigations of Biological Processes, Using Primates and Small Vertebrates

Cluster No.	Title
INVERTEBRATES	
2-IN-1	Preliminary Investigations of Biological Processes, Using Invertebrates
2-IN-2	Intermediate Investigations of Biological Processes, Using Invertebrates
2-IN-3	Advanced Investigations of Biological Processes, Using Invertebrates
PROTISTS AND TISSUE CULTURES	
2-P/T-1	Preliminary Investigations of Biological Processes, Using Unicellular Specimens (protists and tissue cultures)
2-P/T-2	Intermediate Investigations of Biological Processes, Using Unicellular Specimens (protists and tissue cultures)
2-P/T-3	Advanced Investigations of Biological Processes, Using Unicellular Specimens (protists and tissue cultures)
PLANTS	
2-PL-1	Preliminary Investigations of Biological Processes, Using Plants
2-PL-2	Intermediate Investigations of Biological Processes, Using Plants
2-PL-3	Advanced Investigations of Biological Processes, Using Plants
SPACE ASTRONOMY	
OPTICAL	
3-OW	Optical Structure of Small Extended Sources
3-OB	High-Resolution Planetary Optical Imagery
3-OS	Optical (Faint Threshold) Surveys
3-OP	High Precision Stellar Photometry
3-SO	Optical Studies of the Solar Photosphere and Chromosphere

Cluster No.	Title
X-RAY	
3-XR	Precise Location, Size, and Structure of Known Discrete X-ray Sources, and Existence of Additional Unknown Sources
LOW FREQUENCY RADIO	
3-LF	Location and Properties of Discrete LF Radio Sources, and Structure and Properties of Diffuse Sources
SPACE PHYSICS	
PHYSICS AND CHEMISTRY LABORATORY	
4-P/C-1	Effect of the Space Environment on Chemical Reactions
4-P/C-2	Shape and Stability of Liquid-Vapor Interfaces
4-P/C-3	Boiling and Convective Heat Transfer in Zero-G
4-P/C-4	Effect of Zero-Gravity on the Production of Controlled Density Materials
4-P/C-5	Effect of Electric and Magnetic Fields on Materials
4-P/C-6	The Use of Zero-Gravity to Produce Materials Having Superior Physical Characteristics
4-P/C-7	Improvements of Materials by Levitation Melting
4-P/C-8	Effect of Zero-Gravity on the Production of Films and Foils
4-P/C-9	Effects of Zero-G on Liquid Releases, Size Distribution of Liquid Drops
4-P/C-10	Capillary Flow in Zero-G
4-P/C-11	Behavior of Superfluids in the Weightless State
PLASMA PHYSICS LABORATORY	
4-PP-1	Spacecraft-Environment Interaction
4-PP-2	Energetic Particle Dynamics in the Magnetosphere (3 parts)

Cluster No.	Title
4-PP-2-1	Use of Alkali Metal Clouds as a Space Diagnostic
4-PP-2-2	Use of Electron Beams as a Space Diagnostic
4-PP-2-3	VLF Wave Propagation
4-PP-3	Thermal Plasma in the Ionosphere and Magnetosphere (3 parts)
4-PP-3-1	(Essentially the same as 4-PP-2-1)
4-PP-3-2	(Essentially the same as 4-PP-2-3)
4-PP-3-3	RF Plasma Resonance Studies
4-PP-4	Auroral Processes (3 parts)
4-PP-4-1	(Essentially the same as 4-PP-2-1)
4-PP-4-2	(Essentially the same as 4-PP-2-2)
4-PP-4-3	(Essentially the same as 4-PP-2-3)

COSMIC RAY LABORATORY

4-CR-1	Charge and Energy Spectra of Cosmic Ray Nuclear Component
4-CR-2	Energy Spectrum of High-Energy Primary Electrons and Positrons
4-CR-3	Energy Spectrum and Spatial Distribution of Primary Gamma Rays
4-CR-4	Long-Lived Heavy Isotopes in Cosmic Rays
4-CR-5	Antinuclei in Cosmic Rays
4-CR-6	Quarks (Stable Fractionally Charged Particles) in Cosmic Rays
4-CR-7	Unknown Particles in Cosmic Rays
4-CR-8	Characteristics of Albedo Particles Above 100 MeV
4-CR-9	Nucleon-Nucleon Cross-Sections at High Energies
4-CR-10	Spallation Cross-Sections at High Energies

Cluster No.	Title
COMMUNICATIONS AND NAVIGATION	
NOISE	
5-N-1	Terrestrial Noise Measurements
5-N-2	Noise Source Identification
PROPAGATION	
5-P-1	Ionospheric Propagation Measurements
5-P-2	Tropospheric Propagation Measurements
5-P-3	Plasma Propagation Measurements
5-P-4	Multipath Measurements
TEST FACILITIES	
5-TF-1	Space Deployment and Calibration
5-TF-2	Demonstration and Test
COMMUNICATIONS SYSTEMS	
5-CS-1	MM Wave Demonstration
5-CS-2	Optical Frequency Demonstration
NAVIGATION SYSTEMS	
5-NS-1	Satellite Navigation Techniques for Terrestrial Users
5-NS-2	Laser Ranging
5-NS-3	Autonomous Navigation Systems for Space
5-NS-4	Surveillance Systems
5-NS-5	Collision Avoidance System Techniques
5-NS-6	Search and Rescue Systems
EARTH OBSERVATIONS	
EARTH PHYSICS	
6-EP-1	Photographic Coverage of the Earth
6-EP-2	Identification of Volcanic Activity

Cluster No.	Title
AGRICULTURE, FOREST, AND RANGE RESOURCES	
6-A/F-1	Crop Inventory and Land Use
6-A/F-2	Soil Type Mapping
6-A/F-3	Crop Identification
6-A/F-4	Crop Vigor and Yield Prediction
6-A/F-5	Wildfire Detection and Mapping
GEOGRAPHY, CARTOGRAPHY, AND CULTURAL RESOURCES	
6-G/C-1	Photographic and Multisensor Mapping
GEOLOGY	
6-G-1	Rock and Soil Type Identification
6-G-2	Use of Earth's Crust to Store and Condition Commodities or Waste
6-G-3	Geologic Disaster Avoidance
6-G-4	Utilization of Geothermal Energy Sources
6-G-5	Mineral and Oil Deposit Discovery
6-G-6	Identification of Land Forms and Structural Forms
HYDROLOGY AND WATER RESOURCES	
6-H-1	Determination of Pollution in Water Resources
6-H-2	Flood Warning and Damage Assessment
6-H-3	Synoptic Inventory of Major Lakes and Reservoirs
6-H-4	Synoptic Inventory of Snow and Ice
6-H-5	Survey of Soil Moisture in Selected Areas of the North American Continent
6-H-6	Location of Underground Water Sources in Selected Areas
6-H-7	Survey of Hydrologic Features of Major River Basins

Cluster No.	Title
OCEANOGRAPHY AND MARINE RESOURCES	
6-O-1	Ocean Pollution Identification, Measurement, and Effects
6-O-2	Solar Energy Partition and Heating in the Sea Surface Layer
6-O-3	Ocean Population Dynamics and Fishery Resources
6-O-4	Ocean Currents and Tide Forecasting
6-O-5	Ocean Physical Properties
6-O-6	Ocean Solid Boundary Processes
6-O-7	Ocean Surface Activity Forecasting
METEOROLOGY	
6-M-1	Determination of Boundary Layer Exchange Processes Using IR Radiometry
6-M-2	UHF Sferics Detection
6-M-3	Atmosphere Density Measurements by Stellar Occultation
6-M-4	Zero-G Environment Cloud Physics Experiment
6-M-5	Detection and Monitoring of Atmospheric Pollutants
6-M-6	Support of Studies of Special Geographical Areas

RESEARCH CLUSTER SYNOPSIS--EARTH OBSERVATIONS

6-EP-1 Photographic Coverage of the Earth

1. Research Objectives
The basic objective of this research cluster is to generate and update geotectonic maps of the Earth's surface, with a resolution of less than 500 meters. This objective will be met if Research Cluster 6-G/C-1 (Photographic and Multisensor Mapping) is flown in polar orbit, using metric and multispectral cameras.

2. Background and Current Status
Large areas of the land masses of the Earth have never been mapped on a scale better than 1:1,000,000. Limited photography of certain regions of CONUS from space, notably from Apollo 6, 7, and 9, has demonstrated the value of space photography in the compilation of geotectonic and geomorphological maps. Such maps are required in high latitudes and in developing areas of the world. The synoptic coverage obtainable from space offers a valuable tool for global mapping.

3. Description of Research
This experiment would be designed to optimize the generation of geological maps for world-wide dissemination. Research would involve the selection of appropriate film and filter combinations, as a function of geographical location and atmospheric conditions, to optimize the information return while minimizing the subsequent image processing.

4. Impact on Spacecraft
Precise location of geological features requires knowledge of spacecraft ephemeris, altitude, and attitude to enable location of the subpoint to less than 500 meters, relative to ground control points. Crew functions include the location of cloud-free areas; selection and use of cameras, films, and filters; and correlation of image and prior map data.

5. Required Supporting Technology Development
Techniques for precise determination of spacecraft ephemeris, altitude, attitude, and optical axis orientation require refinement.

Critical Issues Addressed by Research Cluster

6-EP-1

PHOTOGRAPHIC COVERAGE OF THE EARTH

6.1.1.1.1.6
What are the photographic characteristics of the Earth to ±500m?

6.3.1.3.4.1
How can the mapping of dynamic features and processes be accomplished? What is the time frame?

6.3.1.3.4.2
What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.:

Land use
Crop-timber
Hydrologic
Political
Population migration
Urban development
Economic
Climatic
Physical/chemical
Cultural

6.3.1.3.4.3
How can maps displaying time variant entities be effectively produced and distributed for use?

6.4.2.2.3.2
What are the positions of land masses, polar ice sheets, and ocean basins?

6.4.2.2.4.3
What evidence is there that the continents are drifting?

6.4.2.2.4.4
What evidence is there of sea floor spreading?

6.4.2.3.2.5
What is the relative rate of drift of the continents?

6.4.2.3.2.7
What are the rates of relative movements of the Earth's major fault systems?

6.4.2.3.2.9
What are the rates of sea floor spreading?

6-EP-1 Photographic Coverage of the Earth

The measurement and instrumentation list of this Cluster are covered by Research Cluster No. 6-G/C-1.

Table 1

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-EP-1	-1	Checkout Equipment	All	4	None		5-C	5-7 Orb/wk	20-30	1			
	-2	Clean Sensor Optical Surfaces		5	EVA		5-B	1/wk	1-2 hrs	1			
	-3	Perform Onboard Preparation - Checkout three sensors, load as required, review map/pictorial data.	Sensors	3	None		5-B	5-7 Orb/wk	20-30	1			
	-4	Operate Equipment - All sensor selection & cycling controls, initiate sequencing plan photographic frame rate & degree of overlap, operate scan optics & monitor electronic operation of all sensor equipment.		3	None		5-B	5-7 Orb/wk	20-30	1			
	-5	Visual Operations - Telescope & TV scan of target conditions for imaging (visible) portions of missions, description of prevailing wind conditions.					15-B	5-7 Orb/wk	20-30	1			
	-6	Other Measurement Taking - Monitor camera operation, ancillary electronics, film storage or interior data processing cryo system operation & communication in real-time with ground.					15-B	5-7 Orb/wk	20-30	1			
	-7	Adjust Equipment - Calibrate instruments boresighting & internal adjustments.					5-B	5-8 Orb/wk	10-20	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 1

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

Do not Reproduce

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-EP-2
IDENTIFICATION OF VOLCANIC ACTIVITY

RESEARCH CLUSTER
NO. 6-EP-2

RESEARCH CLUSTER SYNOPSIS—EARTH OBSERVATIONS

6-EP-2 Identification of Volcanic Activity

The objectives and requirements of this research cluster are covered by the synopsis for Research Cluster No. 6-G-4.

C-6-6

RESEARCH CLUSTER
NO. 6-EP-2

RESEARCH CLUSTER
NO. 6-EP-2

Critical Issues Addressed by Research Cluster 6-EP-2

Critical Issues Addressed by Research Cluster 6-EP-2

IDENTIFICATION OF VOLCANIC ACTIVITY

IDENTIFICATION OF VOLCANIC ACTIVITY

6. 1. 2. 1. 3. 1
What are the locations of incipient volcanic activity?

What are the locations of incipient volcanic activity?

6. 4. 2. 2. 4. 2
What tectonic and volcanic belts are active?

What tectonic and volcanic belts are active?

6. 6. 1. 1. 4. 1
How do the volcanological characteristics of the ocean relate to the occurrence of tsunamis?

How do the volcanological characteristics of the ocean relate to the occurrence of tsunamis?

RESEARCH CLUSTER
NO. 6-EP-2 6 EP-2

Table 1

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-EP-2	-1	Checkout Equipment	All	4	None		5-B	1/wk	15-45	1			
	-2	Clean Sensor Optical Surfaces		5	EVA		21-B	1/wk	1-2 hrs	1			
	-3	Perform onboard preparation - Load cameras, warmup scanners, chill down IR instruments, flight plan referencing, precision determination & impact.		3	None		5-B	10-12 Orb/wk	30-60	1			
	-4	Operate Equipment - Scan optics ancillary electronics equipment, slewing controls, experiment sequencing & voice tape recorder, computation & data processing equipment.		3			5-B	8-10 Orb/wk	30-70	1			
	-5	Visual Observations - Scan target area (optical sensor and displays). Compare previous synoptic photos with real time sensor display.		2			5-B	8-10 Orb/wk	30-70	1			
	-6	Other measurement taking - Distance & optical measurements using precision angle measuring instruments with scan optics to pinpoint potential geothermal areas.		2			11-A	8-10 Orb/wk	30-70				
	-7	Monitor Equipment - Cameras, sensor status indicators, electronic test & logic equipment & data recording/processing equipment.		1			5-C	8-10 Orb/wk	30-70	1			
	-8	Adjust equipment - Internal camera & sensor adjustments (focussing & boresighting) & calibrate with ground truth data.		1			5-C	2-3 Orb/wk	30-70	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 1

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10 - Agriculture
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12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
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TASK CONCURRENCY

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DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER–6-A/F-1
CROP INVENTORY AND LAND USE

RESEARCH CLUSTER SYNOPSIS--AGRICULTURE/FORESTRY

6-A/F-1 Location and Acerage of Present and Potential Cultivated, Forested, and Ranged Lands

1. Research Objectives

This research cluster is directed toward evolving a complete data system, from acquisition of remote sensor data to the eventual application by a user to a specific problem. In particular, this cluster will develop techniques and formats for data acquisition, handling, and utilization. This data system would be used to provide information on the distribution of cultivated, forested, and ranged lands. Such information is needed to effectively administer programs to improve soils and forest stands, and to protect watersheds. The principal hypothesis to be tested is that spacecraft can provide better data at less expense than other methods.

A specific objective is to construct thematic and land-use maps of the proper scale, showing rural areas that are cultivated, forested, ranged, or wild; location of fields, roads, and canals; and acreages of major crop, forest, and range types.

2. Background and Current Status

The U.S. Department of Agriculture annually surveys about 200-million acres of the United States by air. The objective is to completely rephotograph the U.S. with aerial cameras every 5 years. The visual photographic interpretation techniques are well developed, and the photographs are used extensively as a base for mapping.

The Department took part in NASA's Apollo 9 Scientific Photographic Experiment No. SO-65 in March 1969. The study is being continued with follow-on, high-altitude, sequential aircraft flights made at approximately monthly intervals since the Apollo 9 flight.

From the studies of the Apollo 9 photographs and of the supporting high-flight photographs, it was found that:

1. Precise crop identification, crop-yield determination, and crop-stress determination were not possible without the sequential imagery. Considering that only two orbital passes were made (only 3 days apart), the inability to make the desired determinations is understandable.

2. The accurate discrimination of some important Earth resource features (e.g., agricultural lands versus timberland and vegetated versus fallow fields) is possible.

3. Many Earth resource features are still identifiable despite the coarse resolution (e.g., of certain individual crop types and various types of timber stands).

4. The feasibility of using space photography for timber inventory was demonstrated by successfully using Apollo 9 photographs and a multistage probability sampling system to estimate the volume of 10-million acres of timberland, with a sampling error of only 13 percent and at a cost of about 1 cent per acre.

5. Color infrared photographs were significantly more interpretable for certain purposes than black-and-white photographs.

6. The interpretability of some features is increased further through the use of optical and electronic enhancement techniques

3. Description of Research

To construct the thematic and land-use maps desired by users, research related to developing recognition criteria and signatures is needed. These criteria and signatures will be developed from cameras, scanners, spectrometers, radiometers, and radar. As an example, these data should yield information on shape, texture, color, spatial frequency, and size of fields. Three methods of acquiring information from aerial photographs are currently employed by the Department of Agriculture: field mapping, photo-interpretation, and stereoscopic photointerpretation. The imagery and analog data supplied should be amenable to interpretation, using these conventional techniques.

For example, conventional aerial photographs of forests show percent crown closure and average crown diameter. This yields gross volume information only. The tree height is needed for accurate volume estimates, and a ground resolution element size of about 5 ft is required for height determination.

The initial measurements will be made over agricultural truth sites in cooperation with a user on the ground. The replication of previous ground and aircraft experiments will be stressed, and the results will be used to verify signatures and measurement techniques, and to calibrate sensors. The next phase will be to fly missions over the United States and to correlate with USDA records taken in previous decades by means of conventional techniques. For best results, data should be taken for a 60-degree sun elevation and at the end of the growth season.

Ground truth data includes (1) meteorological data on cloud cover (i.e., type, height, and amount), visibility, solar radiance, temperature, humidity, wind, and rainfall; (2) the standard optical bar pattern; and (3) data on vegetation types.

4. Impact on Spacecraft

The large number of test sites and instruments involved in taking data for this research will have a significant impact on the crew activities, and on the data storage and processing requirements. The scientific activities are mainly concerned with monitoring the data for quality. A quick-look capability for data evaluation may be desired. This includes electronic readout and photodevelopment facilities.

5. Required Supporting Technology Development

The research effort needed here is the development of spectral signature and general criteria for identifying the type and extent of vegetation covering. Development is also required to improve the ground resolution of cameras and multispectral scanners.

6. References

1. R. Colwell and W. Draiger. Vegetation Resource--User Requirements Versus Remote-Sensing Capabilities. Second Annual Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, Houston, Texas, 1969.

2. P. G. Langley, R. C. Aldrich, and R. C. Heller. Multi-Stage Sampling of Forest Resources by Using Space Photography. Second Annual Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, Houston, Texas, 1969.

3. C. E. Poulton. Range Resource Inventory from Space and Supporting Aircraft Photography. Second Annual Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, Houston, Texas, 1969.

RESEARCH CLUSTER
NO. 6-A/F-1

Critical Issues Addressed by Research Cluster

6-A/F-1

CROP INVENTORY AND LAND USE

6.2.1.1.1.1
What is the location and acreage of food and fiber crops?

6.2.1.1.1.2
What is the location and acreage of grazing and browsing land?

6.2.1.1.1.3
What is the location and acreage of commercial timber forests?

6.2.1.1.1.6
What is the location and acreage of fallow or soil improvement land?

6.2.1.1.1.7
What is the location and acreage of harvested crop and forest land?

6.2.1.1.1.8
What is the location and acreage of noxious weed infested land?

6.2.1.1.1.9
What is the location and acreage of forest land that is pastured?

6.2.1.1.2.11
What is the age of orchards, vineyards and forests?

6.2.1.2.1.1
What basic sensor and signature research should be done?

6.2.1.2.1.2
What are the changes in acreage of cultivated, forest and wild lands?

6.2.1.2.1.3
What are the changes in numbers and distribution of livestock?

6.2.1.2.3.2
What are the sources of pollution?

6.2.1.2.3.3
What are the distribution mechanisms of pollution?

6.2.1.3.1.1
What is the location and acreage of potentially arable land?

6.2.1.3.1.2
Where should intensive land management be applied or improved?

6.2.1.3.1.3
Where should better timber cutting and logging methods be used?

6.2.1.3.1.5
Where should more land be converted to cultivation?

6.2.1.3.1.7
Where should conservation practices be improved?

6.2.1.3.1.9
Which countries currently have undeveloped forest and rangeland resources?

6.2.1.3.1.10
Where is better conversion of forage into meat products needed?

6.2.1.3.2.1
What are the location and type of transportation routes?

6.2.1.3.2.2
What are the potential access routes to resources that are difficult to reach?

6.2.1.3.2.3
Where and by whom are the food and timber resources consumed?

6.2.2.1.1
What new instrumentation and measurement techniques are needed?

6.2.2.1.2
What is the better form of data collection—statistics or maps?

6.2.2.1.3
What is the best size sampling unit for area classification?

6.2.2.1.4
What is the effect of cloud obscuration?

6.2.2.1.6
How effectively can an astronaut work with a PI on the ground?

6.2.2.1.7
Can large structures, e.g., antennas, be erected in space?

6.2.2.1.8
Can man perform calibration, repairs and maintenance of sensors in space?

6.2.2.1.9
What sensor modifications can and should be done in space?

6.2.2.2.2
What is the better form of data presentation--statistics or maps?

6.2.2.2.4
What is the cost of data collected from space compared to air and ground?

6.2.2.2.5
How can man's capabilities be combined in real time analysis, evaluation and decision making?

6.2.2.2.6
How much data reduction should be done in space?

6.2.2.2.7
What is the value of visual observation and verbal comment by the astronaut?

6.2.2.2.8
What are the specific environmental factors affecting the interpretation of sensor data?

6.2.2.3.1
What is the effect of cloud obscuration?

6.2.2.3.2
What is the effect of illumination intensity and angle?

6.2.2.3.3
What is the effect of season?

6.2.2.3.4
What is the effect of orbit altitude and slant range?

6.2.2.3.5
What is the effect of orbit inclination?

6.2.2.3.7
Can perennially clouded-over resources be observed through occasional breaks in the clouds?

6.2.3.1.1.1
Which countries are importing/exporting food or fiber?

6.2.3.1.1.2
Which countries could be combined into common markets?

6.2.3.1.1.3
Which countries have undeveloped agricultural, forest, range or wild resources?

6.2.3.1.1.4
Where are new large dams or irrigation projects needed?

6.2.3.1.2.1
Where will current data on supply and demand improve market efficiency?

6.2.3.1.2.3
Where should land be entered or removed from cultivation?

6.2.3.1.2.4
Where is better conversion of forage into meat products needed?

6.2.3.1.2.5
Where are dams or irrigation projects needed?

6.2.3.1.2.6
What are the market implications of storm, drought and disease?

6.2.3.1.3.1
Where can tax revenue from resources be increased?

6.2.3.1.3.3
What is the ownership of specific forest, range and wild lands?

6.2.3.2.1.1
What are the natural food production and consumption areas?

6.2.3.2.1.2
What information or training is needed by developing countries?

6.2.3.2.1.3
What international cooperation in data acquisition and application is needed?

6.2.3.2.1.4
Where should migratory wild life sanctuaries be established?

6.2.3.2.2.1
What are the recreation potentialities of forest, water and wild areas?

6.2.3.2.2.2
Where should green belts or wilderness areas be established?

6.2.3.2.2.3
Where should new cities be placed?

6.2.3.2.2.4
What are the ecological effects of dams and irrigation projects?

6.2.3.2.2.6
Where should wild life sanctuaries and game preserves be established?

6.2.3.2.3.1
Where will future expansion of urban into rural areas occur?

6.2.3.2.3.3
Where is regional development planning needed?

6.2.3.2.3.4
Where is noncompliance with minimum land management practices occurring?

6.3.1.1.1.2.1
What aspects of geography and cartography may be applied to the analyses of remote lands for food resources applications?

6.3.1.1.1.2.2
How many remote lands be located; categorized, indexed, and displayed in map form?

6.3.1.1.1.2.3
How can land in the higher latitudes be used more effectively for food reserves?

6.3.1.1.1.3.1
How can geography be applied to the utilization or remote stands of timber?

6.3.1.1.1.3.2
How can the location and configuration of remote timberlands be categorized, indexed and displayed in map form?

6.3.1.1.1.3.3
How may geography and cartography be applied to more efficient monitoring and management of timberlands?

6.3.1.1.2.1.4
Can air terminals be more efficiently or remotely located and satisfy the demands of the business society?

6.3.1.1.2.2.3
How can monitoring of population movement and land use be used effectively for the location of railroad connections?

6.3.1.1.2.3.1
What aspects of geography/cartography can be applied to more efficient routing of existing and future highways and internal urban accesses?

6.3.1.1.3.1.1
What significant impact does expanding urbanization have on the condemnation of usable agriculture and forest lands?

6.3.1.1.3.1.4
How may expanding communities be most advantageously monitored?

6.3.1.1.3.2.3
How can mapping techniques be applied to the specific requirements of marketing?

6.3.1.1.3.3.1
What aspects of geography can be applied to the selection of potentially usable land areas?

6.3.1.1.3.3.2
How can unused lands be located, categorized, and indexed for specific uses?

6.3.1.1.3.3.3
How can cartographic techniques best be applied to all phases of land use from urban development to internationally controlled or monitored lands?

6.3.1.2.2.3
How can geographic relations be more effectively used for recreational pursuits?

6.3.1.2.3.1
How can changing seasonal crop conditions be more efficiently dealt with by application of Geographic principles?

6.3.1.2.3.2
What and how are ecological trends being influenced by man's presence and cultural development?

6.3.1.2.3.3
What is the rate of environmental change and how can this be measured meaningfully?

6.3.1.2.4.1
How can the problem of population density be controlled and/or modified in urban areas?

6.3.1.2.4.3
How can the world food supply be effectively distributed to areas of need and how can the distribution be more efficiently managed in heavily populated urban areas?

6.3.1.2.4.4
How can the migration and distribution of urban population be monitored?

6.3.1.3.1.1
How can the major geographic land areas of the world be identified, classified for use?

6.3.1.3.1.2
How can the most appropriate use of specific land areas be determined?

6.3.1.3.4.1
How can the mapping of dynamic features and processes be accomplished? What is the time frame?

6.3.1.3.4.2
What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.:

Land use
Crop-timber
Hydrologic
Political
Population migration
Urban development
Economic
Climatic
Physical/chemical
Cultural

6.3.1.3.4.3
How can maps displaying time variant entities be effectively produced and distributed for use?

6.3.2.2.1.1
What is the ratio of unused to used land and the rate of change of this ratio?

6.3.2.2.1.2
What percentage of unused lands is considered usable for cultivation?

6.3.2.2.1.3
How has man changed the natural vegetation?

6.3.2.2.1.4
What factors have dictated the major crops, the location and amounts of the crops?

6.3.2.2.1.5
What is the present ratio of specific crops to world population and the rate of change of this ratio?

6.3.2.2.2.6
To what extent and to what scales is the physical surface of man's environment depicted?

6.3.2.2.3.5
What is the rate of development in new communities?

6.3.2.2.3.6
What is the rate of expansion of existing populations, (a) countries, (b) states, (c) counties, (d) cities, (e) towns?

6.3.2.3.3.3
How can waste disposal in large populated centers be significantly reduced or how can the rate of disposal be increased?

6.3.3.2.3.1
How will the expanding population affect the decisions on tillable versus urban development land?

6.3.3.2.3.3
What effect is exerted by man and his environment on land usage?

6.3.3.2.3.4
How do settlement patterns relate to land use?

6.3.3.2.3.5
What are the effects of urban development on erosion of the land?

6.3.3.3.2.3
To what extent do man's modifications of the environment for expansion affect the land and ecologic system?

6.5.1.2.1.1
How can land-use mapping and classification be improved?

6.5.1.2.1.2
What is the extent of diversion of water for user requirements?

6.5.2.1.2.5.3
What are the regional effects of changes in land use on the climate?

6.5.2.2.1.2
How is the watershed affected by changes in use of land?

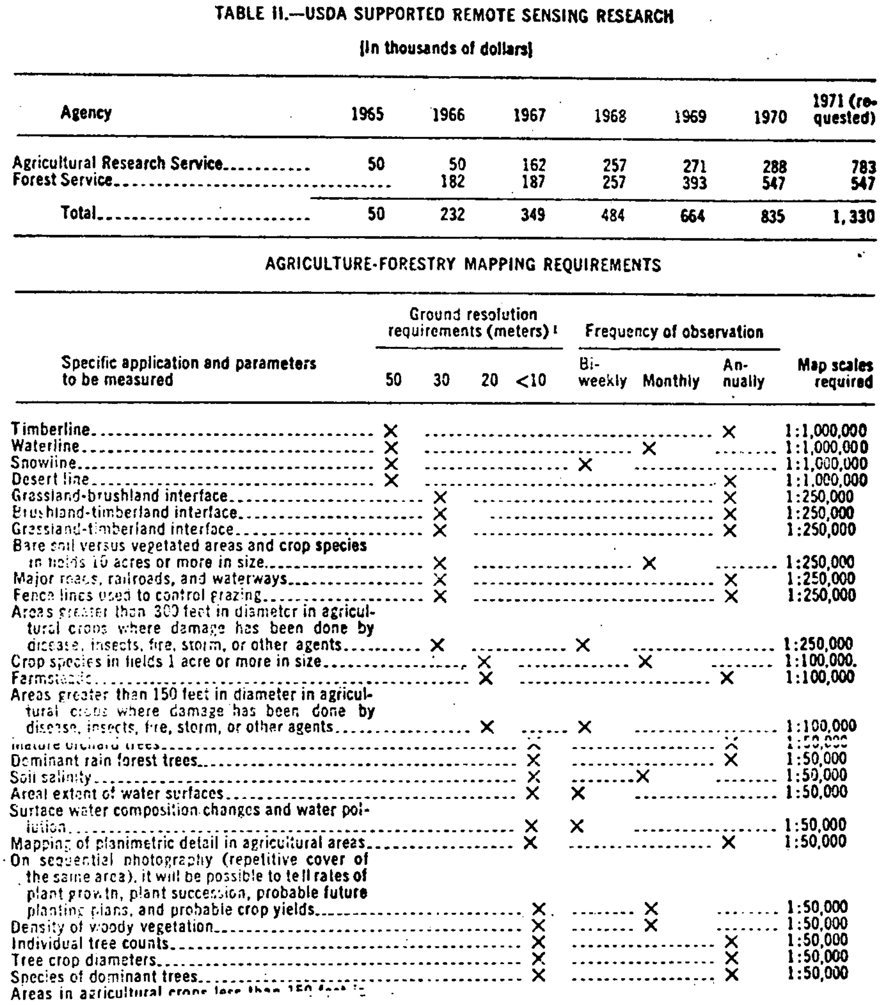

TABLE II.—USDA SUPPORTED REMOTE SENSING RESEARCH

[In thousands of dollars]

Agency	1965	1966	1967	1968	1969	1970	1971 (requested)
Agricultural Research Service	50	50	162	257	271	288	783
Forest Service		182	187	257	393	547	547
Total	50	232	349	484	664	835	1,330

AGRICULTURE-FORESTRY MAPPING REQUIREMENTS

Specific application and parameters to be measured	Ground resolution requirements (meters)¹				Frequency of observation			Map scales required
	50	30	20	<10	Bi-weekly	Monthly	Annually	
Timberline	X						X	1:1,000,000
Waterline	X					X		1:1,000,000
Snowline	X				X			1:1,000,000
Desert line	X						X	1:1,000,000
Grassland-brushland interface		X					X	1:250,000
Brushland-timberland interface		X					X	1:250,000
Grassland-timberland interface		X					X	1:250,000
Bare soil versus vegetated areas and crop species in fields 10 acres or more in size		X				X		1:250,000
Major roads, railroads, and waterways		X					X	1:250,000
Fence lines used to control grazing		X					X	1:250,000
Areas greater than 300 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents		X			X			1:250,000
Crop species in fields 1 acre or more in size			X			X		1:100,000.
Farmsteads			X				X	1:100,000
Areas greater than 150 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents			X		X			1:100,000
Mature orchard trees				X			X	1:50,000
Dominant rain forest trees				X			X	1:50,000
Soil salinity				X		X		1:50,000
Areal extent of water surfaces				X	X			1:50,000
Surface water composition changes and water pollution				X	X			1:50,000
Mapping of planimetric detail in agricultural areas				X			X	1:50,000
On sequential photography (repetitive cover of the same area), it will be possible to tell rates of plant growth, plant succession, probable future planting plans, and probable crop yields				X		X		1:50,000
Density of woody vegetation				X		X		1:50,000
Individual tree counts				X			X	1:50,000
Tree crop diameters				X			X	1:50,000
Species of dominant trees				X			X	1:50,000
Areas in agricultural crops less than 150 feet in								

Figure 6-A/F 1.4 Agriculture-Forestry Ground Resolution Requirement From Hearings before the Committee on Aeronautical and Space Sciences. United States Senate on S3374, NASA Authorization for Fiscal Year 1971, p. 838.

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation									
					Instrument Resolution						
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial*	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Field boundaries, roads railroads, timber lines, etc.	Metric camera panchromatic B&W IR and/or UV films	Shape, size aspect ratio, frequency of linear elements	feet	10/200 ft.	100 ft	4000Å	-	±10%	atmospheric refraction, diffraction and scattering	Cloud type and amount, temperature, humidity surface wind speed and direction, visibility solar illumination
2. Broadband color differences of crops, trees, grass lands, soil, etc.	Metric camera color and color IR films	Spectral radiance	watt/m^2-srad-μ	20/400	50-150 ft	4000Å	-	±10%	atmospheric scattering	
3. Narrowband color differences of crops, trees, grass, soil, etc.	Multispectral camera and scanner	Spectral radiance and its spatial distribution	watt/m^2-srad-μ	20/400	75-150 ft	1 μ		±10% 1 μ	atmospheric scattering	
4. Temperature differences between fields, forest, range, water, etc.	Radiometer and spectrometer	Narrowband spectral radiance and its spatial distribution	watt/m^2-srad-μ	250/325°K equivalent brightness temp	50-200 ft	radiometer 1μ spectrometer 0,3-1μ	±1°K	±10%	atmospheric emission	
5. Surface texture or roughness of terrain	Radar	Angle of polarization and corresponding radiance	angular degrees watt/m^2-srad-μ	0/180° 20/400	200 ft	-	-	±10%	atmospheric scattering	
6. Surface topography roads, railroads, power lines, etc.	Radar imager Scatterometer	Amplitude and azimuth dependence of backscatter	decibels	-40/10	50-150 ft	-	-	±10% amplitude ±5 deg	multiple signals from same target	

See Figure 6-A/F-1.4 and 6-A/F-4.2 for details

Table 2
INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	Possible alternative: 24-in. panoramic camera
2.	Multispectral Camera	X	
3.	Ten-Band Multipsectral Scanner	X	Only five channels required
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	O	Possible alternative to No. 3
7.	Radar Altimeter-Scatterometer	O	Possible alternative to No. 4
8.	Microwave Scanner Radiometer	O	Resolution too gross for most mapping
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star-Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-Imaging Camera	O	Support sensor
14.	IR Interferometer-Spectrometer**	X*	Use 8- to 13-μ band
15.	Multispectral Tracking Telescope	O	Used to train No. No. 14
16.	Selective Chopper	X	0.8 to 2.5μ, modify LWIR to 8 to 13 μ, (atmospheric)
17.	IR Filter Wedge Spectrometer	X	Use 0.7- to 2.5-μ band
18.	IR Temperature Sounder **		
19.	Satellite IR Spectrometer**	X*	Use 8- to 13-μ band
20.	Temperature Profile Radiometer **		
21.	Visible Wavelength Polarimeter	X	Use 0.4- to 0.8-μ band
22.	UV Imager-Spectrometer	X	

*Both types are not required. Best type should be selected.
**Instrument to provide supportive meteorological data

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO. 6-A/F-1

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY†	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK SEQUENCY†
6-A/F-1	A-1	Checkout Equipment	All	4	None	X	5-2	1/wk	15-45	1	1975		
	A-2	Clean lens	Sensors	4	EVA	X	21-1	1/wk	60-120	1			
	A-3	Perform onboard preparation (periodic camera loading and focusing, childown of IR scan instruments, prepare for optical tracking, prepare data storage equipment)	Cameras, IR scan instruments	3	None	X	5-2	daily	30-40	1			
	A-4	Operate Equipment (operate sensor cycling control and indicate by means of sequencer input, duration, extent of coverage, control coordinated sensor track-point control and optical scan. Operate image call up equipment for comparison of new and stored data)	See task Description	5&6	None		9, 10-1	1/5 days	30-50	1			
	A-5	Visual Observations (predata taking area scan for cloud cover and prevailing conditions; photographic quick look processing to ascertain image quality, and comparison of present with previously acquired sensor data)		7	None		9, 10-1	daily	30-70	1			
	A-6	Voice Annotation (Complement sensor data with voice annotation and other correlative measurements with information derived from sensor displays and optical scan of target areas)	Microphone and Audio recorder	8	None		9, 10-1	daily	30-40	1			
	A-7	Monitor Equipment Operation (Monitor sensor associated electronics, camera operation including speeds, opening and film advance, operation of data gathering, & processing equipment and instrument maintenance)		5	None		19-2	daily	30-50	1			
	A-8	Adjust Equipment (Calibrate sensors in conjunction with measured signals from ground truth sites and onboard bore sighting references. Periodic lens adjustments for all cameras)	All sensors	4	None	X	5-2	1/2 days	20-30	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-A/F-2
SOIL TYPE MAPPING

RESEARCH CLUSTER SYNOPSIS--AGRICULTURE/FORESTRY

6-A/F-2 Principal Agricultural Soil Types and Soil Quality

1. Research Objectives

This research cluster is directed toward determining the performance of remote sensors in identifying Earth resources and establishing signature recognition criteria for soil-type mapping. The basic objective is to develop techniques and instrumentation to obtain data, not only to determine soil types but also to indicate moisture content, salt content, organic content, friability, insect population, and micro-organism content of typical soil classes. This research should provide knowledge that will enable agronomists and economists to prepare maps and tables of statistics that show not only the soil type but also the soil quality on a current basis. This information is needed to optimize the use of land.

2. Background and Current Status

The Department of Agriculture, Soil Conservation Service, has a continuing program of soil classification and mapping. It maps 50-million acres annually, primarily by field observation, and to some extent by stereoscopic photointerpretation. After soil-type boundaries are located in the ground, they are delineated on photographic enlargements. The two special advantages of aerial photographs over ground surveys are the essentially correct geometry and the abundance of pictorial detail, which in mapping activities negates much of the task of developing horizontal control by ground traverse.

In recent testimony before the U.S. Senate, the USDA stated that the Department has planned systematic and aggressive research, which is aimed at the full utilization of satellite remote-sensing data and, of greater importance, the timely application of such instrument systems to the solution of major agricultural and forestry problems. The results of the Department's remote-sensing research activities to date are indicative of some of the now-definite capabilities that were considered earlier to be only possibilities worthy of investigation. The research represents a major accomplishment in methods used for soil mapping in that it (1) allows quantitative determination of surface soil boundaries, (2) allows quantitative determination of areas processing similar surface characteristics, and (3) is an automatic technique that makes possible the analysis of data and its timely reduction to useful information (maps).

3. Description of Research

Multispectral imagery and photography will be used in conjunction with radiometry and spectrometry of the vegetation and soil to develop signatures, criteria, and techniques to accomplish the objective outlined above.

The initial measurements will be made over agricultural truth sites; e.g., Weslaco, Texas, in cooperation with an agronomist on the ground. Stress will be placed on the replication of previous ground and aircraft signatures and characteristics, and the discovery of new criteria of soil quality. The next phase will be to fly missions over Western United States and to correlate with USDA on a soil series.

Since the experiment consists principally of research in measurements from space through the entire atmosphere, additional measurements should be made of the state of the atmosphere that probably would not be part of an operational agricultural soil-identification system. Spectrometers and radiometers operating in the ozone, water-vapor, and carbon-dioxide absorption bands of the atmosphere should be operated concurrently with the surface-viewing sensors to gather data on the effect of the atmospheric scattering, refraction, and reflection on the signature of the resource being studied.

Ground truth data are also needed on the soil condition; e.g., moisture, salt, and organism content; radiation environment; and vegetation type and vigour. The required meteorological data include cloud type and height, temperature, humidity, and wind velocity. A standard optical bar pattern is required.

4. Impact on Spacecraft

The large number of instruments needed to take data for this research cluster indicates significant data bussing, storage, and processing requirements. Scientific objectives require close coordination with aircraft overflights of test locations. Necessary onboard evaluation of photographs and scanner images requires photographic development and electronic readout facilities. Voice annotation of the atmospheric and ground conditions is desirable.

5. Required Supporting Technology Development

Soil identification signatures are needed. Assisting in their development requires models that relate the reflective emissive and radiative spectra of soils to solar altitude and atmospheric properties, such as aerosol content and water vapor. Development of cameras, scanners, and spectrometers will be necessary to improve both ground and spectral resolution.

6. References

1. R. B. MacDonald. Application of Automatic Recognition Techniques to Earth Resources. Second Annual Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, Houston, Texas, September 1969.

2. M. G. Tangeray, R. M. Hoffer, and R. D. Miles. Multispectral Imagery and Automatic Classification of Spectral Response for Detailed Engineering Soil Mapping. Proceedings of the Sixth International Symposium on Remote Sensing of the Environment, Vol. 1, October 1969.

RESEARCH CLUSTER
NO. 6-A/F-2

Critical Issues Addressed by Research Cluster

6-A/F-2

SOIL TYPE MAPPING

6.2.1.1.2.10
What is the location, type and amount of beneficial and harmful organisms in the soil?

6.2.1.1.3.1
What is the fertility of the soil?

6.2.1.1.3.2
What is the salinity of the soil?

6.2.1.1.3.3
What is the moisture content, porosity and permeability of the soil?

6.2.1.1.3.4
What is the organic material content of the soil?

6.2.1.1.3.5
What is the incursion of brackish water in ground and surface water?

6.2.1.1.3.6
What is the location and extent of soil types?

6.2.1.2.3.1
What is the signature of brackish water or soil?

6.2.1.2.3.4
What is the location and amount of ground water?

6.2.1.2.3.8
Where are fertilizers being used?

6.2.2.1.1
What new instrumentation and measurement techniques are needed?

6.2.2.1.7
Can large structures, e.g., antennas, be erected in space?

6.2.2.1.8
Can man perform calibration, repairs and maintenance of sensors in space?

6.2.2.1.9
What sensor modification can and should be done in space?

6.2.2.2.1
What models are needed and what should be their inputs?

6.2.2.2.3
What is the degree of usefulness of data that has marginal resolution?

6.2.2.2.5
How can man's capabilities be combined in real time analysis, evaluation and decision making?

6.2.2.2.6
How much data reduction should be done in space?

6.2.2.2.7
What is the value of visual observation and verbal comment by the astronaut?

6.2.2.2.8
What are the specific environmental factors affecting the interpretation of sensor data?

6.2.2.3.2
What is the effect of illumination intensity and angle?

6.2.2.3.3
What is the effect of season?

6.2.2.3.4
What is the effect of orbit altitude and slant range?

6.2.2.3.5
What is the effect of orbit inclination?

6.2.2.3.6
What coordination with ground truth sites and aircraft underflights is needed?

6.2.3.1.3.6
Where is soil exhaustion or overgrazing occurring?

6.2.3.2.2.4
What are the ecological effects of dams and irrigation projects?

6.2.3.2.3.5
Where should conservation practices be improved?

6.3.1.1.1.2.3
How can land in the higher latitudes be used more effectively for food reserves?

6.3.2.2.1.2
What percentage of unused lands is considered usable for cultivation?

6.3.2.2.1.4
What factors have dictated the major crops, the location and amounts of the crops?

6.4.1.1.1.1
How can specific rock/soil types be detected, identified, classified, and put to productive use?

6.4.2.2.1.6
How can structures be identified by vegetation?

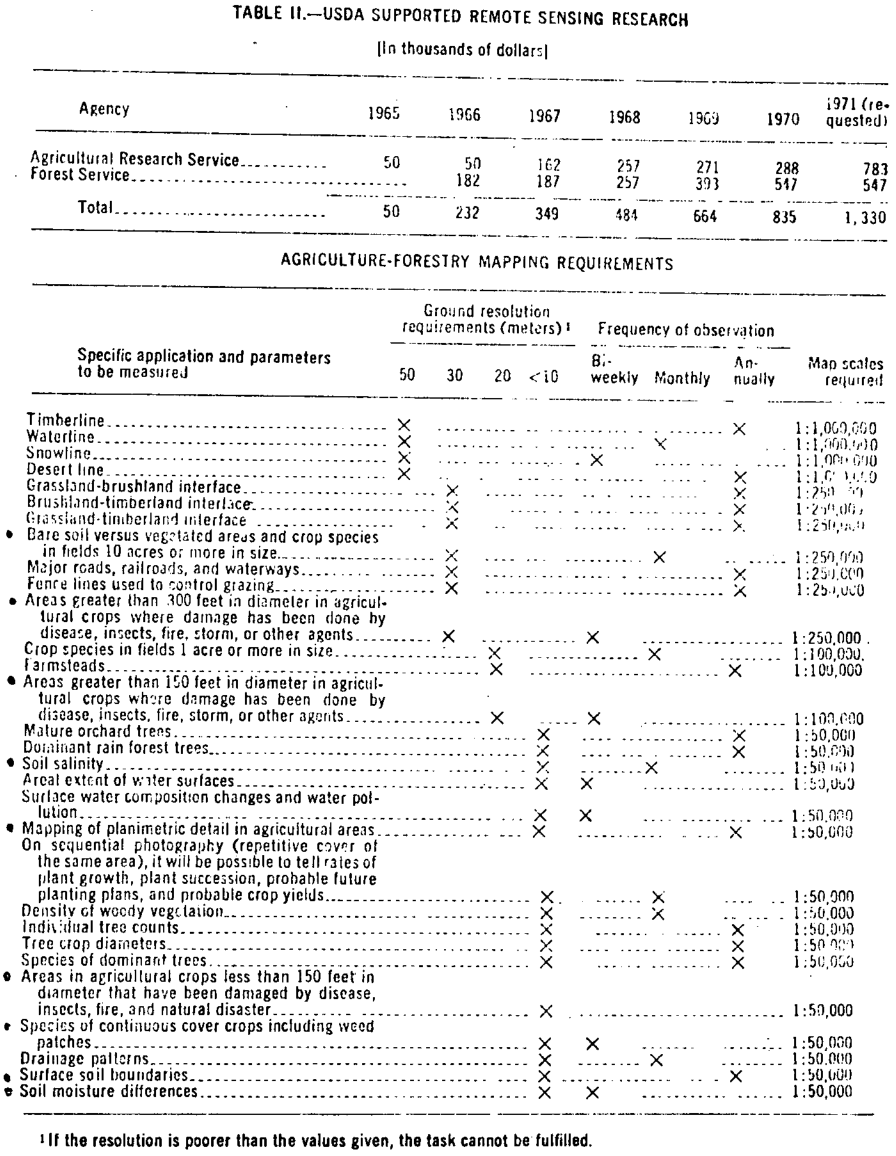

TABLE II.—USDA SUPPORTED REMOTE SENSING RESEARCH

[In thousands of dollars]

Agency	1965	1966	1967	1968	1969	1970	1971 (requested)
Agricultural Research Service	50	50	162	257	271	288	783
Forest Service		182	187	257	393	547	547
Total	50	232	349	484	664	835	1,330

AGRICULTURE-FORESTRY MAPPING REQUIREMENTS

Specific application and parameters to be measured	Ground resolution requirements (meters)[1]				Frequency of observation			Map scales required
	50	30	20	<10	Bi-weekly	Monthly	Annually	
Timberline	X						X	1:1,000,000
Waterline	X					X		1:1,000,000
Snowline	X				X			1:1,000,000
Desert line	X						X	1:1,000,000
Grassland-brushland interface		X					X	1:250,000
Brushland-timberland interface		X					X	1:250,000
Grassland-timberland interface		X					X	1:250,000
• Bare soil versus vegetated areas and crop species in fields 10 acres or more in size		X				X		1:250,000
Major roads, railroads, and waterways		X					X	1:250,000
Fence lines used to control grazing		X					X	1:250,000
• Areas greater than 300 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents		X			X			1:250,000
Crop species in fields 1 acre or more in size			X			X		1:100,000
Farmsteads			X				X	1:100,000
• Areas greater than 150 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents			X		X			1:100,000
Mature orchard trees				X			X	1:50,000
Dominant rain forest trees				X			X	1:50,000
• Soil salinity				X		X		1:50,000
Areal extent of water surfaces				X	X			1:50,000
Surface water composition changes and water pollution				X	X			1:50,000
• Mapping of planimetric detail in agricultural areas				X			X	1:50,000
On sequential photography (repetitive cover of the same area), it will be possible to tell rates of plant growth, plant succession, probable future planting plans, and probable crop yields				X		X		1:50,000
Density of woody vegetation				X		X		1:50,000
Individual tree counts				X			X	1:50,000
Tree crop diameters				X			X	1:50,000
Species of dominant trees				X			X	1:50,000
• Areas in agricultural crops less than 150 feet in diameter that have been damaged by disease, insects, fire, and natural disaster				X				1:50,000
• Species of continuous cover crops including weed patches				X	X			1:50,000
Drainage patterns				X		X		1:50,000
• Surface soil boundaries				X			X	1:50,000
• Soil moisture differences				X	X			1:50,000

[1] If the resolution is poorer than the values given, the task cannot be fulfilled.

Figure 6-A/F-2.2. Agriculture-Forestry Ground Resolution Requirements. From Hearings before the Committee on Aeronautical and Space Sciences. United States Senate on S3374, NASA Authorization for Fiscal Year 1971, p. 838.

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation									
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Reduced vigor in vegetation	Multispectral scanner	Reduced chlorophyll absorption and radiance	watt/m^2-srad-μ	20/400	100 - 200 ft	Visible 3000Å IR 1μ	-	±10%	Atmospheric scattering	Cloud type and amount, temperature, humidity, surface wind speed and direction, visibility, solar illumination. Soil moisture measured at root level. Samples of soil for laboratory analysis of moisture, salts, trace elements, biological content, etc.
2. Broadband color of vegetation and soil	Metric camera color film	Spectral radiance	watt/m^2-srad-μ	20/400	10-100 ft	4000Å	-	Not applicable	Atmospheric scattering	
3. Narrow band color of vegetation and soil	Multispectral camera	Spectral radiance	watt/m^2-srad-μ	20 - 400	75 ft	1000Å	-	±10%	Atmospheric scattering	
4. Spectrograms of vegetation and soil	UV, visible and IR spectrometer	Spectral radiance	watt/m^2-srad-μ	20/400	30-100 ft	30- 1000A	-	1-10%	Atmospheric scattering	
5. Temperature difference between moist and dry soil	LWIR radiometer	Spectral radiance	watt/m^2-srad-μ	5/10	30-100 ft	1μ	1°K	±10%	Atmospheric scattering	
6. Surface texture or roughness	Radar imager	Amplitude and azimuth of back-scatter, angle of polarization, signal strength at various polarizations	decibels	-40/10 db	100-300 ft	-	-	±10%	Multiple signals from same target (radar)	

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	Ten-band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	0	Possible alternative to No. 3
7.	Radar Altimeter-Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star-Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-Imaging Camera	0	Support
14.	IR Interferometer-Spectrometer*	X	0.8- to 2.4-μ range and 7.5- to 15 μ
15.	Multispectral Tracking Telescope	X	
16.	Selective Chopper Radiometer	X	0.8 to 2.5, modify LWIR to 8 to 13 μ
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder*		
19.	Satellite IR Spectrometer*	X	
20.	Temperature Profile* Radiometer		
21.	Visible Wavelength Polarimeter	X	To 0.4 to 0.8 μ
22.	UV Imager-Spectrometer	X	

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*Instrument provides supportive meteorological data

RESEARCH CLUSTER
NO. 6-A/F-2

Table 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE ‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN.)	NO. OF CREWMEN	[illegible]†	[illegible]†	TASK [illegible]†
6A/F2 -1	Checkout Equipment	All	4	None		5-C	1/wk	15-45	1			
-2	Clean Lenses	Sensors	5	EVA		21-B	1/wk	1-2 hrs.	1			
-3	Perform onboard preparation (periodic camera focussing, chilldown of IR scanner, prepare optical tracking sensor	Cameras, IR Scanner	3			5-B	8-10 Orb/wk	30-40	1			
-4	Operate equipment (Operate sensor cycling controls, initiate sequency & duration control)		3			5-B	"	30-50	1			
-5	Visual Observations (Optical scan of target area)		2			9-B	"	20-50	1			
-6	Voice Annotation (record correlative information, optical scan of target area for unusual & potential contributing conditions)	Microphone, audio recorder	2			9-B	"	30-70	1			
-7	Monitor equipment operation (Sensor associated electronics, camera operation including film advance and data taking equipment operation)		1			5-B	"	30-40	1			
-8	Adjust Equipment (Calibrate cameras & non-imagery sensors using both onboard references and ground-truth signal updates)		1			5-C	3-5 Orb/wk	10-30	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-A/F-3
CROP IDENTIFICATION

RESEARCH CLUSTER
NO. 6-A/F-3

RESEARCH CLUSTER SYNOPSIS--AGRICULTURE/FORESTRY

6-A/F-3 Species of Food, Fiber, and Wood Crops

1. Research Objectives

This research cluster is directed toward developing measurement techniques, sensors, and subsystems for application to future operational satellite systems. A specific objective is to develop measurement techniques that can provide data for use by the agricultural community to formulate maps or tables of stastics to show the plant and tree species in principal agricultural areas. Such information is needed by the Department of Agriculture to more effectively administer the Department's programs. Such information is also needed by the Food and Agricultural Organization of the United Nations to estimate available food supplies.

2. Background and Current Status

The ASCS and SRS of the U.S. Department of Agriculture currently interpret aerial photographs to identify cultivated crops and major vegetation types on range lands. The census of agriculture gathers information on crop species at 5-year intervals and publishes it by counties.

Quantitative reflectance and thermal radiation signatures of agricultural crops have been remotely sensed by low-flying aircraft. Subtle variations in these signatures have been identified, and normalizing methods have been developed to distinguish species. Electronic processing of the remotely sensed signatures is currently being used to rapidly determine the sizes and types of field crops.

The current capacity in automatic data processing of agricultural parameters (i.e., machine classification of large data quantities) is as follows:

1. Data formating techniques (analog-to-digital conversion, tape-to-punch-card conversion, and data editing) which are now more or less mechanical procedures.

2. Agricultural data reduction, which can now be handled as spectral matching techniques, as automatic pattern-recognition techniques, or as combinations of these.

3. The ability to recognize areas of agricultural crops, soil, and water, and to determine their various conditions in real-time by means of aerial observations.

4. The ability to scan aerial photographs of forest land, automatically record gray-scale variations, and print out maps delineating major cover type and land-use boundaries.

The capability to successfully and automatically classify aircraft-obtained data gathered over large geographic areas is now demonstrable. The high reliability of the data is the direct result of computerized spectral scanner data. The earlier capability was only about 5 sq mi; the present capability is approximately 500 sq mi.

3. Description of Research

Multispectral photography will be used in conjunction with radiometry and spectrometry to develop spectral signatures, and other criteria that can be used to identify field and forest species. The initial measurements will be made over agricultural truth sites; (e.g., Buck's Lake, California; Purdue, Indiana) in cooperation with a user on the ground. Replication of the results of previous experiments by the USDA and associated contractors will be stressed. Measurements should be restricted to a 60-degree sun elevation and should be made close to the time of crop maturity.

Since the experiment consists principally of research in measurements from space through the entire atmosphere, additional measurements should be made of the state of the atmosphere. These additional measurements probably would not be part of an operational agricultural resources system. Spectrometers and radiometers operating in the ozone, water vapor, and carbon dioxide absorption bands of the atmosphere should be operated concurrently with the surface-viewing sensors to gather data on the effect of atmospheric scattering, refraction, and reflection on the signatures of the resource being studied.

Identification is best made close to harvest time and must be repeated about every 3 or 4 months in specialized horticulture; e.g., truck-farming areas. In range areas, once every 2 or 3 years is sufficient, and in timber areas once a decade is adequate.

Ground truth data include (1) meteorological data, such as cloud type and amount, solar and sky spectral radiance, aerosol content, wind velocity, temperature, and humidity; and (2) vegetation type. A standard optical bar pattern is needed at all ground truth sites.

4. Impact on Spacecraft

The large number of instruments and test sites needed for this research will require close cooperation between scientists in space and those on the ground. The crew will use the observation telescope to evaluate the cloud cover, contrast, and transmission qualities of the atmosphere, as well as for training sensors on the crop being studied. The onboard data analysis will monitor the quality of the data and eliminate sets that have unacceptable atmospheric cloud cover, ground contrast, or noisy signatures. Photographic development and computer-controlled analog and digital display facilities are needed. The altitude should be as low as practicable, and the sun elevation should be 60 degrees or greater.

5. Required Supporting Technology Development

Unique combinations of spectral signatures are needed for the different species. To assist in rapid identification, models are needed that relate reflectance and radiance spectra of particular species to illumination, time of day, and season. The reflectance signature research should be extended to the thermal infrared and microwave areas of the spectrum. In addition to unique signatures, sensors with improved spectral and ground resolution are needed.

6. References

1. A. J. Richardson, W. A. Allen, and J. R. Thomas. Discrimination of Vegetation by Multispectral Reflectance Measurements. Proceedings of the Sixth International Symposium on Remote Sensing of Environment, Vol. 2, Ann Arbor, Michigan, October 1969.

2. P. L. Johnson, ed. Remote Sensing in Ecology. University of Georgia Press, 1969.

3. D. Steiner. Time Dimension for Crop Surveys from Space. Photogrammetric Engineering. Vol. XXXVI, 1970, pp. 187-194.

Critical Issues Addressed by Research Cluster

6-A/F-3

CROP IDENTIFICATION

6.2.1.1.2.1
What are the species of food crops and fiber crops?

6.2.1.1.2.2
What are the species of trees?

6.2.1.1.2.3
What is the palatability of forage on grazing and browsing lands?

6.2.1.1.2.6
What is the species of weeds and phreatophytes?

6.2.1.2.1.1
What basic sensor and signature research should be done?

6.2.1.2.2.1
What is the signature of the species of food, fiber and wood crops?

6.2.1.2.2.2
What is the signature of livestock and wild life?

6.2.1.2.2.3
What is the signature of the unique ecological systems?

6.2.2.1.1
What new instrumentation and measurement techniques are needed?

6.2.2.1.2
What is the better form of data collection--statistics or maps?

6.2.2.1.5
How effectively can an astronaut recognize and track a resource?

6.2.2.1.6
How effectively can an astronaut work with a PI on the ground?

6.2.2.1.7
Can large structures, e.g., antennas, be erected in space?

6.2.2.1.8
Can man perform calibration, repairs and maintenance of sensors in space?

6.2.2.1.9
What sensor modification can and should be done in space?

6.2.2.2.1
What models are needed and what should be their inputs?

6.2.2.2.2
What is the better form of data presentation--statistics or maps?

6.2.2.2.3
What is the degree of usefulness of data that has marginal resolution?

6.2.2.2.5
How can man's capabilities be combined in real time analysis, evaluation and decision making?

6.2.2.2.6
How much data reduction should be done in space?

6.2.2.2.7
What is the value of visual observation and verbal comment by the astronaut?

6.2.2.2.8
What are the specific environmental factors affecting the interpretation of sensor data?

6.2.2.3.2
What is the effect of illumination intensity and angle?

6.2.2.3.3
What is the effect of season?

6.2.2.3.4
What is the effect of orbit altitude and slant range?

6.2.2.3.5
What is the effect of orbit inclination?

6.2.2.3.6
What coordination with ground truth sites and aircraft underflights is needed?

6.3.2.2.1.4
What factors have dictated the major crops, the location and amounts of the crops?

6.3.2.2.1.7
What is the present ratio of livestock to world population and the rate of change of this ratio?

6.4.2.2.1.6
How can structures be identified by vegetation?

6.5.1.2.1.4
What are the effects of changes in vegetation patterns on the runoff of precipitation?

TABLE II.—USDA SUPPORTED REMOTE SENSING RESEARCH

[In thousands of dollars]

Agency	1965	1966	1967	1968	1969	1970	1971 (requested)
Agricultural Research Service	50	50	162	257	271	288	783
Forest Service		182	187	257	393	547	547
Total	50	232	349	484	664	835	1,330

AGRICULTURE-FORESTRY MAPPING REQUIREMENTS

Specific application and parameters to be measured	Ground resolution requirements (meters)[1]				Frequency of observation			Map scales required
	50	30	20	<10	Bi-weekly	Monthly	Annually	
Timberline	X						X	1:1,000,000
Waterline	X					X		1:1,000,000
Snowline	X				X			1:1,000,000
Desert line	X						X	1:1,000,000
Grassland-brushland interface		X					X	1:250,000
Brushland-timberland interface		X					X	1:250,000
Grassland-timberland interface		X					X	1:250,000
Bare soil versus vegetated areas and crop species in fields 10 acres or more in size		X				X		1:250,000
Major roads, railroads, and waterways		X					X	1:250,000
Fence lines used to control grazing		X					X	1:250,000
Areas greater than 300 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents		X			X			1:250,000
Crop species in fields 1 acre or more in size			X			X		1:100,000.
Farmsteads			X				X	1:100,000
Areas greater than 150 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents			X		X			1:100,000
Mature orchard trees				X			X	1:50,000
Dominant rain forest trees				X			X	1:50,000
Soil salinity				X		X		1:50,000
Areal extent of water surfaces				X	X			1:50,000
Surface water composition changes and water pollution				X	X			1:50,000
Mapping of planimetric detail in agricultural areas				X			X	1:50,000
On sequential photography (repetitive cover of the same area), it will be possible to tell rates of plant growth, plant succession, probable future planting plans, and probable crop yields				X		X		1:50,000
Density of woody vegetation				X		X		1:50,000
Individual tree counts				X			X	1:50,000
Tree crop diameters				X			X	1:50,000
Species of dominant trees				X			X	1:50,000
Areas in agricultural crops less than 150 feet in diameter that have been damaged by disease, insects, fire, and natural disaster				X				1:50,000
Species of continuous cover crops including weed patches				X	X			1:50,000
Drainage patterns				X		X		1:50,000
Surface soil boundaries				X			X	1:50,000
Soil moisture differences				X	X			1:50,000

[1] If the resolution is poorer than the values given, the task cannot be fulfilled.

Figure 6-A/F-3 Agriculture-Forestry Ground Resolution Requirements. From Hearings before the Committee on Aeronautical and Space Sciences. United States Senate on S3374, NASA Authorization for Fiscal Year 1971, p. 838.

Table I
PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Size and shape of fields associated artifacts	Metric camera panchromatic film	Shape, size, aspect ratio, frequency of linear boundaries	Feet	10/100	10 ft	4000Å	-	±10%	Atmospheric refraction, diffraction, scattering	Cloud type and amount, atmospheric temperature and humidity, surface wind, speed and direction, visibility, solar illumination
2. Color, texture, reflectance of vegetation	Metric camera, color and color IR films	Spectral radiance	watt/m^2-srad-μ	20/400	10-100 ft	4000Å	-	±10%	Atmospheric scattering	
3. Maturity and vigor of vegetation; plowed or harvested fields	Multispectral camera	Spectral radiance	watt/m^2-srad-μ	20/400	100 ft	1μ	-	±10%	Atmoshperic scattering	
4. Temperature differences between adjacent vegetation, soils	Multispectral scanner IR radiometer MW Radiometer	Spectral radiance	watt/m^2-srad-μ	5/10	100-200 ft	Scanner: 1μ Radiometer: 1μ TBD	1°K	±10%	Atmospheric emission	
5. Very narrow band spectral reflectance	UV, Vis, and IR spectrometers	Narrow band spectral radiance	watt/m^2-srad-μ	20/400	100-200 ft	0.03-1μ	-	±1-10%	Atmospheric scattering	
6. Texture of vegetation polarization	Radar imager polarimeter	Amplitude and angle of polarization of backscatter	decibels	-40/10	10-100 ft	-	-	Amplitude ±10%	Radar: multiple signals from same target polarimeter: atmospheric aerosol scattering	

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	2 bore-sighted, 1 black and white and 1 color
2.	Multispectral Camera	X	6-camera assembly black and white
3.	Ten-Band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	0	Possible alternative to No. 3
7.	Radar Altimeter-Scatterometer		
8.	Microwave Scanner Radiometer	X	Current GRE size is too large.
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star-Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-Imaging Camera	0	Support
14.	IR Interferometer-Spectrometer*	X	Use 8- to 13μ band
15.	Multispectral Tracking Telescope	0	Supports radiometer and spectrometer
16.	Selective Chopper Radiometer	X	Add 0. 8- to 2. 5-μ band, expand LWIR to 8 to 13 μ
17.	IR Filter Wedge Spectrometer	X	Increase SWIR band to 0. 7 to 2. 5μ
18.	IR Temperature Sounder*		
19.	Satellite IR Spectrometer*		
20.	Temperature Profile* Radiometer		
21.	Visible Wavelength Polarimeter	X	Modify to 0. 4 to 0. 8μ as a reflectrometer
22.	UV Imager-Spectrometer	X	

*Instrument to provide supportive meteorological data

RESEARCH CLUSTER NO. 6-A/F-3

Table 3 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-A/F-3	-1	Checkout Equipment	All	4			5-C	1/wk	15-45	1			
	-2	Clean Lenses and Sensor Surfaces	All Sensors	5	EVA		21-B	1/wk	1-2 hrs	1			
	-3	Perform Onboard Preparation (Load cameras [3] and cyro preparation of other sensors [6]; input emphemeris data & prepare other optical equipment)	Cameras, Sensors	3			5-B	8-10 Orb/wk	20-40	1			
	-4	Operate Equipment (Experiment [cycling] controls for sequencing scan-photography duration and coverage, operation of optical scan equipment & data processing equipment)		3			5-B	"	20-40	1			
	-5	Visual Operations (Assess image quality using TV monitors & optical scan equipment)		2			10-B	"	20-40				
	-6	Other measurement taking (Correlate other sensor outputs with primary data through voice recording, calibrate interim instruments with ground truth sites)		2			5-B	"	20-40				
	-7	Monitor Equipment Operation (Monitor film advance progress sensor electronics, storage & processing equipment - generally all instruments to assure in-tolerance operations)		1			5-B	"	20-40				
	-8	Adjust Equipment (Calibrate 3 cameras and non-imagery sensors)		1			5-C	"	10-30				

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER–6-A/F-4
CROP VIGOR AND YIELD PREDICTION

RESEARCH CLUSTER SYNOPSIS--AGRICULTURE/FORESTRY

6-A/F-4 Crop Vigor and Yield Prediction

1. Research Objectives

This research cluster is oriented toward evolving a complete data system, from acquisition of remote sensor data to the eventual application by a user to a specific problem. The specific objective is to do research and development in space sensing and measurement techniques for gathering data from which agronomists and economists can prepare statistical information on the size, vigor, and expected yield of crops. The data should indicate the presence of transient stress caused by disease or insect infestation, and stress caused by longer-duration factors, such as drought, shortage of agriculture chemicals, and saline water. The user will perform the statistical compilations and updating, probably using computer data-processing techniques.

An additional objective is to coordinate data gathered from space with historical data gathered from conventional sources. Examples of the latter are the historical cropping practices in an area, its climate, the soil type and fertility, the transportation routes in and out of the area, and the general vigor of agribusiness.

2. Background and Current Status

Improved techniques, including the use of infrared films, special filters, and false-color imagery are being used to appraise insect damage to forests. Fast and accurate surveys over extensive areas now can be made to locate and estimate damaged timber, permitting prompt salvage. Large-scale color aerial photographs and a stratified two-stage probability sampling scheme recently were used to inventory 1.5-million acres of Douglas-fir timber killed by bark beetles. This was done at a cost of only 1/2 cent per acre. Similarly, newly developed remote-sensing techniques and sampling systems were used to evaluate the extent and severity of smog damage to 160,000 acres of forest east of Los Angeles.

Various researchers have experimented with infrared photography of 1:20,000 scale in defining areas of vegetation stress, such as root rot fungus, potato blight, air pollution damage, and similar adverse conditions. Infrared photography has been used at the USDA Station at Weslaco, Texas, to map the extent and severity of physiological drought as a result of saline soil. Most research involves the natural occurrence of a sharp rise in reflectance at 0.7 μ, which appears to be a unique property of living vegetation. Disease and stress decrease the absorption of sunlight by chlorophyl at 0.68 μ, and, consequently, the rise is not as pronounced in vegetation under stress.

University of California researchers have used panchromatic, color, infrared, and color-infrared photography of controlled nursery plots to identify healthy grain and grain infected with black stem rust and other diseases. They found that color photographs at scales as large as 1:500 might be required for accurate estimates of disease severity and resultant yield reduction. The most useful scales ranged between 1:2,000 and 1:10,000.

3. Description of Research

The detection of stress in crops is straightforward and can be done with almost any crop that is visible from space. Determining the cause of the stress and its effect on yield, however, requires additional research in a controlled environment, which is available only at instrumented truth sites. Consequently, the experimental approach will be two-fold: (1) overflights during periods of high sun of growing crops, trees, and range, seeking areas of reduced vigor, and (2) truth-site overflights in cooperation with an agronomist on the site to monitor the surface environment and to control the experiment.

Needed ground truth data include (1) cloud cover, precipitation, wind, temperature, humidity, and aerosol measurements, (2) soil moisture and quality measurements, (3) plant species and vigor, and (4) a standard optical bar pattern.

4. Impact on Spacecraft

The large number of instruments and test sites involved in this research will require close cooperation between scientists in space and on the ground. Precision pointing of the sensors will be accomplished using an observation telescope trained either manually or by programmed computer. Onboard data analysis will include evaluation of data as to quality, contrast, and lack of clouds. The altitude should be as low as practicable, maximum latitude at least 55 degrees, and solar angle 60 degrees.

5. Required Supporting Technology Development

Continued research is needed on the color, texture, spectral reflectance, and backscatter characteristics of vegetation, and their relationship to vigor and yield. The physical and biological laws that influence the reflectance, emittance, and transmittance of radiant energy from plants, soil, and water are not completely understood. The results of research using aircraft should be verified using spacecraft sensors. This undoubtedly will require development of sensors with improved spectral and spatial resolution.

6. References

1. V.R. Schleter, Weidner, and J.D. Kuder. Spectral Properties of Naturally Occurring and Man-Made Materials. National Bureau of Standards Report 8626, December 1964.

2. P.L. Johnson. Remote Sensing in Ecology. University of Georgia Press, 1969.

3. C.L. Wiegand, H.W. Gausman, W.A. Allen, and R.W. Leamer. Interaction of Electromagnetic Energy with Agricultural Crops. Second Annual Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, Houston, Texas, September 1969.

4. D.H. Von Steen, R.W. Leamer, and A.H. Gerbermann. Relationship of Film Optical Density to Yield Indicators. Proceedings of the Sixth International Symposium on Remote Sensing of Environment, Vol. II, Ann Arbor, Michigan, October 1969.

Critical Issues Addressed by Research Cluster

6-A/F-4

CROP VIGOR AND YIELD PREDICTION

6.2.1.1.1.10
What is the location, type and extent of storm damage?

6.2.1.1.2.7
What is the location, type and extent of beneficial and harmful insect infestation of vegetation?

6.2.1.1.2.8
What is the location, type and extent of disease?

6.2.1.1.2.9
What is the location, type and numbers of beneficial and harmful insects in the soil?

6.2.1.1.2.10
What is the location, type and amount of beneficial and harmful organisms in the soil?

6.2.1.1.2.11
What is the age of orchards, vineyards and forests?

6.2.1.1.3.1
What is the fertility of the soil?

6.2.1.1.3.2
What is the salinity of the soil?

6.2.1.1.3.3
What is the moisture content, porosity and permeability of the soil?

6.2.1.1.3.4
What is the organic material content of the soil?

6.2.1.1.3.5
What is the incursion of brackish water in ground and surface water?

6.2.1.2.1.1
What basic sensor and signature research should be done?

6.2.1.2.1.2
What are the changes in acreage of cultivated, forest and wild lands?

6.2.1.2.1.5
What is the potential in board feet of timber lands?

6.2.1.2.1.6
What is the location and extent of erosion, siltation and pollution?

6.2.1.2.2.3
What is the signature of the unique ecological systems?

6.2.1.2.2.4
What is the yield forecasts for major flood, fiber and forage crops?

6.2.1.2.2.5
What is the state of vigor of crops, forests and range?

6.2.1.2.2.6
Where are crops, forests or range under stress?

6.2.1.2.2.7
What is the location and cause of major crop failure?

6.2.1.2.2.8
What is the location and extent of insect or disease infestation?

6.2.1.2.3.4
What is the location and amount of ground water?

6.2.1.2.3.5
What are the nutrient deficiencies of the soil?

6.2.1.2.3.6
What are the organism deficiencies of the soil?

6.2.1.2.3.8
Where are fertilizers being used?

6.2.1.3.1.6
Where should pesticides be used?

6.2.1.3.1.7
Where should conservation practices be improved?

6.2.2.1.1
What new instrumentation and measurement techniques are needed?

6.2.2.1.2
What is the better form of data collection--statistics or maps?

6.2.2.1.6
How effectively can an astronaut work with a PI on the ground?

6.2.2.1.7
Can large structures, e.g., antennas, be erected in space?

6.2.2.1.8
Can man perform calibration, repairs and maintenance of sensors in space?

6.2.2.1.9
What sensor modification can and should be done in space?

6.2.2.2.1
What models are needed and what should be their inputs?

6.2.2.2.2
What is the better form of data presentation--statistics or maps?

6.2.2.2.3
What is the degree of usefulness of data that has marginal resolution?

6.2.2.2.4
What is the cost of data collected from space compared to air and ground?

6.2.2.2.5
How can man's capabilities be combined in real time analysis, evaluation and decision making?

6.2.2.2.6
How much data reduction should be done in space?

6.2.2.2.7
What is the value of visual observation and verbal comment by the astronaut?

6.2.2.2.8
What are the specific environmental factors affecting the interpretation of sensor data?

6.2.2.3.3
What is the effect of season?

6.2.2.3.4
What is the effect of orbit altitude and slant range?

6.2.2.3.5
What is the effect of orbit inclination?

6.2.2.3.6
What coordination with ground truth sites and aircraft underflights is needed?

6.2.3.1.2.2
Where should intensive land management be applied?

6.2.3.1.2.5
Where are dams or irrigation projects needed?

6.2.3.1.2.6
What are the market implications of storm, drought and disease?

6.2.3.1.3.1
Where can tax revenue from resources be increased?

6.2.3.1.3.2
Where can damaged timber or grain be salvaged?

6.2.3.1.3.4
What is the economic worth of the knowledge?

6.2.3.1.3.5
What is the condition and economic value of the grain or wood in a stand?

6.2.3.1.3.6
Where is soil exhaustion or overgrazing occurring?

6.2.3.2.2.5
Where is pollution or overuse endangering the recreational use of water or forest areas?

6.2.3.2.3.5
Where should conservation practices be improved?

6.3.1.2.3.2
What and how are ecological trends being influenced by man's presence and cultural development?

6.3.2.3.4.3
How can the hazards of pesticides and herbicides to the soil, rivers, and standing bodies of water be eliminated or controlled?

6.3.3.3.2.1
What effect is exerted on micro-macro organisms by expanded land use and pollution by man?

6.3.3.3.2.2
What effects do herbicides/insecticides have on natural vegetation and soils?

6.3.3.3.2.3
To what extent do man's modifications of the environment for expansion affect the land and ecologic system?

6.3.3.3.3.1
How are all ecologic systems affected by atmospheric pollution?

6.3.3.3.3.3
What effect is exerted on the air ecologic system by the pollution of water and soil?

6.4.3.3.3.1
What effects would large-scale volcanic eruptions have on plants?

6.4.3.3.3.2
What effects would increased glacial activity have on plants?

6.5.1.2.1.5
What are the location where excessive irrigation is increasing the saline content of soil?

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
					Spatial	Spectral	Temp			
1. Color of vegetation compared to known vigorous vegetation	Metric camera	Spectral radiance	watt/m^2-srad-μ	20/400	100-200 ft	4000Å	-	Depends upon fims available, filters used, shutter speeds, etc. that are not readily quantified	Atmospheric Scattering	For all measurements will need cloud type and amount, temperature, humidity, surface wind, speed and direction, visibility solar illumination For precisely controlled research at truth site also need soil moisture, salinity and chemical composition, presence of agricultural chemicals, etc.
2. Reduced vigor in vegetation	Multispectral camera Multispectral scanner	Reduced chlorophyll reflection and absorption	watt/m^2-srad-μ	20/400	30-100 ft 100-200 ft	0.1μ	-		Atmospheric Scattering	
3. Reduced vigor of vegetation in very narrow spectral bands	Spectrometer/radiometer 0.5-0.8μ 0.8-2.4μ	Reduced chlorophyll absorption and reflection	watt/m^2-srad-μ	20/400	30-100 ft	0.1μ	-	1-10%	Atmospheric Scattering	
4. Presence of agricultural chemicals and of certain soil or water minerals	Spectrometer 2000-4000Å	Chemical and mineral luminesence	watt/m^2-srad-μ	20/400	100 ft	300Å	-	1-10%	Atmospheric Scattering	
5. Temperature differences between moist and dry soil	Radiometer/spectrometer 0.8-2.4μ 7.5-15.5μ	Spectral radiance	watt/m^2-srad-μ	5/10	100-200 ft	1μ	1°K	10%	Atmospheric emission	
6. Polarization of reflected radar signal	Radar imager	Amplitude and angle of polarization of reflected energy	Decibels and degrees	-40/10 db ±90°	100-500 ft	N/A		10%	Atmospheric scattering by aerosols	

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	2 bore-sighted, 1 black and white and 1 color
2.	Multispectral Camera	X	6-camera assembly
3.	Ten-Band Multispectral Scanner	X	
4.	Radar Imager	X	May prove to be infeasible
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	0	Possible alternative to No. 3
7.	Radar Altimeter-Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Startracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-Imaging Camera	0	Support
14.	IR Interferometer-Spectrometer*	X	Use 8 to 15 μ band
15.	Multispectral Tracking Telescope	0	Supports radiometer and spectrometer
16.	Selective Chopper Radiometer	X	0.8 to 2.4 μ, expand LWIR to 7.5 to 15.5 μ
17.	IR Filter Wedge Spectrometer	X	Increase SWIR band to 0.8 to 2.4 μ
18.	IR Temperature Sounder*		
19.	Satellite IR Spectrometer*		
20.	Temperature Profile Radiometer*		
21.	Visible Wavelength Polarimeter	X	Modify to 0.5 to 0.8 μ
22.	UV Imager-Spectrometer	X	Adjustable passband

*Instrument to provide supportive meteorological data

Table 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO 6-A/F-4

RESEARCH CLUSTER NO.		EQUIPMENT [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FREQUENCY	[illegible]	NO. OF CREWMEN	START	DURA- [illegible]	[illegible]
6-A/F-4 -1	Checkout Equipment	All	4	None		5-C	1/wk	15-45	1			
-2	Clean Lenses & Optics	Sensors	5	EVA		21-B	1/wk	1-2 hrs	1			
-3	Perform onboard preparation (loading of metric and multispectral cameras and cyro preparation of scanners, radiometers, spectrometer, data recorder preparation, ephemeris input & weather checking)		3			5-B	10-12 Orb/wk	20-40	1			
-4	Operate Equipment (Sensor [cycling] control, [illegible]ing rates, duration and coverage, optical [scan] monitoring, integral logic [test] equipment. Estimate cloud cover.)		3			5-B	"	20-60	1			
-5	Visual Observations (Determine target state, cloud cover, atmospheric conditions & indices of crop vigor. Record on voice tape.		2			10-B	4-5 Orb/wk	20-40	1			
-6	Other Measurement Taking (Correlate other sensor out with primary data through voice recording or digital input to computer)		2			10-B	10-12 Orb/wk	20-40	1			
-7	Monitor Equipment Operations (Monitor film advance, electronics and cryo systems, storage and for processing operations)		1			5-B	"	20-40	1			
-8	Adjust equipment (calibrate the cameras [focussing]; adjust other sensors [5], particularly in conjunction with results from truth site overflys)		1			5-C	3-4 Orb/wk	20-40	1			

[illegible] of Codes, next page. †X (or other entry) indicates that time of [illegible] be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

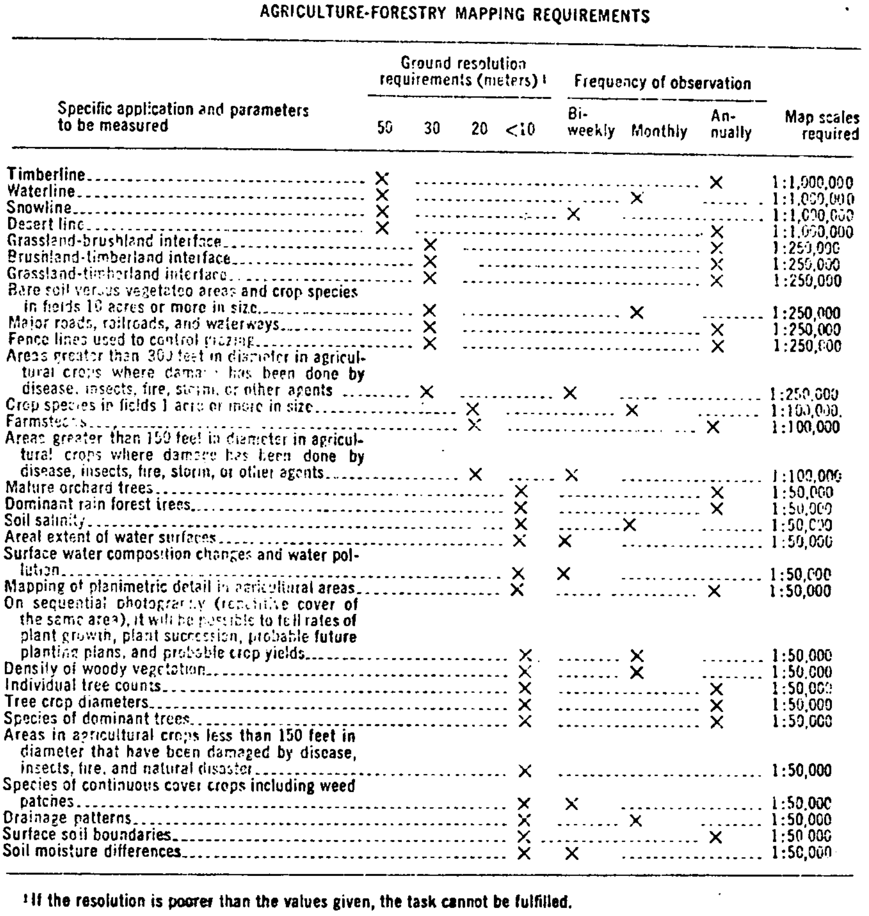
Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.



AGRICULTURE-FORESTRY MAPPING REQUIREMENTS

Specific application and parameters to be measured	Ground resolution requirements (meters)[1]				Frequency of observation			Map scales required
	50	30	20	<10	Bi-weekly	Monthly	Annually	
Timberline	X						X	1:1,000,000
Waterline	X					X		1:1,000,000
Snowline	X				X			1:1,000,000
Desert line	X						X	1:1,000,000
Grassland-brushland interface		X					X	1:250,000
Brushland-timberland interface		X					X	1:250,000
Grassland-timberland interface		X					X	1:250,000
Bare soil versus vegetated areas and crop species in fields 10 acres or more in size		X				X		1:250,000
Major roads, railroads, and waterways		X					X	1:250,000
Fence lines used to control grazing		X					X	1:250,000
Areas greater than 300 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents		X			X			1:250,000
Crop species in fields 1 acre or more in size			X			X		1:100,000
Farmsteads			X				X	1:100,000
Areas greater than 150 feet in diameter in agricultural crops where damage has been done by disease, insects, fire, storm, or other agents			X		X			1:100,000
Mature orchard trees				X			X	1:50,000
Dominant rain forest trees				X			X	1:50,000
Soil salinity				X		X		1:50,000
Areal extent of water surfaces				X	X			1:50,000
Surface water composition changes and water pollution				X	X			1:50,000
Mapping of planimetric detail in agricultural areas				X			X	1:50,000
On sequential photography (repetitive cover of the same area), it will be possible to tell rates of plant growth, plant succession, probable future planting plans, and probable crop yields				X		X		1:50,000
Density of woody vegetation				X		X		1:50,000
Individual tree counts				X			X	1:50,000
Tree crop diameters				X			X	1:50,000
Species of dominant trees				X			X	1:50,000
Areas in agricultural crops less than 150 feet in diameter that have been damaged by disease, insects, fire, and natural disaster				X				1:50,000
Species of continuous cover crops including weed patches				X	X			1:50,000
Drainage patterns				X		X		1:50,000
Surface soil boundaries				X			X	1:50 000
Soil moisture differences				X	X			1:50,000

[1] If the resolution is poorer than the values given, the task cannot be fulfilled.

Figure 6-A/F-4.2. Agriculture-Forestry Ground Resolution Requirements. From Hearings before the Committee on Aeronautical and Space Sciences. United States Senate on S3374, NASA Authorization for Fiscal Year 1971, p. 838.

RESEARCH CLUSTER
NO. 6-A/F-5

RESEARCH CLUSTER SYNOPSIS--AGRICULTURE/FORESTRY

6-A/F-5 Wildfire Detection and Mapping

1. Research Objectives

The objectives of this research cluster are oriented toward evolving a complete wild-fire monitoring system, from acquisition of remote sensor data to the eventual suppression of a particular fire. The initial research will determine the feasibility and advantages of using a manned satellite to detect and monitor incipient and active wild fires in forest, range, and wild lands. Research will be done in mapping existing fires and in communication methods to direct fire fighters quickly to the danger areas. Research also will be done in the remote determination of the flammability index or dryness of forest and range. Data will be gathered on a large scale from space for use in (1) assessing the effectiveness of current fire-detection methods and developing new ones, and (2) managing timber and range lands to minimize fire hazards. The use of in situ sensors to measure soil moisture and other factors related to flammability index, with data readout to a data collection system aboard the spacecraft, will be evaluated.

2. Background and Current Status

The current annual cost of forest fire detection is about $10-million, and the value of timber destroyed annually is about $20-million. Cost of fire control is about $100 million per year. Therefore, suppression of these fires is needed. Effective suppression of major forest fires must be based on the dynamic characteristics of the fire perimeter and its relation to fuels and topography. Smoke and darkness often prevent the collection of this information from fire lookouts or aerial photographs. The Forest Service has developed an airborne remote sensor to produce an image in real-time that depicts the true fire perimeter when visual methods fail. The prototype system has been developed and will be tested in 1970, both in Alaska and in the Northwestern United States.[1]

The results of a Forest Service study on lightning-caused fire detection have shown that certain types of lightning strokes are particularly likely to cause fires, and that these strokes have identifiable electronic signatures. Spheric sensors have been developed that can identify and track storm systems that produce this fire-starting lightning. The equipment has been packaged for aircraft use, and it will be field-tested in Alaska in a cooperative study with the Bureau of Land Management. The technique should be adapted to satellite application.

3. Description of Research

The approach initially will be to extend present fire and lightning surveillance techniques to space. Concurrent surveillance of active fires will be made from lookout towers, airplanes, and satellites; and the results will be compared to evaluate the effectiveness of space altitudes versus low altitudes for fire detection and speed of data processing. Research in detecting smoldering or sleeper fires will be performed in the controlled environment of truth sites.

The sensors basically will detect the hot, active fire areas. Infrared and microwave radiometry will be used for this, and the scanner outputs will be compared with the high-resolution photographs to pinpoint the location of the hot spots. Radar will be used for determining the topography of the fire area through smoke and clouds. Spheric detectors and direction finders will be used to determine areas of possible lightning strikes and subsequent fires (see Meteorology Experiment M-2). The remote data-collection system will gather wind, humidity, and soil moisture data in selected forests or ranges to indicate areas of fire danger.

4. Impact on Spacecraft

Because of the random nature of forest and range fires, especially during a drought period, crew and instrument scheduling will have to be flexible and subject to an on-call status during certain periods. Since the visual detection of smoke on photographs is part of the research, photograph development, radiometer data display, and data analysis facilities are needed. Generally, time is of the essence, and an important impact on the spacecraft will be the requirement for the rapid communication of verbal and electronic data to the ground. To cover the forest areas of North America and Asia requires a maximum latitude of 60 degrees; those of Europe require 70 degrees. An altitude of 230 to 270 mi is satisfactory, except for sleeper fires that require very high spatial resolution obtainable only from lower altitudes.

5. Required Supporting Technology Development

Attaining the research objectives of this cluster requires improved infrared and microwave scanners that have both improved temperature and spatial resolution. A model has to be developed that distinguishes between the microwave emissions from the fire zone and the general background emissions. Concurrent research is needed that investigates the effect of the depth of surface drying, surface texture, and vegetation cover on soil temperature. Communication systems should be developed to transmit information from the space sensor to the fire line within 1 hour.

6. References

1. Hearings before the Committee on Aeronautical and Space Sciences, United States Senate, on Bill S33M4, NASA Authorization for Fiscal Year 1971.

2. S.N. Hirsch. Project Fire Scan: Summary of 5 Years' Progress in Airborne Infrared Fire Detection. Proceedings of the Fifth Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 1968.

3. R.L. Bjornsen. Infrared Mapping of Large Fires. Proceedings of the Fifth Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 1968.

Critical Issues Addressed by Research Cluster

6-A/F-5

WILDFIRE DETECTION AND MAPPING

6.2.1.1.1.11
What is the location, direction and rate of movement of forest fires?

6.2.1.1.2.12
What is the flammability index of forest and range lands?

6.2.1.3.1.3
Where should better timber cutting and logging methods be used?

6.2.1.3.1.4
Where should forest fire detection and fighting methods be improved?

6.2.2.1.1
What new instrumentation and measurement techniques are needed?

6.2.2.1.6
How effectively can an astronaut work with a PI on the ground?

6.2.2.1.7
Can large structures, e.g., antennas, be erected in space?

6.2.2.1.8
Can man perform calibration, repairs and maintenance of sensors in space?

6.2.2.1.9
What sensor modification can and should be done in space?

6.2.2.2.5
How can man's capabilities be combined in real time analysis, evaluation and decision making?

6.2.2.2.6
How much data reduction should be done in space?

6.2.2.2.7
What is the value of visual observation and verbal comment by the astronaut?

6.2.2.2.8
What are the specific environmental factors affecting the interpretation of sensor data?

6.2.2.3.3
What is the effect of season?

6.2.2.3.4
What is the effect of orbit altitude and slant range?

6.2.2.3.5
What is the effect of orbit inclination?

6.2.3.2.1.3
What international cooperation in data acquisition and application is needed?

6.3.1.1.1.3.1
How can geography be applied to the utilization or remote stands of timber?

6.3.1.1.1.3.2
How can the location and configuration of remote timberlands be categorized, indexed and displayed in map form?

6.3.1.1.1.3.3
How may geography and cartography be applied to more efficient monitoring and management of timberlands?

6.3.1.2.1.1
How can the natural distribution of the Earth's surface features be related to the occurrence of natural destructive forces?

6.3.1.2.1.4
How can disaster avoidance and management procedures be identified and initiated?

6.3.2.3.4.2
How can vast forest regions be continuously monitored for fire and how can protection against fire be advanced and controlled?

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Smoke pall or plume	Metric camera color film	Color of smoke	N.A	-	15 ft	-	-	20°	Atmospheric scattering	Cloud type and amount, temperature humidity, surface wind speed and direction, visibility.
2. Vegetation stress due to drought	Multispectral camera Multispectral scanner	Chlorophyll reflection and absorption	watt/m^2-srad-μ	40/100	20-200 ft	1μ	-	20°	Atmospheric scattering	
3. Active fires	MW Scanning radiometer	Spectral radiance of fire	watt/m^2-srad-μ	hot spot temperature will be 100-400°F above background	200 ft		10-40°K	-10%	Smoke obscuration	
4. Sleeper or small fires	IR scanning radiometer	Spectral radiance of fire	watt/m^2-srad-μ	See Sec. 1.7	20-100 ft	-	2-200°K	-10%	Atmospheric and terrain emission	
5. Smoke pall or plume	Tracking telescope	Visual detection of smoke	-	-	75 ft	-	-	-	Atmospheric scattering and reflection	
6. Sferics	Receivers in UHF and MW frequencies	Radio noise generated within strongly convective clouds	decibels	See meterology experiment 6-M-2				-	Extraneous spherics	

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	2 aligned for stereo
2.	Multispectral Camera	X	6-camera assembly
3.	Ten-band Multispectral Scanner	X	
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter-Scatterometer		
8.	Microwave Scanner Radiometer	X	Current GRE is too large
9.	Sferic Detector, UHF	X	
10.	Data Collection System	X	
11.	Star-Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-Imaging Camera	X	
14.	IR Interferometer-Spectrometer**	0*	Support for flamability index research
15.	Multispectral Tracking Telescope	X	
16.	Selective Chopper Radiometer	0*	Support for flamability index research
17.	IR Filter Wedge Spectrometer	X	All transmission bands between 1 and 13 μ
18.	IR Temperature Sounder**	0*	Support for flamability index research
19.	Satellite IR Spectrometer**		
20.	Temperature Profile Radiometer**	0*	Support for flamability index research
21.	Visible Wavelength Polarimeter		
22.	UV Imager-Spectrometer		

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*All four sensors not necessary. Use the one found best by meteorology experiments in atmosphere sounding.
**Instrument to provide supportive meteorological data.

Table 3 —

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO 6-A/F-5

RESEARCH CLUSTER NO.	[illegible]	EQUIPMENT [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NO. OF [illegible]	[illegible]	[illegible]	[illegible]
6-A/F-5												
-1	Checkout Equipment	All	4	None		5-C	1/wk	15-45	1			
-2	Clean Lenses & Optical Surfaces	Sensors	5			21-B	1/wk	1-2 hrs	1			
-3	Prepare Equipment (Load & focus cameras, chilldown scanning sensors, prepare for optical tracking, input ephemeris data)					5-B	3-5 Orb/wk	20-40	1			
-4	Operate Equipment (Sensor cycling controls, initiate sequencing & durations for data taking. Operate tracking telescope during range & forest overfly, monitor target weather state, operate sensor test equipment)		3			5-B	5-7 Orb/wk	20-50	1			
-5	Visual Observations (visual & optically aided technique for cloud cover measurements & displayed IR moisture measurement techniques)		2			9-B	5-7 Orb/wk	20-40	1			
-6	Other measurement taking (displays of raw sensor info such as ground temperature/moisture & storm activity may be either input to mainline data or voice transmitted to ground stations)		2			5-B	5-7 Orb/wk	20-40	1			
-7	Monitor equipment (sensor-associated electronics, film advance, cryo system and data taking system operations)					5-B	2-3 Orb/wk	20-40	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-G/C-1
PHOTOGRAPHIC AND MULTISENSOR MAPPING

RESEARCH CLUSTER SYNOPSIS–EARTH OBSERVATIONS

6-G/C-1 Photographic and Multisensor Mapping

1. Research Objectives

This research cluster will attempt to provide a precise and accurate geometric description of the Earth's surface. The types of probes to be employed and the signatures obtained are as recommended in L13-9852. Through the use of quantitative photogrammetric (and other) cameras and sensors, sufficient accuracy can be obtained at the proposed altitudes to develop a Unified World Datum (UWD) accurate to 10 meters on land in an earth-centered coordinate system. This geodetic control can be extended into continental-shelf and oceanic areas with the same degree of accuracy. Photographic mapping will also permit acquisition of cartographic data with sufficient geometric integrity to locate Earth satellite tracking stations within five meters with respect to each other on the UWD.

One of the needs to be fulfilled by both photographic and multisensor mapping is information on the optimum frequency of observation. Since synoptic imagery is one of the more interesting and possibly the highest potential fallout of an Earth observation program, we need to know how often to monitor cloud patterns and by what sensors, or how often to examine volcanic provinces and at what temperature sensitivities, or how rapidly snow-melt patterns change and whether or not they are meaningful. Finally, the research cluster has the goal of determining how remote sensors function under variable Earth and space environmental conditions.

2. Background and Current Status

All manned space programs (both past and furture) have involved or will involve experiments relevant to geography and cartography. The synoptic terrain photography obtained on the Gemini missions permitted updating of geographical maps in the poorly mapped areas of Chad, for example. Germane to this research cluster was Apollo 9 Experiment S-65 (March, 1969), which proved the feasibility of using vertical space photographs as photobases for standard 1:250,000 topographic maps. No photomosaic can possibly produce the fidelity of tonal changes obtainable from photographs taken from space, especially when the camera is manipulated by an experienced observer.

An evolution of high altitude to space photography has shown that for certain purposes or classes of observables, a single photograph or image can highlight a structure, an event, or a phenomenon that cannot be duplicated by any other means. Prototype experiments conducted by NASA in cooperation with Governmental Departments of the Interior, Commerce, Agriculture, and Defense provide numerous examples of superior spacecraft imagery. The symbiosis of the imagery from the Earth Resources Survey Program with that of EROS or TIROS, for example, will not only permit improved interpretation of their data by ERTS-A in 1972, but also focus ERTS on key areas for additional multisensor scrutiny.

3. Description of Research

Three instruments that apply to this research cluster are the metric and the multispectral cameras, and the 10-band multispectral scanner. These instruments, providing black and white and color imagery at high resolution, will record objects and phenomena necessary to prepare modern and thematic maps for geographers, geophysicists, geologists, and civil engineers. These maps, in turn, will permit intelligent research and development in the areas of urbanization, transportation, resource exploitation, natural hazard prediction, and agriculture.

Currently, less than 20 percent of the world is mapped at scales suitable for engineering analysis, Earth resources exploitation, or land planning. Even with the Gemini data, inaccessible areas of Egypt and the Sudan were shown to have potential chromite deposits. Presumably, other inaccessible areas of the world, such as the Amazon Basin or the Andean Cordillera, may show areas of economic potential that will spur access routes and the internal economic development of the host nation.

The camera geometric precision (0.02 to 0.05 percent) and multispectral sensitivty (about 10 percent) is predicted on an orbital altitude of less than 200 nautical miles. Location precision is a function of photograph/map scale and system resolution. Certain experimental activities may be governed by seasonal characteristics. Ice flow patterns, for example, can be determined by observing at low sun angle and comparing periods of freeze. Some areas that are usually under clouds, such as the south end of Isabela Island in the Galapagos, should be monitored to permit phtotgraphing during minimum cloud cover so that topographic maps of this part of the world can be completed.

An optimum sun angle for best viewing is mandatory. Much geographical mapping requires a sun angle of greater than 30 degrees. For certain specific geological structures, however, a low sun angle of less than 30 degrees is required to enhance such details as fold structures, low domes, and peak profile shadows. All of these variables relate to the ground resolution. With the sensors proposed and a target location accuracy of 0.5 to 1.0 nautical mile, resolutions ranging from approximately 5 to 300 feet will be required for the phenomena sought.

To calibrate and better interpret high altitude photography and multispectral scanner data, ground truth sites have been selected in the U.S. For example, the Southern Calibornia test site from the Salton Sea to the Pacific shoreline will have a multitude of geographic and geological parameters that will facilitate meaningful calibration and interpretation of data obtained elsewhere. Ground instrumentation at these truth sites logically includes climatic data. As in all experiments, interferences will be continuously monitored and reduced. These interferences include film instability, atmospheric turbulence, aerosols, and electronic detector noise.

4. Impact on Spacecraft

Since the photographic and multisensor coverage of the Earth is for multiple user application, onboard data processing is required to prepare for retakes or to assure optimum sensor use on later overflights. This means that the crew should be capable of determining what constitutes a good picture and how a picture might be improved. While all this activity is going on, spacecraft altitude must be recorded and maintained to supplement the metric data obtained. Crew members may also be required to annotate targeted features if a phenomenon is transient.

Possibly the most important requirement on the spacecraft is that of performing specific sensor manipulation to obtain the optimum observation angle at the most favorable sun angle. These operations will require careful programming of spacecraft activities to avoid errors. Interface of duties must exist between the general support technician, the experiment support engineer, the observer-experimenter, and the flight control crewman.

The crew must be aware of timing and power requirements. The metric camera, for example, operating at 504 watts, can consume peak loads of 784 watts. The multispectral camera operates at 700 eatts with a peak demand of 1,120 watts. The 10-band multispectral scanner has a much lower power requirement (190 watts peak) than either the metric or multispectral camera. Moreover, allowances must be made for the 30-second warmup period when approaching possible transient targets. A temperature greater than 40°C will also deteriorate the film of both the metric and multispectral cameras. Real-time tradeoffs must be made by the crewman in the event of power or time restrictions.

All of the following functions of the crew will relate to a successful experiment in this and other research clusters: onboard preparation of targeted sites, equipment operation and sequencing, visual observation by telescope and TV, coordination of ground truth data with orbital data, camera and sensor monitoring (including data processing), and equipment adjustment for optimum readout.

5. Required Supporting Technology Development

In almost all areas of remote sensing, the equipment requires further development. The metric camera, for example, must be space-qualified, in contrast to the multispectral camera, which was flown on the Apollo 9 mission. However, the vibration and shock limitations of the multispectral camera have yet to be determined. Most of the development work in this research cluster has to be done on the multispectral scanner, especially from the standpoint of cryogenics; band 10 requires a cryostat of less than 100°K.

In addition to ground truth sites, ground calibration sites of a special nature are required. To estimate ground resolution in various types of terrain, orbiting runs should be made from aircraft to determine what can be quantitatively observed and recorded at various sun angles of the Earth's surface relief and roughness. A possible calibration site for this test is Pisgah Crater, California, where four test squares measuring 1,000 ft on a side have been contoured to a 12 inch interval.

6. References

1. G. A. McCue and J. Green. Roughness of Simulated Planetary Terrain: Photogrammetric-Engineering, Vol. 36, pp. 273-279; 1970.

RESEARCH CLUSTER
NO. 6-G/C-1

Critical Issues Addressed by Research Cluster

6-G/C-1

PHOTOGRAPHIC AND MULTISENSOR MAPPING

6.3.1.1.1.1.1
How can the natural water supplies of remote wildlands, marshes, and other bird/animal sanctuaries be monitored?

6.3.1.1.1.1.2
How can natural snow and watershed capacities be increased and the runoff controlled and monitored?

6.3.1.1.1.1.3
How can topography be used more effectively for the generation of electrical power and control of silting of major dam and reservior systems?

6.3.1.1.1.1.4
How can potential irrigation water be located and possibly transferred to remote and reclaimed land areas?

6.3.1.1.1.1.5
How can the distribution and rate of use of water supplies be monitored and presented in map form?

6.3.1.1.1.2.1
What aspects of geography and cartography may be applied to the analyses of remote lands for food resources applications?

6.3.1.1.1.2.2
How may remote lands be located; categorized, indexed, and displayed in map form?

6.3.1.1.1.2.3
How can land in the higher lattitudes be used more effectively for food reserves?

6.3.1.1.1.3.1
How can geography be applied to the utilization or remote stands of timber?

6.3.1.1.1.3.2
How can the location and configuration of remote timberlands be categorized, indexed and displayed in map form?

6.3.1.1.1.3.3
How may geography and cartography be applied to more efficient monitoring and management of timberlands?

6.3.1.1.2.1.1
How can urban land areas be more effectively used for airport and maintenance facilities?

6.3.1.1.2.1.4
Can air terminals be more efficiently or remotely located and satisfy the demands of the business society?

6.3.1.1.2.1.5
How can access and egress be more effectively implemented in the design of internal urban terminals?

6.3.1.1.2.2.1
What aspects of geography/cartography can be applied to more efficient routing of existing and future railroads?

6.3.1.1.2.2.3
How can monitoring of population movement and land use be used effectively for the location of railroad connections?

6.3.1.1.2.2.4
How may the development of railroad demands be monitored and portrayed?

6.3.1.1.2.3.1
What aspects of geography/cartography can be applied to more efficient routing of existing and future highways and internal urban accesses?

6.3.1.1.2.3.2
How can geography be applied to the location of road materials and how may the sources be indexed and displayed?

6.3.1.1.2.3.4
How can the development of internal urban roads be efficiently monitored?

6.3.1.1.2.4.2
How might inland short water bodies be adapted to air terminals?

6.3.1.1.2.4.3
How can natural river systems be more expeditiously exploited as transport media, and how can these systems be effectively monitored, managed and controlled?

6.3.1.1.2.5.1.1
How can pipelines be more efficiently routed and dependent upon local surface gradients?

6.3.1.1.2.5.2.4
How can power, phone, and other lines be eliminated from the urban environment?

6.3.1.1.3.1.1
What significant impact does expanding urbanization have on the condemnation of usable agriculture and forest lands?

6.3.1.1.3.1.2
How significant is the cement to land ratio of an expanding community on the erosion cycle and how might it be controlled?

6.3.1.1.3.1.4
How may expanding communities be most advantageously monitored?

6.3.1.1.3.1.5
How can optimum community configurations be predicted?

6.3.1.1.3.3.1
What aspects of geography can be applied to the selection of potentially usable land areas?

6.3.1.1.3.3.2
How can unused lands be located, categorized, and indexed for specific uses?

6.3.1.1.3.3.3
How can cartographic techniques best be applied to all phases of land use from urban development to internationally controlled or monitored lands?

6.3.1.2.1.1
How can the natural distribution of the Earth's surface features be related to the occurrence of natural destructive forces?

6.3.1.2.1.2
What aspects of river dynamics can be explored to aid in the effective control of flood condition discharge?

6.3.1.2.2.1
How can internal urban cultural and recreational facilities be created in rapidly expanding/deteriorating population centers?

6.3.1.2.2.3
How can geographic relations be more effectively used for recreational pursuits?

6.3.1.2.3.3
What is the rate of environmental change and how can this be measured meaningfully?

6.3.1.2.3.4
How can population and traffic statistics be used for cultural studies?

6.3.1.2.4.1
How can the problem of population density be controlled and/or modified in urban areas?

6.3.1.2.4.3
How can the world food supply be effectively distributed to areas of need and how can the distribution be more efficiently managed in heavily populated urban areas?

6.3.1.2.4.4
How can the migration and distribution of urban population be monitored?

6.3.1.3.1.1
How can the major geographic land areas of the world be identified, classified for use?

6.3.1.3.1.2
How can the most appropriate use of specific land areas be determined?

6.3.1.3.4.1
How can the mapping of dynamic features and processes be accomplished? What is the time frame?

6.3.1.3.4.2
What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.:

Land use
Crop-timber
Hydrologic
Political
Population migration
Urban development
Economic
Climatic
Physical/chemical
Cultural

6.3.1.3.4.3
How can maps displaying time variant entities be effectively produced and distributed for use?

6.3.2.1.1.1
How was the Earth's surface topography developed?

6.3.2.1.1.2
What Earth features prompted settlement of population groups?

6.3.2.2.1.1
What is the ratio of unused to used land and the rate of change of this ratio?

6.3.2.2.2.6
To what extent and to what scales is the physical surface of man's environment depicted?

6.3.2.2.3.1
What is the ratio of expansion of transportation facilities to the expanding population, (a) roads, (b) railroads, (c) waterways, (d) airlines/airports?

6.3.2.2.3.2
What influence of community development is imposed by each mode of transportation?

6.3.2.2.3.3
What relation exists between population movement and transportation facilities?

6.3.2.2.3.4
What is the pattern of population migration and its rate of change?

6.3.2.2.3.5
What is the rate of development in new communities?

6.3.2.2.3.6
What is the rate of expansion of existing populations, (a) countries, (b) states, (c) counties, (d) cities, (e) towns?

6.3.2.2.3.9
What are the cement/soil/cultivation ratios of major urban developments?

6.3.2.3.1.1
How do the various modes of transportation effect physical changes on the environment and population movement?

6.3.2.3.3.3
How can waste disposal in large populated centers be significantly reduced or how can the rate of disposal be increased?

6.3.3.2.2.5
How can urban development be related to available water supplies?

6.3.3.2.3.1
How will be expanding population affect the decisions on tillable versus urban development land?

6.3.3.3.1.2
What effect do river/dam systems have on the biosphere?

6.4.2.2.3.2
What are the positions of land masses, polar ice sheets, and ocean basins?

6.4.2.2.4.3
What evidence is there that the continents are drifting?

6.4.2.2.4.4
What evidence is there of sea floor spreading?

6.4.2.3.2.5
What is the relative rate of drift of the continents?

6.4.2.3.2.7
What are the rates of relative movements of the Earth's major fault systems?

6.4.2.3.2.9
What are the rates of sea floor spreading?

6.5.1.1.3.1
What is the topography, geologic structure, and soil cover in underdeveloped regions of the world?

6.5.1.2.1.1
How can land-use mapping and classification be improved?

6.5.2.2.1.1
What is the effect of cultural changes of the surface of the Earth on the elements of the hydrologic cycle?

Table 1

EARTH OBSERVATIONS -GEOGRAPHY AND CARTOGRAPHY PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation			Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Physical and cultural features of the Earth's surface.	Metric camera (panchromatic, color, false color)	Patterns, areal and linear delineation and extent distributions, elevations	Feet and nmi	5 ft to 10% of nmi	20 to 200 ft for mapping 5-100 ft for geographic applications Elevations to approx 150 ft using stereo			0.02 to 0.05%	Film stability, atmosphere	
	Multispectral camera (pan, IR, color, false color)	Spectral radiance of scene	w/m^2-strdn-μ	20-400	30-200 ft	0.1μ		±10% sensitometry	Atmosphere	
	Multispectral scanner	Spectral radiance of scene	w/m^2-strdn-μ	20-400	Approx 100 ft	0.1μ in the visible; 0.1-0.2μ in near IR, 2μ in IR window region	1C° (relative) in IR window region	±5%	Detector noise, atmosphere	

Table 2

EARTH OBSERVATIONS—GEOGRAPHY AND CARTOGRAPHY INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10-band Multispectral Scanner	X	
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO 6-G/C-1

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-G/C-1	-1	Checkout Equipment		4			5-C	1/wk	15-45	1		1 yr.	
	-2	Clean Lenses		3			21-B	1/wk	1-2 hrs	1		"	
	-3	Prepare Equipment Checkout three sensors, load as required; review map/pictorial data		3			5-C	5-7 orb/wk	20-30	1		"	
	-4	Operate Equipment Sensor selection and cycling controls, initiate sequencing plan photographic frame rate and degree of overlap, operate scanoptics and monitor electronic operation of all sensor support equipment		3			5-B	" "	" "	1		"	
	-5	Visual Operations Telescope and TV scan of targets (weather conditions) voice record of prevailing ground conditions		2			14-B	" "	" "	1		"	
	-6	Other Measurements Ground truth - orbital data taking closely coordinated in time visual scan/TV frame to map comparisons		2			14-B	" "	" "	1		"	
	-7	Monitor Equipment Camera operation, ancillary electronics, film storage/interim data processing; cryo system operations and communicating in real-time with ground		1			14-B	" "	" "	1		"	
	-8	Adjust Equipment Instrument calibration, boresighting and internal adjustments		1			5-C	" "	10-20	1		"	

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew members cannot be shared with any other task.

Table

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-G-1
ROCK AND SOIL TYPE IDENTIFICATION

RESEARCH CLUSTER SYNOPSIS—EARTH OBSERVATIONS

6-G-1 Rock and Soil Type Identification

1. Research Objectives
Systematic mapping can provide a better understanding of type, location, and distribution of geologic resources. A basic goal of this research cluster is to determine the performance of sensors in identifying these resources and in establishing signature recognition criteria (Document L 13-9852). The first step in such a program, which ultimately requires a multispectral record of Earth features to at least a 300-foot ground resolution, must be photographic mapping. Providing such coverage of North and South America was defined as the primary goal of the geological panel on the NASA Summer Study on Space Applications. The data sought are soil type (as related to geological province), rock units, and structural realtionships. When these are displayed in relationship to one another, significant interpretations can be made of the distribution of resources. The product is the geological map, which also serves as the planning document for persons involved in solving urbanization and transportation problems, persons seeking areas of high heat flow as geothermal sites, persons seeking hydrothermal anomalies as a guide to ore deposits, persons inventory potential dam sites, and persons concerned with defining new oil- and gas-bearing structures.

Synoptic coverage will permit analysis of changes that have he heretofore been unobtainable on a systematic basis. Possibly, theories on ore genesis can be documented by a better identification of the structural control of metallogenic provinces or by the association of oil fields with areas of critical fracture intensity and frequency. With sophisticated laser altimetry, movement of continental masses can conceivably be detected from orbit.

Documentation of spectral signatures of identified rock and soil types, with varying degrees of water saturation, grain size, and known thermal regimen is planned at selected ground truth sizes.

2. Background and Current Status
It is difficult to define the current status of analysis of landforms by image processing because of the rapid rate of change in today's investigations. Fourier transforms of optical imagery may soon permit quantitative analysis of directions, spacing, and symmetries of mappable features. For example, the drainage patterns of Pelly Bay in Canada appear to have a strong NW-SE transform, which is not apparent on the aerial photograph. Electronic processing of satellite imagery can facilitate the statistical analysis of landforms, such as slope analysis, on a far more systematic and quantitative basis than in the past.

In other words, not only are the raw data provided by multispectral photography and imagery of value, but current trends indicate that derivative data by electronic processing and Fourier transforms may provide a second generation of useful data. When this second generation of data can be displayed on a computer within a few seconds after the raw data are fed in, the geological engineer, the photogrammetrist, or the economic geologist may realize an academic windfall.

The data obtained in proposed terrestrial orbiting programs relate to long-range needs in the space program, since what we can interpret from altitude on theEarth can likewise apply to Mars or Ganymede. Earth observations of mappable features may render analogs suitable for understanding the origin of planetary features. For example, we need to quantify morphological features of caldera or impact craters by means of Earth observations so that we will be able to speak intelligently of these features on other planets.

3. Description of Research

Six instruments are prescribed for this research cluster: the metric camera, multiband camera, multispectral scanner, infrared thermal imagery, side-look radar, and microwave radiometer data are to be displayed on a 9- by 9-9-inch film of scale 1:700000; The infrared spectrometer data will be on computer printout and will have a relative temperature resolution of < 1° F, the same as the microwave radiometer.

With the precisions noted in the experiment group description, all of these instruments, either singly or in combination, will be used at certain times and under certain target conditions to quantitatively define the area of interest. In areas of exposed rock, surveys can be made with stereoscopic coverage to best measure the dip and strike of strata, the inclination of folds, the plunge of anticlines, and the length of lineaments. Side-look radar (SLR) can be used to map heavily foliated or cloud-covered regions. This means that areas directly under the spacecraft must be surveyed on successive passes by SLR for correlation with data obtained previously by vertical imagery.

Ground truth sites for combination vertical imagery with subsequent oblique coverage include theheavily forested Cascade range where there are excellent examples of rifting in areas of geothermal highs. In this case, temperature sensing devices will be required. As an example, Paulina Lake of the Newberry caldera is colder than East Lake in the same caldera because of fumarolic and hot-spring activity on the eastern part of the caldera floor. Details of this nature can be determined at ground truth sites, with obvious extrapolations to unknown areas.

The experiment also will deal with the definition of stratigraphic boundaries, especially in petroliferous provinces. For conservation projects, coverage and analysis will be made of water runoff and drainage patterns. Areas in Puerto Rico have been selected as truth sites for this mission. For a study of soil types, much synoptic data have been accumulated in the Phoenix and El Centro areas (Arizona and California) by Gemini- and aircraft-borne sensors. Soil mineralogy and crop type in these localities may be correlated as a function of irrigation history, climatic conditions, and other environmental factors.

4. Impact on Spacecraft

Much of the information to be obtained in this research will depend on the weather. The predominant noise source for the metric camera, multispectral camera, radar imager, and microwave radiometer is the atmosphere. Therefore, one of the significant crew activities will be the careful planning of target sites, on the basis of telescopic observation and weather data relayed to the spacecraft. In the event of marginal cloud cover over a selected target, the infrared interferometer/ spectrometer might be used in preference to the multispectral camera even if the spectral ranges are not the same. A highly qualified observer and experimenter is therefore required to choose the best instruments to maximize the geoscientific return from each target sensed. Coordinated data taking will be required. Spectral imaging of a terrain segment just after a heavy rainfall may be important for interpreting microwave radiometry, for example. Knowledge of ground conditions at the time of survey must be relayed to the crew so that they can properly coordinate the right equipment.

For this reason, the crew should consist of a ground support technician, experiment support engineer, an observer-experimenter, and a flight control crewman. These men will perform a great deal of onboard preparation of the equipment, inasmuch as the metric camera, multispectral scanner, and radar must have a warmup period—the radar requiring 30 minutes—which might be critical when approaching transient targets. Certain bands of the multispectral scanner and the infrared spectrometer must be cooled. The spacecraft must also be designed to withstand a possible peak power load, if all instruments are operating, of 4 to 6 kw.

5. Required Supporting Technology Development

A continuing laboratory program supported by aircraft surveys is recommended to improve the interpretation of data obtained through all of the instruments used in this research cluster. Very little is published on color degradation as a function of altitude. For certain of the truth sites, color photography taken at various altitudes should be available when the spacecraft orbits the target. Two examples can be cited. The first is over areas of hydrothermal alteration, which can be used as guides to ore mineralization. If color or multispectral photography is washed out at critical wavelengths at high altitudes or at certain threshold humidities viewed from the spacecraft, the object of the experiment is lost. As another example, IR false-color photography sensitive to algae scum in lakes, for instance, is clearly seen at aircraft altitudes. Determining the degree that colors are degraded at spacecraft altitudes should lead to improved data interpretation.

Research is also needed in the area of side-look radar (SLR). Aircraft SLR will probably be more useful than spacecraft SLR for certain geological problems involving structures under heavy foilage. Paradoxically, supporting research in SLR from aircraft can be carried out to limit the use of SLR from spacecraft, thereby giving premium time to the operation of other spacecraft instruments that are better suited to high-altitude performance. Aircraft can also carry sensors that cannot be flown in space.

Critical Issues Addressed by Research Cluster

6-G-1

ROCK AND SOIL TYPE IDENTIFICATION

6.2.1.1.3.1
What is the fertility of the soil ?

6.2.1.1.3.2
What is the salinity of the soil ?

6.2.1.1.3.6
What is the location and extent of soil types ?

6.2.1.2.3.1
What is the signature of brackish water or soil ?

6.2.1.2.3.8
Where are fertilizers being used ?

6.2.3.1.3.6
Where is soil exhaustion or overgrazing occurring ?

6.3.2.1.1.1
How was the Earth's surface topography developed ?

6.3.2.1.1.2
What Earth features prompted settlement of population groups ?

6.3.2.2.1.2
What percentage of unused lands is considered usable for cultivation ?

6.4.1.1.1.1
How can specific rock/soil types be detected, identified, classified, and put to productive use ?

6.4.1.1.2.2
How can areas of thick detrital-fill be detected and evaluated ?

6.4.2.2.1.6
How can structures be identified by vegetation ?

6.4.2.3.3.1
What are the physical characteristics of the Earth's crust and mantle ?

6.5.1.1.3.1
What is the topography, geologic structure, and soil cover in underdeveloped regions of the world ?

Table 1

RESEARCH CLUSTER
NO. 6-G-1

EARTH OBSERVATIONS–GEOLOGY
PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
					Spatial	Spectral	Temp			
1. Rock and Soil Types, Structural Geology	Metric Camera (color and false color film)	Spectral Radiance	w/m^2-st-μ	20-400	100 ft	4 w/m^2-st-μ		±10% (Sensitometry)	Atmosphere	Spectral Radiance (visible and near IR)
2. Rock and Soil Types, Structural Geology	Multispectral Camera	Spectral Radiance	w/m^2-st-μ	20-400	100 ft	4 w/m^2-st-μ		±10% (Sensitometry)	Atmosphere	Spectral Radiance (visible and near IR)
3. Spectral Signatures of Rocks and Soil	10-Band Multispectral Scanner	Spectral Radiance (visible and IR)	w/m^2-st-μ	20-400 (vis) 2-10 (IR)	300 ft (vis) 600 ft (IR		1°K	±5% Radiometry	Detector Noise (Background and Internal)	Spectral Radiance (visible and thermal IR ranges of the spectrum)
4. Structural Geology (Lineaments, faults, folds)	Radar Imager	Slant Range of objects on terrain	nmi	0 to 40	200 ft			50 ft	Atmosphere	N/A
5. Soil Types and Moisture Content	Microwave Scanner Radiometer	Radiometric Brightness Temperature	K°	130 to 280	1 to 2 nmi		1°K	1°K	Preamp Noise, Atmosphere	Radiometric Brightness Temperature
6. Spectral Signatures of Rock Types	IR Interferometer Spectrometer	Spectral Radiance (8-13μ)	w/m^2-st-μ	2 to 10	100 to 300 ft	0.003μ		±5% Radiometry	Detector Noise (Background and Internal)	Spectral Radiance (8-13μ)

Table 2

EARTH OBSERVATIONS—GEOLOGY
INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer	X	
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO 6-G-1

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-G-1	-1	Checkout Equipment		4			5-C	8-9 Orbits/wk	15-45	1			
	-2	Clean Optical Surfaces		3	EVA		21-B	1/wk	1-2 hrs.	1			
	-3	Perform Onboard Preparation - Load cameras, warmup scanners, chilldown IR instruments, flight plan referencing, precision determination of spacecraft/attitude for input ephemeris.		3			5-B	8-10 Orbits/wk	30-50	1			
	-4	Operate Equipment - Operate scan optics including magnification & filtering controls, ancillary electronics and slewing controls, pointing & tracking gimballed instruments toward target sights.		3			11a	"	30-50	1			
	-5	Visual Observations - Orient sensors and coordinated sensor pointing to specific area.		2			11-A	"		1			
	-6	Monitor Equipment - Monitor data taking, camera operation, & support electronics.		1			5-C	"	20-50	1			
	-7	Adjust Equipment - Internal calibrations - camera focusing & boresighting, calibrations with ground truth site data.		1			5-C	"	1-2 hr	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER
NO. 6-G-2

RESEARCH CLUSTER SYNOPSIS—EARTH OBSERVATIONS

6-G-2 Use of the Earth's Crust to Store and Condition Commodities or Waste

1. Research Objectives

The Earth Orbital Experiment Program is directed in general to evolving a complete data system from the acquisition of remote sensing data to its application by a user to solve a specific problem. To get rid of, or to store waste, is this kind of a problem. The immediate goal of the research cluster is to use spacecraft altitudes in identifying regions that are remote from population centers and might be suitable for storage or disposal of waste materials. Recognition of drainage patterns, karst topography, and soil types would aid in solving some long-range waste disposal problems. On a shorter time scale, areas in populated portions of the world require scanning by remote sensors to better plan for urbanization growth, landfill sites, and transportation routes (possibly over potential waste disposal areas). Recognition of any geological criteria such as salt domes near large waste-producing centers would also be involved. Other subsurface storage sites, such as gravel lenses under abandoned river oxbows might also be inspected by drill after detection from orbit.

We do not know how many gaps in our knowledge will be filled by a study of this type. In sophisticated nations, a great deal of data already exists on potential waste disposal sites near industrial or urban centers. Most of the salt domes in the Gulf Coast area for example are fairly well known. Possibly the best defined objective in this study would be the overview obtained from the United States, where much control data already exist, compared with underdeveloped nations, where waste-disposal problems have yet to arise.

2. Background and Current Status

Contamination of the water supply is a serious problem facing any civilized community. In the United States, serious efforts are being made to contain the radioactive and poisonous chemicals released to the surface of the land by encapsulating the waste product or, in the case of sewage, to render it harmless. In any program relating to the storage of harmful materials, therefore, a working knowledge of the local hydrology or regional hydrology is required. Knowledge of the level of the water table and its movement is required to determine whether storage will be permanent and safe. Spacecraft surveillance can aid in better defining drainage systems and the rate of water runoff. The distribution of permeable strata and their dip and strike can be obtained from altitude although much of these data are already available from existing archives.

The distribution of exposed waste disposal sites in the U. S. and other sophisticated nations with good topographic and geological map coverage is also well known. Even in this country, however, low-sun-angle photography often picks up subtle surface details within the contour interval of the map covering the area that might indicate a possible salt dome or sink. In other areas of the world, however, the presence of natural storage sites (salt domes and caves) is relatively unknown. It is in these areas that maximum return from spacecraft sensors can be expected in the detection of natural waste-storage sites.

3. Description of Research

Stereo photography and low-angle conventional color and black-and-white photography will play an important role in this experiment. Side-look radar may also be important, but its competition with aircraft SLR is not yet known. The rate of change in the response of an area after a heavy rainfall may be an index to the rate of absorption by an aquifer or to the rate of runoff on an impermeable stratum.

This relates to two of the three categories of storage sites: hydrologic and dangerous chemical disposal. For hydrologic sites, location of dams would be dictated by the local geomorphology, by the competence of the rocks, by the number and orientation of fractures, and the projected area of the impounded lake produced by the dam. Many potential dam sites, especially in overseas areas with difficult access but close to large cities, may possibly be better defined by spacecraft surveillance of this type. Dam sites on certain Argentinian rivers, for example, would benefit the expanding populations of Buenos Aires and Bahia Blanca.

Remote from population centers, underground storage of dangerous and radioactive chemicals is mandatory. Injection of these materials as fluids into shale strata offers much promise. Analysis of regional geology for undeformed shale that is not in proximity to aquifers would be a worthy assignment of the orbiting spacecraft.

With San Francisco considering exporting its garbage to Lassen county, the time is prime to seek offshore sites for airports and marinas using city wastes as ballast. As implied earlier, many studies have been made for this purpose, using conventional aircraft photography. However, spacecraft inspection might reveal seacoast patterns of silt transport that would be useful in considering the offshore areas for waste disposal and simultaneously the creation of new, high-land-value acreage.

The instruments of this research cluster are similar to those for the other geological missions, consisting of metric camera, multiband imager, multispectral camera, IR thermal imagery, side-look radar, and microwave scanner. Although a nominal

30-degree solar elevation angle at 50 degrees north latitude at spring equinox is suggested for photography, much of the data should be taken at lower sun angles to define the low surface relief of possible underground storate areas. Linear ground resolutions, with the exception of the microware scanner, are less than 300 feet for all instruments. A 100-foot resolution is desirable.

4. Impact on Spacecraft

Because high resolution at low sun angles is an important consideration in the waste-disposal site mission, fine coordination of spacecraft with the simultaneous overflights of aircraft over the truth sites are essential. The experimenter/observer in the aircraft will have to relay information about the prevailing climatic and surface conditions of the target being flown to the experimenter/observer in the spacecraft. Ground computational assistance will permit a high degree of accuracy in instrument pointing required in this study. The most important activity will be the description of the general geological parameters: systems of drainage patterns of dolines, or distributions of salt domes.

In addition to the experimenter/observer, the spacecraft would have the normal complement of the general support technician, the experiment support engineer, and the flight control crewman.

5. Required Supporting Technology Development

Geological and geophysical work, as with almost all ground truth sites, is required prior to overflights by either aircraft or spacecraft to build up a bank of data that can be used in sensor analysis. For the several possible hydrologic site locations proposed (Peace River and MacKenzie River in Canada and the Parana and Colorado-Negro Rivers in South America), geoscientific survey teams should engage in on-site research on the fracture patterns, rock permeability, and drainage analysis of these areas. For storage of waste products, more geological investigation (with aircraft support) should be made of lava tubes, abandoned mines, and salt domes. Basic research is needed such as the rate of volume in the reduction of rooms in salt domes as a function of time, depth, and temperature. For offshore landfill problems, submarine geology of silt and sand transport, and the bearing capacity and compressibility of offshore muds where non-toxic wastes could be dumped offer much opportunity for study.

In this connection, the use of multispectral photography for water penetration and bottom mapping means that detailed film density measurements should be quantitatively compared with bathymetric maps. Also, depending on the sediment content of the intervening water, varying scattering laws may prevail (Reference 1, p. 74). Much preliminary quantitative work by geologists is required if the sensing data are to make sense.

6. Reference

1. D. T. Hodder. Multispectral Photography in Earth Resources Research: Optical Spectra. Vol. 4, Issue 7, P. 71-75, 1970

Critical Issues Addressed by Research Cluster

6-G-2

USE OF EARTH'S CRUST TO STORE AND CONDITION COMMODITIES OR WASTE

6.4.1.1.2.1

How can natural caverns, porous and permeable formations, and aquifers be detected and identified?

6.4.1.1.2.3

How can the Earth's crust be used to store or condition waste products.

RESEARCH CLUSTER
NO. 6-G-2

Table 1

EARTH OBSERVATIONS–GEOLOGY PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Rock and Soil Types, Structural Geology, Topography	Metric Camera (color and false color film)	Spectral Radiance	w/m^2-st-μ	20-400	100 ft	4 w/m^2-st-μ		±10% (Sensitometry)	Atmosphere	Spectral Radiance (visible and near IR)
2. Rock and Soil Types, Structural Geology	Multispectral Camera	Spectral Radiance	w/m^2-st-μ	20-400	100 ft	4 w/m^2-st-μ		±10% (Sensitometry)	Atmosphere	Spectral Radiance (visible and near IR)
3. Spectral Signatures of Rocks and Soil	10-Band Multispectral Scanner	Spectral Radiance (visible and IR)	w/m^2-st-μ	20-400 (vis) 2-10 (IR)	300 ft (vis) 600 ft (IR		1°K	±5% Radiometry	Detector Noise (Background and Internal)	Spectral Radiance (visible and thermal IR ranges of the spectrum)
4. Structural Geology (Lineaments, faults, folds), Topography	Radar Imager	Slant Range of objects on terrain	nmi	0 to 40	200 ft			50 ft	Atmosphere	N/A
5. Soil Types and Moisture Content	Microwave Scanner Radiometer	Radiometric Brightness Temperature	K°	130 to 280	1 to 2 nmi		1°K	1°K	Preamp Noise, Atmosphere	Radiometric Brightness Temperature
6. Spectral Signatures of Rock Types	IR Interferometer Spectrometer	Spectral Radiance (8-13μ)	w/m^2-st-μ	2 to 10	100 to 300 ft	0.003μ		±5% Radiometry	Detector Noise (Background and Internal)	Spectral Radiance (8-13μ)

Table 2

OBSERVATIONS-GEOLOGY

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10-Band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer	X	
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

C.3

Table. 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO 6-G-2

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN†	START†	DURATION†	TASK CONCURRENCY†
6-G-2 -1	Checkout Equipment	All	4	None		5-C	1/wk	15-45	1	*	1 yr.	
-2	Clean Optical Surfaces		5	EVA		21-B	1/wk	1-2 hrs	1			
-3	Perform Onboard Preparation - Load cameras, warmup scanners, chill down IR instruments, flight plan referencing, precision determination & input ephemeris	All	3			5-B	8-10 Orb/wk	20-50	1			
-4	Operate Equipment - Scan optics ancillary electronics, slewing controls, experiment sequencing equipment & voice recording, computation & data processing equipment.		3			11-A	8-10 Orb/wk	30-70	1			
-5	Visual Observations - Voice descriptions of contextual elements such as vegetation, proximity to urban areas, area distance & direction from prominent land forms, & unusual sensor readings.	Audio recorder	2			11-A	8-10 Orb/wk	20-50	1			
-6	Other Measurement Taking - Distance & optical measurements using precision angle measuring equipment with scan optics to pinpoint potential storage areas for follow-up ground studies.		2			11-A	"	30-70	1			
-7	Monitor Equipment - Cameras, sensor status indicators, electronic test & logic equipment & data recording/processing equipment.		1			5-C	8-10 Orb/wk	30-70	1			
-8	Adjust Equipment - Internal camera & sensor adjustments (focussing & boresighting) & calibrate with ground truth data.		1			5-C	2-3 Orb/wk	20-60	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task. *Late Spring, Summer or Fall (at least two seasons)

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-G-3
GEOLOGIC DISASTER AVOIDANCE

RESEARCH CLUSTER SYNOPSIS–EARTH OBSERVATIONS

6-G-3 Geologic Disaster Advoidance

1. Research Objectives

As the Earth's population expands into the available space, emphasis will be placed on the detection of natural hazards. Identifying "the temporal characteristics of significant Earth features utilizing remote sensors" is one of the more pertinent objectives of the Earth Orbital Experiment Program (L13-9852). The specific objective of the program is to identify the geological symptoms of a destructive event and to relay these data to the site affected to reduce loss of life and destruction of property. Regional alerts could also be provided to areas likely to receive damage from a dangerous event already in existence. In other words, if a tidal wave that could affect large coastal areas were detected, the areas could be placed on alert by spacecraft telemetry. An earthquake along an isolated portion of a major fault system could produce others along the same fault system. Communities disposed on this system could be warned. On a time scale often too slow to provoke concern is the slow subsidence of communities on tracts being pumped for oil. On a time scale too fast for precautionary action is the rapid advance of a nuée ardente threatening a village. Yet both events are capable of useful synoptic study from spacecraft.

The most significant objective here is in the predictive possibilities of hazard analysis. The results of thermal monitoring of volcanic structures may result in very important economic gains.

2. Background and Current Status

Man has alwasy been plagued with natural disasters that destroy both life and property. Some processes, such as land subsidence, are slow; others, such as sand dune encroachment or erosional dissection, are more rapid. On a shorter time scale, a volcanic eruption, storm surge or tsunami, landslide, or earthquake create havoc. For some of these hazards, existing equipment has already been employed for their detection. Laser interferometry has proved successful in monitoring minute earth movements along faults, and precise leveling and geophysical methods have proven to be accurate in predicting the eruption of the Kilauea caldera. In other cases, entire cities, such as San Francisco, St. Pierre, and Pompeii, have been destroyed with no preliminary indications of disaster.

At present we can predict hazards with difficulty, we can detect hazards with ease, and we can disclose their impending danger depending upon the site of the disaster. Orbiting spacecraft can add another dimension of reality to these three functions especially when coupled with The Center for Short-Lived Phenomena, Smithsonian Institution, at Cambridge, Massachusetts. A coordinated effort between the administration of this program and that of the Center would permit rescue and research teams to reach the site of a geological disaster more quickly than before. Status reports could be relayed to the Center, with the Center disseminating the data through normal channels.

3. Description of Research

Perhaps the clearest description of the research proposed should begin with the targets selected. Landslide areas near active faults require orbital scanning, especially if there are any spectral peculiarities that might indicate the presence of a quick-clay substratum. Volcanic provinces are another natural target area. A complete literature on the periodicity of many volcanoes exists, but for others only sketchy information is available. Spacecraft inspection of the thermal emission, morphological changes, and color variations of volcanoes is an important part of the research proposed. The ring of fire is a general locus for the spawning of volcanic and seismic phenomena, often with accompanying tsunamis. Storm surges unrelated to internal processes are another category of spacecraft surveillance targets. Side-look radar, used at night, may pick up these high-amplitude ocean waves.

No orbital warning system is possible for landslides or earthquakes; only nearby communities can be alerted after the event. For volcanic eruptions, thermal mapping, using the 10.2-to 12.6-μ bandwidth of the 10-band multispectral scanner and the microwave radiometer, will focus on volcano and caldera flanks and on major fracture systems. Possibly temperature differences of as little as 0.2°K may be detected over large areas.

Truth sites in this experiment cluster overlap those of the photographic mapping experiment (6-G-1) and the waste disposal and storage site experiment (6-G-2). Of the Cascade chain sites, it should be noted that Dr. R. Decker of Dartmouth University has stated that Mount Rainier is currently showing thermal changes. Other turth sites planned for surveillance include the Phlegraean Fields in Italy, Western Turkey, the Taal volcano, the San Andreas fault in California, and Mount Etna in Sicily. These sites warrant daily to monthly observations.

In the case of catastrophic event, high-resolution television imagery is required in near real-time as well as side-look radar and photographic data. Daily observation is required in these cases. For radar and microwave radiometry up to 100-percent cloud cover is permissible, and 20-percent cloud cover is permissible for the other sensors. The resolution requirement for the metric and multispectral cameras is 100 feet. Data-collection systems used on the ground to interrelate with the orbiting system includes seismic, strain-gage, and tiltmeter instrumentation. In the near future, laser interferometry may be integrated with this system. On the oceans, buoys capable of sensing large waves and climatic characteristics are planned.

One interesting experiment that relates to snow avalanches, snow-melt floodwater runoff, and ice-flow breakup is the synoptic analysis of snow distributions and their melting patterns. A study of this type has never been made from orbit on a regional basis.

The instrumentation required by this experiment cluster is similar to others monitoring geologic phenomena.

4. Impact on Spacecraft

The prediction and monitoring of geologic hazards and disasters will probably be the most "relevant" experiment in terms of its real-time interactions. The requirements to show a flood in progress relative to the eye of a hurricane, a tidal wave relative to a volcanic eruption, or a landslide relative to an earthquake will affect both the onboard data-management system and the ground-based data facilities. In this experiment, however, the demands on the crew will be greater than in the other experiments. The experimenter/observer must keep in constant touch with the Smithsonian Institution Command Center; he must have at his fingertips the photocoverage of the site threatened; he must be able to have all equipment in a ready condition (which places constraints on the 30-minute warm-up period for the radar unit); and he must be able to point all instruments at the target within the limits of very short lead times.

This experiment cluster requires onboard film processing and readout facilities to assess the progress of damage, to determine the frequency of overpass, and to budget the use of premium-time instruments. The crew must have the responsibility of making these judgements probably within seconds after word of a major disaster. Suspected hazard data would be processed immediately. Although distance measurements for rate-of-change phenomena by photo-interpretation methods are prescribed, other techniques discussed in the following section may be worth adding to the spacecraft after the mission demonstrates their usefulness.

5. Required Supporting Technology Development

There is a need for laser altimetry, possibly using a CW CO_2 laser altimeter onboard the spacecraft. Certain volcanic features, such as those of Mount Trident in Alaska, have risen hundreds of feet during the last few years. The rate of movement of these potentially dangerous structures deserves quantitative analysis by a remote control system. Large-diameter corner reflectors could be emplaced on features of suspected hazard (such as glaciers, volcanoes, calderas, and dam sites), which could be monitored from altitude to detect small differences in elevation. Additional development of spacecraft laser rangers is required to permit lock-on and measurement of distances between a suspected hazard point and a stable site, with both sites in view of the spacecraft. Research on precision pointing and control systems for more-powerful CW CO_2 lasers is deemed worth while.

Other supporting research is aimed at increasing the understanding of seismic and volcanic phenomena. Basic research is required on the rate of movement of magma, the degree of vesiculation produced by vertical tectonic movements, and the heat flow in volcanic and seismic terrains. Very little support has been given in the past to geoscientific research of this type, using the sensors that are scheduled for use in the spacecraft.

In many of the ground truth sites suggested, more systematic mapping and sample analysis should be performed. University and Department-of-the-Interior studies are recommended to create detailed geological maps of potentially hazardous locations throughout the world so as to make the interpretation of spacecraft data more meaningful.

Critical Issues Addressed by Research Cluster

6-G-3

GEOLOGIC DISASTER AVOIDANCE

6.1.2.1.1.1
What are position changes along fault zones to ±15cm (by 1974) inferred from laser tracking and VLBI supplemented by detailed ground survey?

6.1.2.1.3.1
What are the locations of incipient volcanic activity?

6.3.1.2.1.1
How can the natural distribution of the Earth's surface features be related to the occurrence of natural destructive forces?

6.3.1.2.1.4
How can disaster avoidance and management procedures be identified and initiated?

6.4.1.1.3.1
How can present and future areas of interest be more effectively protected from geologic processes such as earthquakes, volcanic erruptions, landslides, erosion/transportation/deposition, and subsidence.

6.4.1.1.3.2
How can dam sites for flood control and other controlling structures sites be identified?

6.4.2.2.4.2
What tectonic and volcanic belts are active?

Table 1

EARTH OBSERVATIONS–GEOLOGY PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial	Spectral	Temp			
1. Erosion, subsidence, fracture patterns, snow melting patterns	Metric camera (color and false color film)	Spectral radiance	w/m^2-st-μ	20-400	100 ft	4 w/m^2-st-μ		±10% (Sensitometry)	Atmosphere	Soil and rock radiance and emissivity in thermal infrared and microwave range of the spectrum. Surface and subsurface temperature. Air temperature, wind velocity, and relative humidity.
2. Erosion, subsidence patterns, snow melting patterns	Multispectral camera	Spectral radiance	w/m^2-st-μ	20-400	100 ft	4 w/m^2-st-μ		±10% (sensitometry)	Atmosphere	
3. Thermal anomalies indicative of volcanic activity	10-band multispectral scanner	Spectral radiance (10.2 - 12.6μ)	w/m^2-st-μ	2 to 10	100 ft		1°K	±5% Radiometry	Detector noise (background and internal)	
4. Structural geology (lineaments, faults, folds)	Radar imager	Slant range of objects on terrain	nmi	0 to 40	200 ft			50 ft	Atmosphere	
5. Thermal anomalies indicative of volcanic activity	Microwave scanner radiometer	Radiometric brightness temperature	K°	130 to 280	1 to 2 nmi		1°K	1°K	Preamp noise, atmosphere	
6. Imagery of surface features for damage assessment in near real-time	Photo-imaging camera	Linear extent of features on terrain	nmi	0-100	100 ft			0.1% (spatial)	Vidicon electron optic distortion	

Table 2

EARTH OBSERVATIONS—GEOLOGY

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera	X	
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/ Spectrometer		

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO 6-G-3

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-G-3 -1	Checkout Equipment	All	4			5-C	1/wk	15-45	1	*	1 yr	
-2	Clean Lenses			EVA		21	1/wk	1-2 hrs	1			
-3	Prepare Equipment - Load cameras, warmup scanners, chill-down IR equipment, reference flight plan & input ephemeris prior to target overflight		3			5-B	8-10 Orb/wk	20-70	1			
-4	Operate Equipment - Scan optics, ancillary electronics equipment, slewing controls, experiment sequencing equipment & voice tape recorder, computation & data processing equipment.		3			11A	8-10 Orb/wk	30-70	1			
-5	Visual Observations - Scan ground & ocean targets, compare obtained with stored imagery, monitor sensor & status displays.		2			11A	8-10 Orb/wk	30-70	1			
-6	Other Measurements - Distance measurements for interior assessment of glacial sand snow & rate of change phenomena made by photo-interpretation methods.		2			11A	2/wk	2-3 hrs	1			
-7	Monitor Equipment - Monitor operation of camera, check sensor status, monitor electronic test equipment & ascertain proper operation of data processing equipment.		1			5-C	8-10 Orb/wk	30-70	1			
-8	Adjust Equipment - Internal adjustments of cameras (focussing & boresighting), calibrate with ground measurement stations & truth sites.		1			5-C	2-3 Orb/wk	30-120	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

*Each of the four seasons

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER
NO. 6-G-4

RESEARCH CLUSTER SYNOPSIS–EARTH OBSERVATIONS

6-G-4 Utilization of Geothermal Energy Sources

1. Research Objectives

Pollution-free energy sources are available from below the earth's crust as geothermal energy or from above the earth's crust as solar energy. Whereas the range of solar energy is relatively confined over a global area, that of geothermal energy is enormous over very restricted areas. Determining how remote sensors might identify these geothermal power sources and the signature-recognition criteria that exist for them are two major objectives in the Earth Observation Program. As a start, one of the goals is that of monitoring large known geothermal fields, of which about a dozen exist. Then by ground truth calibration, an attempt will be made to extrapolate known fields to unknown areas, bearing in mind the geological constraints on the low-chlorine, high-volume, water-steam reservoirs of commercially feasible power centers. Finally, areas remote from known fields will be assessed for their geothermal potential as related to access directly or indirectly to population centers. The study will also fill in gaps in the global inventory of heat-flow data. What remains to be evaluated is the tradeoff of resolution versus temperature sensitivity for the heat-sensing instruments involved in this research cluster.

2. Background and Current Status

Probably in this geological research effort, more than in the others, we must respect the admonition of Giacconi and Harris (Reference 1), "The explosive increase of data cannot be stopped at the receiving end, but at the source, in the questions we ask." If we seek geothermal power, we must ask the following questions:

1. What threshold heat flow will constitute an area of interest?

2. If a given area has a <u>high</u> heat flow, for instance, 5μ cal/cm^2 sec, does this mean that it is associated with an aquifer?

3. Is the aquifer <u>influx</u> rate sufficient for a power station of the desired power level?

4. Is the ground water saline?

5. Would development be economically practical?

If these questions are not asked first, computer synthesis of returned data would be meaningless even if there were enough geologists and geophysicists to analyze the readout. Selectivity in conceptual approach and instrumental sensing is the keyword in this and other research clusters tied in to a specific matrix of geology and economics.

An impressive literature exists on the geothermal power sites in New Zealand, Kamchatka, California, Italy, and Iceland. In Iceland, for example, an early attempt by Myvatin to tape geothermal power (in the 1940's) failed because there was insufficient capital to obtain corrosion-resistant pipes. Now, with modern equipment and technology, economically successful efforts are in progress near the original sites. Much modern literature of the Icelandic case history, complete with the role of remote sensors in defining these sites, may be found in the publications of Dr. J. P. Friedman of the United States Geological Survey in Washington.

3. Description of Research

The final practical product of the experiment is a new thermal power station or the extension of an old one. This objective for this experiment cannot be achieved by remote sensing alone. Beginning with stereo and multispectral photography with a geometric precision 0. 05 and 0. 5 percent, respectively, and side-looking radar with a geometric precision of 1 percent, regional structures likely to contain geothermal centers would be scanned. After bracketing possible centers, intensive spacecraft analysis of thermal anomalies would be performed by infrared imagery with a geometric precision of 0. 1 percent and a relative temperature resolution of $< 1°$ K, the same as the microwave radiometer. Associated hydrothermal patterns would be analyzed. On the ground, flow rates and temperature gradients would be measured, drilling would be implemented, and cores would be measured for permeability. Corrosion aspects would be balanced against potential reservoir volume, temperature, and flow rates. Finally, the economics of the enterprise would be evaluated, using all ground and spacecraft inputs.

The final academic product of the experiment is a better understanding of heat flow. The size of the area chosen as the thermal grid would be determined by the experimenter and his budget. Already gross heat flux rates are known for the continental shields and ocean basins. The contrast of other zones (such as subduction rift, oceanic rise, and volcanic and transcurrent fault) to continental shields and ocean floors would aid materially in interpreting major crustal processes as being continental drift and mantle processes or convection/phase changes.

4. Impact on Spacecraft

Geothermal anomalies are often disposed on lines along narrow fractures or at points where fracture traces intersect. Because of this, the crew's manipulation of sensing equipment must be precise. The experiment observer must be aware of the structural history and pattern of the region examined. The fact that near subsurface temperatures may be higher at night than during the day may require different scheduling of the microwave radiometer in potentially geothermal areas rather than nongeothermal. Synoptic day-to-night sensing before and after rainfall, before and after spring thaw, and before and after winter snowfall would provide useful data on local heat flux

The observer/experimenter must also draw upon his knowledge (or that of others) of vegetation response to thermal anomalies or gases evolved in thermal areas. In heavily vegetated areas, it may be more advantageous to rely on the multispectral camera rather than side-looking radar to trace the fracture system along which thermal waters rise.

5. Required Supporting Technology Development

A literature search on the history of geothermal fields should be started, contouring the data within the detection limits of the instruments proposed for this experiment. In short. synthetic imagery readout should be created from the wealth of accumulated borehole and surface data of existing geothermal power stations. This is a different task from that anticipated for ground truth survey teams, who would only provide control data to the spacecraft at the time of overpass.

The existing absorption spectrometer or the Barringer-type sulfur-dioxide detection systems should be included in the instrument package because of the common association of fumarolic and hot-spring products with sulfur-bearing gases. Sulfur dioxide above a given threshold could be used to eliminate certain thermal areas as possible geothermal steam-generating sites. Unfortunately, the present 2-km resolution of the scanning Ebert absorption spectrometer may be too coarse to provide data on gas emissions from narrow fracture zones.

6. Reference

1. R. Giacconi, and B. Harris. Comments on Remote Sensing. IEEE Transactions on Geoscience Electronics, Vol. Ge-7, 1970, pp. 179-189.

Critical Issues Addressed by Research Cluster

6-G-4

UTILIZATION OF GEOTHERMAL ENERGY SOURCES

6.4.1.1.4.1
How can geothermal sources of energy (e.g., igneous, hydrothermal) be detected and identified?

Table 1

EARTH OBSERVATIONS—GEOLOGY
PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation									Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source		
1. Thermal anomalies on terrain	10-band multispectral scanner	Spectral radiance (10.2-12.6μ)	w/m^2-st-μ	2 to 10	600 ft		1°K	±5% radiometry	Detector noise (background and internal)		Soil and rock radiance and emissivity in thermal infrared and microwave range of the spectrum
2. Thermal anomalies on terrain	Microwave scanner radiometer	Radiometric Brightness Temperature	k°	130 to 280			1°K	1°K	Preamp noise, atmosphere		Surface and subsurface temperature and moisture content.
3. Structural geology (lineaments, faults, folds, fracture patterns)	Metric camera (color and false color film)	Spectral radiance	w/m^2-st-μ	20-400	100 ft	w/m^2-st-μ		±10% (sensitometry)	Atmosphere		Air temperature, wind velocity, and relative humidity.
4. Structural geology (lineaments, faults, folds, fracture patterns)	Multispectral Camera	Spectral radiance	w/m^2-st-μ	20-400	100 ft	w/m^2-st-μ		±10% (sensitometry)	Atmosphere		
5. Structural geology (lineaments, faults, folds, fracture patterns)	Radar Imager	Slant Range of objects on terrain	nmi	0 to 40	200 ft			50 ft	Atmosphere		

Table 2
EARTH OBSERVATIONS—GEOLOGY
INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO 6-G-4

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-G-4	-1	Checkout Equipment	All	4	None		5-B	1/wk	15-45	1			
	-2	Clean Sensor Optical Surfaces		5	EVA		21-B	1/wk	1-2 hrs	1			
	-3	Perform onboard preparation - Load cameras, warmup scanners, chill down IR instruments, flight plan referencing, precision determination & impact		3	None		5-B	10-12 Orb/wk	30-60	1			
	-4	Operate Equipment - Scan optics ancillary electronics equipment, slewing controls, experiment sequencing & voice tape recorder, computation & data processing equipment.		3			5-B	8-10 Orb/wk	30-70	1			
	-5	Visual Observations - Scan target area (optical sensor and displays). Compare previous synoptic photos with real time sensor display.		2			5-B	8-10 Orb/wk	30-70	1			
	-6	Other measurement taking - Distance & optical measurements using precision angle measuring instruments with scan optics to pinpoint potential geothermal areas.		2			11-A	8-10 Orb/wk	30-70				
	-7	Monitor Equipment - Cameras, sensor status indicators, electronic test & logic equipment & data recording/processing equipment.		1			5-C	8-10 Orb/wk	30-70	1			
	-8	Adjust equipment - Internal camera & sensor adjustments (focussing & boresighting) & calibrate with ground truth data.		1			5-C	2-3 Orb/wk	30-70	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—EARTH OBSERVATIONS EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

6-G-5 Mineral and Oil Deposit Discovery

1. Research Objectives

NASA Document L13-9852 specifies the main goal of manned orbiting spacecraft as the detection of national resources. Mineral depostis, including ores, salines, building materials, and fossil fuels, are the target materials of the geological sciencies. Implied in this objective is the ability to discriminate among major classes of mineral deposits, and to a major degree within these classes. Other associated objectives include determination of the size and grade (where applicable) of the deposit, its spacial configuration, and its geological control.

Many major questions concerning ore deposition can be approached by remote sensing, such as the following:

1. Is the mercury belt of Nevada associated with a subcrustal extension of the East Pacific rise under the western United States?
2. Would an overview provide clues for locating new mining camps on the periphery of major volcanic ring structures?
3. Could new structures possibly trap oil found on the flanks of major uplifts in desert provinces?
4. Can ghost patterns of economic significance be sensed through lava flow cover?

Every new advance in the geosciences was preceded by data collection on a new expanding or penetrating scale. Synoptic coverage of new parts of the electromagnetic spectrum on the scale of hundreds of kilometers will provide another conceptual cascade.

2. Background and Current Status

Hand-held Hasselblad cameras have provided conventional color photographs from geologically random points that are worth millions of dollars to oil and ore companies throughout the world. It would be instructive to compile lease acreages filed before and after Gemini flights on terrain that could be seen by the Gemini spacecraft. Even before Gemini overflights, Viking and Aerobee rocket photos had been used on a limiting basis in the search for potential ore and oil deposits.

The human brain is the most-rapid integrating computer known. Man's ability to correlate regional tonal change in the visible wavelengths with geological experience in a fraction of a second is truly remarkable. Proir to spacecraft photography, no means of detecting regional tonal change was possible. The Earth-orbital experiment program will provide this coverage of selected portions of the Earth on a synoptic basis and over wider-than-visual wavelengths. The literature from more than seven symposia on remote sensing and two major journals in remote sensing highlight the advantages that can be gained in the search for economic mineral deposits. What must be borne in mind is that this research cluster will not be directed toward the detection of a single prospective new oil well or mine but toward a new oil field or mining district.

3. Description of Research

Parameters to be measured in the search for ore and fossil fuel deposits are rock types that are usual hosts for such deposits, alternation patterns including gossans that relate to accumulations of certain metals, thermal sources that pertain to some epithermal products, fault patterns that can block or pass fluids accumulating to form economic deposits, structures that can contain minerals, and tonal changes that reflect facies control of minable or drillable deposits.

Stereo black-and-white and color photographs, which have proven invaluable from aircraft, will be analyzed to provide numbers on thickness and orientation of economically useful strata or structures. Side-look radar will provide additional data on potentially valuable structures. Liminescent properties of some regions (using an absorption spectrometer) may also disclose sulfur-bearing gases, such as SO_2 in the 2,950-Å region. Both the microwave radiometer and 10-band multispectral scanner may indicate thermal highs over possible oil fields or gossans, both with temperature resolutions of $<1\,^\circ K$.

For all of these instruments, the linear ground resolution varies over a wide range, and the instruments to be employed will depend on the scale of the feature sought. These resolutions are 100 ft for the cameras, 300 ft in the visible, and 600 ft in the infrared for the multispectral scanner, and 200 ft for the radar imager. An order-of-magnitude spread of resolution is involved, with the microwave radiometer having a resolution of 6.25 nmi and the correlation absorption spectrometer 4 nmi. The swath width also must be taken into consideration; Figure 1 shows the relationship. A further breakdown of resolutions and sun angles in the exploration for ore and oil from altitude on the basis of detailed or reconnaissance surveys is given by Wobber (Reference 1, Page 163).

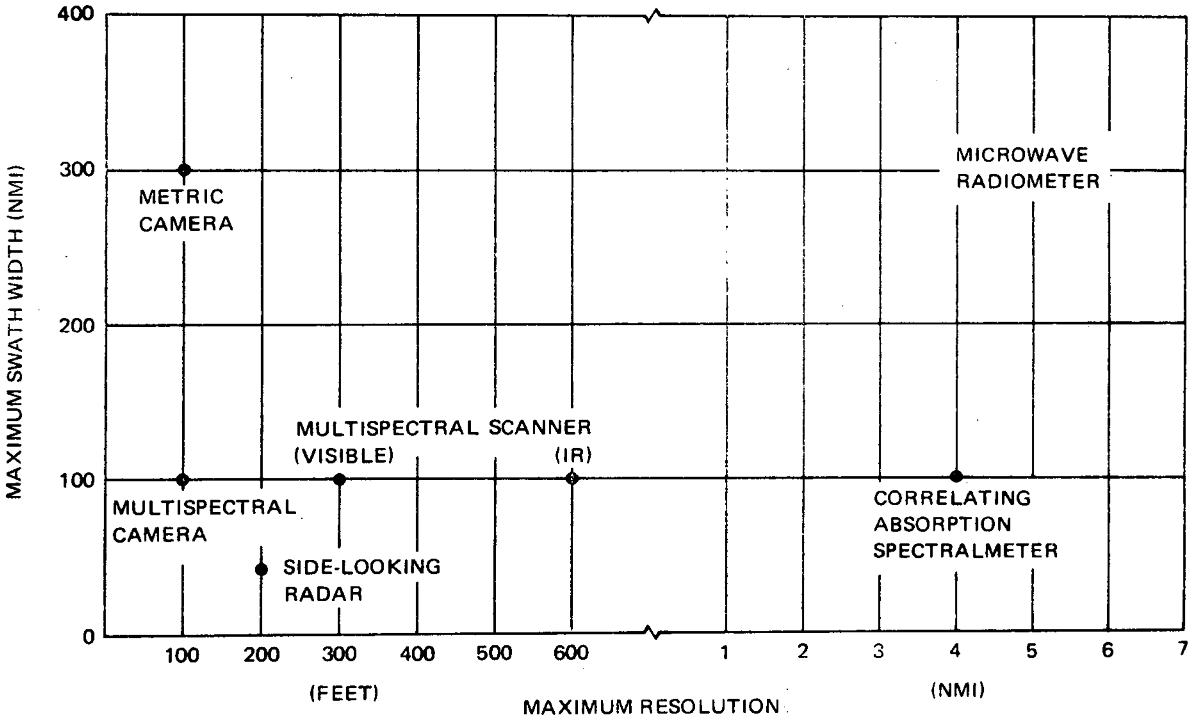

Figure 1. Resolution Requirements

Target areas cover major metalliferrous deposits and petroleum deposits of the world, with emphasis on extending now discarded provinces, such as the Alaskan North Slope. The latter is one of 14 truth sites, some os which are of high priority for economic mineral exploration. The coastal plain west of the Gulf of Aqaba is one of these.

4. Impact on Spacecraft

Commerical interest in finding valuable deposits may affect resource sensing. Arrangements for transmitting proprietary data on a lease basis, coupled with the targeting of a laser-beam corner reflector, emplaced by commercial, governmental, and international organizations, may alter the presently assumed regimen of the spacecraft crew, instrumentation payload, and priorities.

Current plans require a general support technician, an experiment support engineer, and an observer/experimenter. The primary role of the crew will be to collect data (often on a synoptic basis) and to perform preliminary geological assessment of at least the balck-and-white imagery onboard. Visual examination of structures and on-the-spot recommendations for supportin g imagery depending on sun angle and obscuring effects of rainfall should be the responsibility of the observer/ experimenter.

5. Required Supporting Technology Development

Quantitative morphological data are essential in identifying ore or fossil fuel deposits. Local baseline control is adequate in providing dip, strike, plunge, and offset information on ordinary stereo pairs of aerial (aircraft) photographs. In attempting to quantify spacecraft photography of remote regions, ground control of adequate scale is usually not available. Laser altimetry, using CW CO_2 lasers on the spacecraft and large diameter corner reflector arrays on the ground, are required in creating maps of economic mineral deposits. The competitive nature of finding ore and oil deposits makes the use of lasers on the ground economically unfeasible. On the other hand, emplacing widely spaced corner reflectors on specific structural horizons in terrain that is too expensive to survey would yield data of specific use. Obviously, financial arrangements would have to be made between government and industry in matters involving ore or petroleum deposits, especially when these deposits were found on foreign soil.

6. Reference

F. J. Wobber. Environmental Studies Using Earth Orbital Photography. Photogrammetria, Vol. 24, P. 107-165, 1969.

Critical Issues Addressed by Research Cluster

6-G-5

MINERAL AND OIL DEPOSIT DISCOVERY

6.4.1.1.5.1
How can areas of potential mineral deposits be located and identified?

6.4.1.1.5.2
How can potential source areas of petroleum and/or natural gas be located and identified?

6.6.1.2.2.2.9
How can location of oil deposits be improved?

TABLE 1
EARTH OBSERVATIONS - GEOLOGY
PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temperature	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Structural geologic features	Metric camera (stereo-pan film)	Linear extent and relative elevation	nmi	0 to 300	100 ft (a f.) 150 ft (elev.)			0.02 to 0.05%	Film stability	Surveyed ground control targets for aero triangulation
2. Types of soil, rocks, and vegetation	Metric camera (false color film)	Spectral radiance	W/m^2-st-μ	20 - 400	100 ft			± 10% (Sensitometry)	Atmosphere	Spectral radiance of soil, rocks, vegetation (0.4-0.9u)
3. Types of soil, rocks, and vegetation	Multispectral camera (color, multiband b/w, IR film)	Spectral radiance	W/m^2-st-μ	20 - 400	100 ft			± 10% (Sensitometry)	Atmosphere	Spectral radiance of soil, rocks, vegetation (0.4-0.9u)
4. Spectral signatures from soil, vegetation	10-band multi-spectral scanner	Spectral radiance (0.4-2.35u)	W/m^2-st-μ	20 - 400	100 ft			± 5% (Radiometry)	Photon noise	Spectral radiance of soil and vegetation (0.4-2.35u)
5. Thermal emission from rocks and soil	10-band multi-spectral scanner	Spectral radiance (10.2-12.6u)	W/m^2-st-μ	2 to 10	100 ft		1 °K	± 5% (Radiometry)	Detector noise (background and internal)	Spectral radiance of soil and rocks (8-13u)
6. Structural geology (lineaments, faults, folds)	Radar imager	Slant range of objects on terrain	nmi	0 to 40	200 ft			50 ft	Atmosphere	Not Applicable
7. Microwave emission from soil and rocks	Microwave scanner radiometer	Radiometric brightness temperature	K°	130 to 280	6.25nmi		1 °K	1 °K	Preamp. noise, atmosphere	Radiometric brightness of rocks and soil
8. UV luminescense from oil seeps; presence of SO_2 in atmosphere	Absorption spectrometer	Spectral radiance	W/m^2-100A	0 to 10	4 nmi 10Å			0.2%	Photon noise	Spectral radiance of oil seeps, and atmospheric spectral radiance, in UV range of spectrum (2800-3200Å)

Table 2

EARTH OBSERVATIONS—GEOLOGY

INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	
4.	Radar Imager	X	
5.	Absorption Spectrometer	X	
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO. 6-G-5

RESEARCH CLUSTER NO.__	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	FACILITY LEVEL‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-G-5 -1	Checkout Equipment - Checkout experiment support operation & utilities.	All	4			5-B	1/wk	15-45	1	*	1 yr	
-2	Clean optical sensor surfaces		5	EVA		21-B	1/wk	1-2 hrs	1			
-3	Perform Onboard Preparation - Load cameras; electronic preparation, checkout & test: Flight Plan Referencing; input ephemeris data.		3			5-B	8-10 Orb/wk	30-60	1			
-4	Operate Equipment - Scan optics, sensor platform slewing controls, experiment sequencing equipment, voice recording, computational/data processing equipment.		3			5-B	8-10 Orb/wk	30-70	1			
-5	Visual Observation - Survey target area prior to overflight (verify weather conditions and during data taking); voice recording of prominent geologic features and target context elements.		2			11-A	8-10 Orb/wk	30-60	1			
-6	Other measurements - Point measurements of potential oil resource areas.		2			11-A	1-2 Orb/wk	5-10	1			
								Requires accurate angle measurement equipment & precise ephemeris.				
-7	Monitor Equipment - Monitor status of camera, check sensor operating status & data processing equipment. Reference flight plan (assure thorough collection of data).		1			5-C	8-10 Orb/wk	30-60	1			
-8	Adjust Equipment - Internal sensor adjustments for cameras & other sensors (calibrate with ground measurement ground truth stations when required)		1			5-C	1-2 Orb/wk	10-20	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

*Late Spring, Summer & Fall

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER–6-G-6

IDENTIFICATION OF LAND FORMS AND STRUCTURAL FORMS

RESEARCH CLUSTER
NO. 6-G-6

RESEARCH CLUSTER SYNOPSIS—EARTH OBSERVATIONS

6-G-6 Identification of Landforms and Structural Forms

The research involved in this research cluster is essentially the same as that described in the synopsis for Research Cluster 6-G-1, and is therefore not repeated here.

Critical Issues Addressed by Research Cluster

6-G-6

IDENTIFICATION OF LAND FORMS AND STRUCTURAL FORMS

6.3.2.1.1.1
How was the Earth's surface topography developed?

6.3.2.1.1.2
What Earth features prompted settlement of population groups?

6.3.2.1.1.3
What effect did river systems have on the land and man's cultural development?

6.4.2.2.1.1
Is the Earth a homogeneous accumulation of matter?

6.4.2.2.1.2
Is the Earth a heterogeneous accumulation of matter?

6.4.2.2.1.3
Is the Earth composed of readily identifiable masses?

6.4.2.2.1.5
What land forms can be related to dynamic processes?

6.4.2.2.3.2
What are the positions of land masses, polar ice sheets, and ocean basins?

6.4.2.2.4.1
What regions of the crustal mass are experiencing isostatic readjustment?

6.4.2.2.4.2
What tectonic and volcanic belts are active?

6.4.2.3.2.8
What are the rates of sedimentation in major basin of deposition?

6.4.2.3.3.1
What are the physical characteristics of the Earth's crust and mantle?

6.4.2.3.3.4
What geologic features could be modified to serve the needs of man?

6.4.2.3.3.5
How could select geologic features be modified to serve man better?

6.4.2.3.3.6
How could some geologic processes be augmented, stalemated or controlled for the betterment of mankind?

Table 1

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY†	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-G-6 -1	Checkout Equipment		4			5-C	8-9 Orb/wk	15-45	1			
-2	Clean Optical Surfaces		3	EVA		21-B	1/wk	1-2 hrs	1			
-3	Perform Onboard Preparation - Load cameras, warmup scanners, chilldown IR instruments, flight plan referencing, precision determination of spacecraft/attitude for input ephemeris.		3			5-B	8-10 Orbits/wk	30-50	1			
-4	Operate Equipment - Operate scan optics including magnification & filtering controls, ancillary electronics and slewing controls, pointing & tracking gimballed instruments toward target sights.		3			11-A	"	30-50	1			
-5	Visual Observations - Orient sensors and coordinated sensor pointing to specific area.		2			11-A	"		1			
-6	Monitor Equipment - Monitor data taking, camera operation, & support electronics.		1			5-C	"	20-50	1			
-7	Adjust Equipment - Internal calibrations - camera focusing & boresighting, calibrations with ground truth site data.		1			5-C	"	1-2 hr	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 1

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

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6 - Astronomy
7 - Physics
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9 - Forestry
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12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

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DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

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DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-H-1

DETERMINATION OF POLLUTION IN WATER RESOURCES

RESEARCH CLUSTER
NO. 6-H-1

RESEARCH CLUSTER SYNOPSIS--HYDROLOGY

6- H-1 Determination of Pollution in Water Resources

1. Research Objectives

The basic objective of this research experiment is to determine the feasibility of sensing the pollution of water resources from orbital altitude, using photographic, multispectral, and spectrophotometric sensors. This research is necessary to improve methods of detecting and identifying pollution. Information is needed on the extent of the pollution and its effects on water resource utilization.

Another discussion of research for ocean pollution critical issues can be found in Research Cluster Synopsis 6-O-1.

2. Background and Current Status

Control of pollution of the fresh water resources of the United States has become a major domestic issue of the 1970's. Pollution of fresh water results from many causes--municipal, industrial, and agricultural. A major cultural cause is the discharge of both treated and untreated human waste into lakes and streams, resulting in the formation and propagation of algae. Industrial facilities are a source of both chemical and thermal pollution. Thermal pollution results in a reduction of the oxygen content of water necessary for the support of marine life. Pesticides in agricultural areas seep into rivers where they are absorbed by fish, resulting in a poisoning of wildlife that depends on fish as a source of food and representing a danger to humans who consume fish. Oil spills from tankers in both coastal and inland waterways result in destruction of both marine and wildlife and in contamination of recreational facilities.

The measurement of pollution to date has been accomplished primarily by surface observations and by limited measurements with multispectral cameras, correlation spectrometers and infrared line scanners flown on aircraft to determine water quality. Airborne experiments in multispectral remote sensing have demonstrated the feasibility of identifying the formation of algae and plant life in fresh water reservoirs, the circulation patterns of visible contaminants, and saline intrusion in shallow estuaries. Thermal pollution patterns in large bodies of water have been obtained, using thermal infrared imagery.

The synoptic coverage obtainable with satellites, in addition to the capability of data collection from surface-based sensors, offers a rapid means of obtaining and distributing data defining the status of water quality. Attendant with the monitoring of water pollution is the establishment of standards of water quality and a means of governmental enforcement.

3. Description of Research

Initial observations should be conducted over sites previously surveyed in the NASA Aircraft Program, to determine whether results obtained from aircraft can be replicated from orbit. Subsequent sightings can be extended to areas of known pollution adjoining metropolitan areas (i.e., Lake Michigan and the Hudson River), and to areas in which catastrophic pollution may be occurring (e.g., oil spills along the Gulf Coast or Southern California shoreline).

Using cameras with a large film format, wide areal coverage and high resolution will be obtained. Panchromatic film will be used to obtain a high-resolution record, and color film will emphasize the tonal contrasts of visible pollutants.

To facilitate correlation of photographic data with scanner data acquired in the infrared and microwave portions of the spectrum, panoramic camera imagery will also be acquired.

Multispectral cameras with reduced angular coverage will be used as follows: Panchromatic film with a green filter will be used in photographing water penetration to identify sedimentation patterns in shallow water. Color film will be used to emphasize tonal contrasts of visible pollutants. False-color infrared film will enable identification of aquatic plantlife. Infrared film will give high contrast between water and land interfaces.

High-resolution spectroscopy in the near-visual range will enable the detection of pollutants (such as oil slicks) by spectral signature analysis.

Thermal infrared imagery will be used to sense thermal pollution and the presence of surface pollutants (by the reduction in surface-water evaporation rate).

Near real-time data in the visual and near infrared ranges can be obtained with a multispectral point scanner for rapid transmission of information on catastrophic occurrences. The thermal infrared range of this sensor can be used to detect thermal pollution from industrial sources and the presence of oil slicks (by the reduction in surface-water evaporation rate).

Data from surface-based platforms defining water quality (saline content, chemical pollution, and radiological pollution) can be collected by the data-collection system, supported by on-board data processing, display and correlation.

4. Impact on Spacecraft

This experiment uses sensors with a combined extremely large data rate, power requirements. and needed crew support.

Onboard data processing and analysis as a part of a needed data-compression program is necessary and desirable. To support this activity, data-storage, readout, and processing equipment is needed, along with a film development and analysis facility.

5. **Required Supporting** Technology Development
To support this research, sensors and sensing platforms must be developed for ground-truth data acquisition. There is also a need for models that can be used to relate spectral radiance to various types of contamination.

6. **References**

F. H. Ruggles, Jr. A Thermal Survey of the Connecticut River Estuary in Second Annual Earth Resources, Aircraft Program Status Review. NASA Manned Spacecraft Center. September 1969.

J. S. Bailey and P. G. White. Remote Sensing of Ocean Color. Advances in Instrumentation, Vol. 24, Pt. 3. Instrument Society of America, Pittsburgh, Pennsylvania, 1969.

For additional references and bibliography see oceanography Research Cluster G-0-1.

Critical Issues Addressed by Research Cluster

6-H-1

DETERMINATION OF POLLUTION IN WATER RESOURCES

6.2.3.2.3.2
Where is pollutant emission in excess of standards ?

6.3.2.2.2.2
What general aspects of man's progress induce pollution and changes in topography and river systems ?

6.3.2.3.1.5
How can pollution and waste from large population centers be effectively controlled ?

6.3.2.3.3.1
How can pollution from industrial expansion be controlled, i.e., atmospheric/hydrologic ?

6.3.2.3.3.2
How is pollution related to the Earth's topography and climate ?

6.3.2.3.4.3
How can the hazards of pesticides and herbicides to the soil, rivers, and standing bodies of water be eliminated or controlled ?

6.3.3.2.2.4
What is the effect of man's cultural development on surface water bodies ?

6.3.3.3.1.2
What effect do river/dam systems have on the biosphere ?

6.3.3.3.1.3
How are pollutants derived from population increase and the cultural and social advancement of man affecting the water ecologic system ?

6.5.1.2.2.1
What are the water circulation patterns in coastal waters, estuaries, and large lakes ?

6.5.1.2.3.2
What are the effects of streamflow and wastes upon coastal waters ?

6.5.1.2.3.3
What is the extent of saline intrusion in estuaries ?

6.5.1.2.3.4
What is the dispersion of visible pollutants in coastal waters, estauries, large lakes, and reservoirs ?

6.5.1.2.3.5
How can the occurrence and extent of algal blooms be determined ?

6.5.1.2.3.6
How can oil slicks on the surface of water be identified ?

6.5.1.2.3.8
How can the transportation and deposition of sediment be determined ?

Table 1

EARTH OBSERVATIONS—HYDROLOGY

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Areal extent and tonal contrast of pollutants	Metric camera (pan. film)	Spectral radiance of scene	W/M^2-st-μ	20-400'	100 ft	-	-	±10% (sensitometry)	Atmosphere	Aircraft overflights of truth sites with same type of instrumentation
2. Sedimentation, spectral characteristics of plant life, water boundaries	Multispectral cameras (pan, IR, color film)	Spectral radiance of scene	W/M^2-st-μ	20-400'	100 ft	-	-	±10% (sensitometry)	Atmosphere	
3. Concentration of organic pollutants on surface	Multichannel ocean color sensor	Spectral radiance of scene	W/M^2-st-μ	20-80'	1 n. mi.	150A	-	±5% (radiometry)	Atmosphere	
Multispectral data (visual and near IR range)	Multispectral point scanner	Spectral radiance of scene	W/M^2-st-μ	20-400'	300 ft	-	-	±5% (radiometry)	Atmosphere	
4. Thermal pollution, water circulation patterns	Multispectral point scanner	Spectral radiance of scene	W/M^2-st-μ	5-10'	600 ft	-	1°C (Relative)	±5% (radiometry)	Detector noise (background and internal)	

RESEARCH CLUSTER
NO. 6-H-1

Table 2

HYDROLOGY
INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment.

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	4 bands (0.4-0.8μ0) 1 band (10.2-12.6μ)
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	X	
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

FORM 30-1039-1 (REV. 10-67)

Table 3

CREW ACTIVITY MATRIX x

RESEARCH CLUSTER NO. 6-H-1

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-H-1 -1	Checkout Equipment	All	4			5-C	1/wk	15-45	1			
-2	Clean Lenses		5			21-B	1/wk	1-2 hrs	1			
-3	Prepare Equipment - Fire sensors powered up, loaded (as required) & calibrated if time permits. Point scanners & chilled down.		3			15-B	10-12 Orb/wk	20-60	1			
-4	Operate Equipment - Operate 5 sensors: switching & sequencing prior to use; operate scan instruments; monitor sensor & status displays.		3			15-B	10-12 Orb/wk	20-60	1			
-5	Visual Operations - Verify target visibility		2			15-B	10-12 Orb/wk	30-50	1			
-6	Other Measurements - Annotate target features (voice recorded) & unusual display indications.		2			15-B	10-12 Orb/wk	30-50	1			
-7	Monitor Equipment - Data receipt storage and preprocessing; observe film advance & frame rate.		1			5-B	10-12 Orb/wk	20-70	1			
-8	Adjust Equipment - Internal calibrations, boresighting & camera adjustments particularly for metric & multi-spectral cameras.	All	1			5-B	2-3 orb/wk	10-30	1			

C-6-137

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS--HYDROLOGY

6-H-2 Flood Warning and Damage Assessment

1. Research Objectives

This research cluster is directed toward determining the scope and configuration of an operational user-oriented, Earth survey system for flood warning and damage assessment. The basic experimental objectives of this cluster are:

1. To determine the effectiveness of high-resolution imaging sensors (operating in the visual, infrared, and microwave regions of the spectrum) in providing information on the areal distribution of snow cover, precipitation, and the extent of flood water.
2. To evaluate the use of orbital data collection from ground-based sensors to support the user requirements.
3. To assess the usefulness of astronautics-experimenters in rapid evaluation of onboard processed data for real time communication to user agencies.

The pursuit of these objectives would help provide knowledge necessary to satisfy a number of critical issues required for improving water-system management and flood control. For example, needed information includes the synoptic data required for flood forecasting, data for determining the areal extent of precipitation, and data for use in predicting runoff from snowpack.

The basic hypothesis to be tested is that remote sensors in conjunction with data obtained from ground sensors can be useful in the management of water systems.

2. Background and Current Status

There is an urgent need for the rapid synoptic collection of hydrologic data for use in flood forecasting and flood warning. Typical data requirements include river flood stage, the areal extent of precipitation (both rain and snow), tidal stages, water levels of lakes, snowpack water content, near-surface air temperatures, and wind movement. A major portion of these data can be obtained by surface-based sensors, supplemented by synoptic imagery from orbital altitude. However, ESSA estimates that to fulfill its responsibilities in flood forecasting, approximately 10,000 ground stations will be required to obtain data, primarily on river-stage and precipitation. The needs of additional federal, state, local, and private agencies are estimated to require at least twice the number of ground stations required by ESSA. The hydrologic data thus obtained will be used to plan regional emergency action and relief programs, to evaluate flood damage, and for planning and estimation of future flooding conditions.

To date the use of satellites has been limited to the collection of synoptic data in the form of television imagery of relatively low resolution, with data from hydrologic surface sensors being collected by surface communication systems. The imagery obtained from the ESSA weather satellites has been extremely valuable in several instances where the areal extent of snow cover, in conjunction with meteorological forecasts and surface sensor data, has been used to forecast flooding conditions and enabled the initiation of preventative measures to save life and property. The expanded use of satellites to include the use of imaging sensors of higher resolution and new types of sensors operating in the microwave frequency range of the electromagnetic spectrum, combined with synoptic data collection from surface sensors, will offer benefits in both the rapidity and value of the data transmitted for evaluation by user agencies. The economic benefits estimated by the Weather Bureau are savings of $30 million in flood damage for each $1 million invested in preventative measures.

3. Description of Research

High-resolution photography, using metric cameras will be obtained where weather conditions permit observation, with high-resolution television being employed to obtain imagery that can be transmitted in near real time. Where terrain is obscured by clouds, imagery will be obtained by high-resolution side-looking radar. Microwave radiometry will be used to define the areal extent of precipitation and surface temperature. Hydrologic parameters will be obtained by collecting data from surface-based sensors.

4. Impact on Spacecraft

The objectives of this research cluster require extensive data storage, readout, and analysis capability. Flood warning and damage evaluation in particular require quick-look processing for data quality-assessment and transmission purposes. Film development and analysis facilities are required. During times of flood danger, scientific personnel may be required to make nonroutine observations. Flexibility in scheduling the use of equipment will be required.

5. Required Supporting Technology Development

Two areas associated with this research cluster need further development: (1) ground-based data collection platforms and sensors, and (2) onboard film processing and electronic readout. In the first area, sensors and platforms have to be developed or improved to acquire and transmit necessary hydrologic data. The second area needs equipment development for film processing and electronic readout.

6. References

1. C. J. Robinove. The Status of Remote Sensing in Hydrology. Procedures of the Fifth Symposium on Remote Sensing of Environment. Willow Run Laboratory, Ann Arbor, Michigan, April 1968.

2. Useful Applications of Earth Oriented Satellites, Vol. 3. NAS/NRC. National Academy of Sciences, Washington, 1969.

Critical Issues Addressed by Research Cluster

6-H-2

FLOOD WARNING AND DAMAGE ASSESSMENT

6.3.1.1.3.1.2
How significant is the cement to land ratio of an expanding community on the erosion cycle and how might it be controlled?

6.3.1.2.1.1
How can the natural distribution of the Earth's surface features be related to the occurrence of natural destructive forces?

6.3.1.2.1.2
What aspects of river dynamics can be explored to aid in the effective control of flood condition discharge?

6.3.1.2.1.4
How can disaster avoidance and management procedures be identified and initiated?

6.3.2.3.4.1
How can areas of drought and flood be more effectively controlled?

6.5.1.1.1.1
What synoptic data is required for flood forecasting and water-resource systems management?

6.5.1.1.1.2
How can reliable information on the concentration of storm flows be obtained?

6.5.1.1.1.3
How can real-time communication of ground-based hydrologic data be accomplished?

Table 1

EARTH OBSERVATIONS—HYDROLOGY
PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial	Spectral	Temp			
1. Areal Extent of Flood Water and Landforms	Photo-imaging camera (RBV)- One Camera Only	Linear Extent of Water and Landforms	n. mi.	0 - 100	300 ft			0. 1%	Vidicon Electron Optic Distortion	No control measurements required in addition to the hydrologic data obtained by surface-based sensors.
2. Areal Extent of Flood Water and Landforms	Metric C Cameras (color and panchromatic film)	Linear Extent of Water and Landforms	n. mi.	0 - 300	100 ft			0. 02 to 0. 05%	Film Stability	
3. Areal Extent of Flood Water and Landforms	Radar Imager	Linear Extent of Water and Landforms	n. mi.	0 to 40	200 ft			50 ft	Atmosphere	
Area Extent of Soil Moisture and Precipitation	Microwave Scanner Radiometer	Apparent Radiometric Surface Temperature	K^o	120 to 260			1^{o}K	1^{o}K	Preamp Noise, Atmosphere	

Table 2

HYDROLOGY INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment.

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner		
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera	X	Only one camera head required
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-H-2 - 2

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-H-2 -1	Checkout Equipment		4			5-C	1/wk	15-45	1			
-2	Clean lenses & surfaces		5			21-B	1/wk	120	1			
-3	Prepare Equipment - Checkout & childown radar imager & radiometer, replenish film, prepare TV scan camera for rapid processing of high resolution BW photographs.		3			15-C	10-12 Orb/wk	20-70	1			
-4	Operate Equipment - Operate photographic equipment. Switching & sensor cycling equipment operation, TV transmission equipment & digital conversion equipment to enable quick-look and ground processing of data.		3			15-C	10-12 Orb/wk	30-60	1			
-5	Visual Observations - Sequential measurements of snow pack, ground water, content & temperature during successive orbits to measure rate of change.		2			15-C	10-12 Orb/wk	20-50	1			
-6	Monitor Equipment - Data receipt, transmission & reduction/processing.		1			5-B	10-12 Orb/wk	20-70	1			
-7	Adjust Equipment - Internal instrument adjustments, boresighting, calibration with ground stations.		1			5-B	2-3 Orb/wk	10-30	1			

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER
NO. 6-H-3

RESEARCH CLUSTER SYNOPSIS--HYDROLOGY

6-H-3 Synoptic Inventory of Major Lakes and Reservoirs

1. Research Objectives

This research cluster is directed toward evolving a complete data system from acquisition of remote sensor data to the eventual application by a user to a specific problem. This cluster satisfies a number of critical issues related to the better utilization of the world's water resources and an improved understanding of the world's water budget.

The goal of this experiment is to obtain data defining the portion of the world's water budget contained in major lakes, reservoirs, and rivers.

The primary objective of this experiment is to develop methods to obtain an inventory of the areal extent and geographical location of the major lakes and reservoirs of the North and South American continents. A secondary objective is to survey the areal extent of the surface water in major river systems. Data on water depth will be obtained where available to permit volumetric estimates. The data-collection system will obtain hydrologic data where surface sensors are available.

A subsequent objective will be to obtain a world-wide survey, based on the successful negotiation of a cooperative research program.

2. Background and Current Status

In the cooperative program of approximately 100 nations under the sponsorship of UNESCO, the primary project is the study of the world water balance, with the objective of understanding the temporal and spatial variations of water on a regional and world-wide scale. Fresh water resources in major lakes and reservoirs are a small but highly important element of the Earth's total water budget. Only gross data exist on the geographical locations and areal extent of the world's major lakes and reservoirs. Procedures followed to date to obtain information from the many nations on the extent of fresh water resources have been costly and time consuming. The use of space technology offers a rapid and economical basis for obtaining this inventory.

3. Description of Research

Primary data will consist of photographic imagery on black-and-white film to define the areal extent and shape of the water surface of major lakes and reservoirs. The geographic location of the lakes and reservoirs will be defined by the use of known geodetic control points (when available) in the photographic image. When such control points are not available, spacecraft ephemeris data, in conjunction with data defining spacecraft attitude obtained by stellar cameras, will be used to determine the geographic location of objects being observed. Radar imagery will provide survey information in areas with a high percentage of cloud cover and will define the local topography and drainage patterns.

Secondary data will consist of multispectral and false-color photography to define the nature of the surrounding vegetative ground cover. Thermal infrared imagery will permit measurement of the temperature of the water surface, providing information on water circulation, as well as providing data on the drainage characteristics of the surrounding terrain.

Wherever possible, water depth should be obtained by surface-based depth soundings. Approximate estimates of water depth may be obtained through prior knowledge of local topography or by stereo photography from orbital altitude.

Additional hydrologic data (precipitation, streamflow rate, river stage, soil moisture and temperature, air temperature, relative humidity, and wind velocity and direction) will be derived from ground-based sensor platforms, using the data collection system for data acquisition and correlation.

4. Impact on Spacecraft

Since imagery data for at least 27 ground sites are needed for the objectives of this research cluster, facilities and crew time are required for monitoring the quality of the data and selecting those desirable for early transmissions. Onboard correlation with ground truth data may be desirable to assess the utility of the experiment. Facilities for onboard film development and analysis are also necessary.

5. Required Supporting Technology Development

Two areas associated with this research cluster need further development: (1) ground-based data collection platforms and sensors, and (2) onboard film processing and electronic readout. In the first area sensors and platforms need to be developed or improved to acquire and transmit necessary hydrologic data. The second area needs equipment development for the film processing and electronic readout.

6. References

M. C. Kalipinski. Multispectral Data Collection and Processing Techniques Applied to Hydrobiological Investigation, Everglades National Park, Florida. Second Annual Earth Resources Aircraft Program Status Review. NASA Manned Spacecraft Center, September 1969.

J. W. Stewart. Synoptic Remote-Sensing Survey of Lakes in West-Central Florida. Second Annual Earth Resources Aircraft Program Status Review. NASA Manned Spacecraft Center, September 1969.

Critical Issues Addressed by Research Cluster

6-H-3

SYNOPTIC INVENTORY OF MAJOR LAKES AND RESERVOIRS

6.3.1.1.1.1.4
How can potential irrigation water be located and possibly transferred to remote and reclaimed land areas?

6.3.1.1.1.1.5
How can the distribution and rate of use of water supplies be monitored and presented in map form?

6.3.1.1.2.4.2
How might inland short water bodies be adapted to air terminals?

6.3.1.3.4.1
How can the mapping of dynamic features and processes be accomplished? What is the time frame?

6.3.1.3.4.2
What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.:

Land use
Crop-timber
Hydrologic
Political
Population migration
Urban development
Economic
Climatic
Physical/chemical
Cultural

6.3.1.3.4.3
How can maps displaying time variant entities be effectively produced and distributed for use?

6.3.2.3.4.1
How can areas of drought and flood be more effectively controlled?

6.3.3.2.2.3
What is the rate of depletion of natural water supplies in areas of population pressure?

6.3.3.2.2.4
What is the effect of man's cultural development on surface water bodies?

6.5.1.1.2.1
How can a synoptic inventory of the surface area and geographic location of the world's major lakes and reservoirs be obtained?

6.5.1.2.1.2
What is the extent of diversion of water for user requirements?

6.5.1.2.2.1
What are the water circulation patterns in coastal waters, estauries, and large lakes.

6.5.2.1.1.6.1
How can the water content of lakes and rivers be determined?

CLUSTER RESEARCH
NO. 6-H-3

Table 1

EARTH OBSERVATIONS - HYDROLOGY
PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial	Spectral	Temp.			
1. Areal extent of surface water	Metric Camera (Panchromatic film)	Linear extent of surface water	n. mi.	1 to 300	100 feet			0.02 to 0.05%	Film Stability	Surveys of water depth in selected lakes and rivers
2. Areal extent of surface water	Radar imager	Linear extent of surface water	n. mi.	0 to 40	200 feet			50 feet	Atmosphere	
3. Vegetation surrounding water bodies	Multispectral cameras (Pan, IR, color false color film)	Spectral radiance of scene	W/m^2-st-μ	20-400	200 feet			±10% (Sensitometry)	Atmosphere	
4 Water temperature	Multispectral IR scanner (10.4 - 12.6 range only)	Spectral radiance of water	W/m^2-st-μ	5 - 10			1°C (Relative)	±5% (radiometry)	Detector noise background and internal)	

Table 2

HYDROLOGY INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment.

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	One band only (10.2-12.6 microns)
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/ Spectrometer		

RESEARCH CLUSTER
NO. 6-H-3

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-H-3 -1	Checkout Equipment		4			5-C	1/wk	5-20	1		1 yr	
-2	Clean Lens		5	EVA		21-B	1/wk	120	1			
-3	Prepare Equipment - Instrument power-up, input of ephemeris noting ground weather advisories, checking experiment/flight plans.		3			15-B	10-12 Orb/wk	20-50	1			
-4	Operate Equipment - Sensor selection equipment - on-off, slewing, duration & rate control. Ancillary equipment operated in conjunction with experiments includes logic test sets and status & sensor displays. Visual scan equipment associated with target selection & tracking.		3			15-B	10-12 Orb/wk	20-50	1			
-5	Visual Observations - Target selection, tracking and assessment of target weather status using scan telescope viewer & sensor displays. Initiate water resource experiments. (Find & track target areas)		2			15-B	10-12 Orb/wk	20-50	1			
-6	Other measurements - Describe water resource areas subfeatures - voice tape.		2			15-B	10-12 Orb/wk	20-50	1			
-7	Monitor Equipment - Monitor data receipt, desposition, sensor functioning, storage & processing function. Interim logic tests of equipment operation. Maintenance of data library.		1			5-B	10-12 orb/wk	20-70	1			
-8	Adjust Equipment - Calibrate radar imager and IR scanner with gound truth stations. Adjust focus on multi-spectral & metric cameras.		1			5-B	2-3/wk	10-60	1			

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—HYDROLOGY

6-H-4 Synoptic Inventory of Snow and Ice

1. Research Objectives

The basic objective of this research is to evaluate different techniques and instruments to obtain data to define the areal extent of the Earth's snow cover and ice pack. A secondary objective is to obtain measurements of the albedo and surface temperatures of these areas. These experiments will provide information on inventory and assist in verifying models of the hydrologic cycle and weather prediction. The data can be used in a hydrologic atlas showing monthly distribution of snow and ice cover. Weekly observation of snow and ice in selected areas is desired during buildup and breakup. Observation of glacial ice is required only on a seasonal basis.

2. Background and Current Status

On the basis of present knowledge, the total fresh water inventory of the Earth is estimated to be 33 trillion acre-feet, 75 percent of it being contained in polar ice and glaciers. This is equivalent to the total precipitation of the Earth during a period of 60 years. To gain physical understanding of the dynamic characteristics of the Earth's hydrologic cycle requires knowledge of the contribution of snow and ice. Knowledge of the changing extent, surface temperature, thickness, and equivalent water content of seasonal snowpack is required for the management of hydroelectric power production, irrigation systems, flood warning, and regional and municipal water supplies.

The unexploited sources of fresh water are becoming more valuable as more of the world's streams and lakes become polluted. Experiments conducted in Chile have demonstrated the feasibility of increasing fresh water runoff by increasing the absorption of solar radiation by glaciers by dusting with soot. The cost of this experiment was recovered in 81 days through the increase in water production. Theoretically, this resource can be managed to either increase or decrease the melting rate. Melting rate can be decreased by either dusting the glacial ice with insulating material or by seeding of clouds to increase snowfall.

Knowledge of the distribution of ice in large rivers and lakes is important for both navigation and long-range weather prediction. Knowledge of ice formulation and breakup is required for flood forecasting.

Snow and ice inventories to date have been obtained by regional ground and aerial surveys. Limited data have been obtained from

Gemini and Apollo spacecraft by photography and by low-resolution television imagery from ESSA experimental and operational meteorological satellites. The use of large manned spacecraft offers the opportunity of obtaining a synoptic inventory of snow and ice by the use of high-resolution photography supplemented by microwave imagery, the latter offering the advantage of surveillance through cloud cover.

3. Description of Research

Boundaries, texture, and albedo of snow and ice fields will be obtained in clear weather, using black-and-white and color photography. Thermal patterns will be obtained in clear weather, using infrared imagery in the 10.4- to 12.5-micron band. Under cloud cover, distribution patterns will be obtained with side-looking radar. Surface temperature in the microwave region will be obtained using passive microwave radiometry. Surface-based sensing platforms will be used to obtain data on hydrologic parameters (snow depth and water content, runoff, snow temperature, air temperature, relative humidity, and wind velocity and direction) supported by the data collection system and onboard data processing, display and correlation.

Radar and passive microwave radiometry will be evaluated for differentiating between snow and ice and for determining their density and depths.

4. Impact on Spacecraft

To fulfill the objectives of this research cluster, the spacecraft orbit should be polar. Data storage, readout, and processing facilities are necessary along with film development equipment.

5. Required Supporting Technology Development

Techniques need to be developed to determine the depth and density of ice and snow fields, using microwave radiometry or radar. To support this development, mathematical models will be required to relate electromagnetic parameters such as conductivity, dielectric constant and polarization dependence to snow field parameters.

6. References

1. A. T. Edgerton and M. Meier. Snow and Ice Sensing with Passive Microwave and Ground Truth Instrumentation: Recent Results, South Cascade Glacier. Second Annual Earth Resources Aircraft Program Status Review. NASA Manned Spacecraft Center, September 1969.

2. W. P. Waite and H. C. McDonald. Snowfield Mapping with K-Ban Radar. Second Annual Earth Resources Aircraft Program Status Review. NASA Manned Spacecraft Center, September 1969.

Critical Issues Addressed by Research Cluster

6-H-4

SYNOPTIC INVENTORY OF SNOW AND ICE

6.2.1.2.3.2
What are the sources of pollution?

6.2.1.2.3.3
What are the distribution mechanisms of pollution?

6.2.1.2.3.7
What are the seasonal changes in snow packs and glaciers?

6.3.3.2.2.3
What is the rate of depletion of natural water supplies in areas of population pressure?

6.4.2.2.3.2
What are the positions of land masses, polar ice sheets, and ocean basins?

6.4.2.3.1.2.7
How does the water/ice ratio affect the energy budget?

6.4.2.3.2.3
What phenomena trigger widespread glacial activity. What are rates of change of mountain and continental glaciers?

6.4.3.1.1.1
What causes glaciation?

6.4.3.1.1.2
Are we entering interglacial epoch or is the glacial cycle completed?

6.4.3.3.3.2
What effects would increased glacial activity have on plants?

6.5.1.1.1.7
How can the runoff from snowpack be predicted?

6.5.1.1.2.2
How can a synoptic inventory of the world's snow and ice cover be obtained on a perennial and annual basis?

6.5.1.1.2.3
What is the area extent and albedo of snowpacks and the lower limits of snowlines?

6.5.1.1.2.4
What is the areal extent of ice in estauries, rivers, lakes, and glaciers ?

6.5.1.1.2.7
What is the depth and water content of snow ?

6.5.1.1.2.8
What is the location of large icebergs which can be used as a source of fresh water ?

6.5.2.1.1.4.1.1
How can the areal extent of snow cover be determined ?

6.5.2.1.1.4.1.2
How can snow depth and moisture content be determined ?

6.5.2.1.1.4.1.3
How can free water appearing on the snow surface be sensed ?

6.5.2.1.1.4.1.4
How is the apparent temperature of snow in the microwave region affected by density, depth, liquid water content, and sensible temperature ?

6.5.2.1.1.4.2.1
What is the distribution of lake ice ?

6.5.2.1.1.4.2.2
How can the thickness, temperature, and albedo of ice be determined ?

6.5.2.1.1.4.3.1
How is sea ice movement related to climatic and ocean current patterns ?

6.5.2.1.1.4.3.2
How can anomalies in the sea ice pack be related to climatic or subsurface causes ?

6.5.2.1.1.4.4.1
How can the areal extent of glacial ice be determined ?

6.5.2.1.1.4.4.2
How can the volume of glacial ice be determined ?

6.5.2.2.1.2
How is the watershed affected by changes in use of land ?

TABLE 1
EARTH OBSERVATIONS - HYDROLOGY PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
					Spatial	Spectral	Temp.			
1. Areal extent of snow and ice pack	Metric camera (panchromatic and color film)	Linear extent of	n. mi	0 - 300	100 ft			0.02 to 0.05%	Film stability	Ground measurements of surface temperature at several control points for correlation with infrared and microwave measurements of apparent surface temperature
2. Albedo of snow and ice pack	Metric camera (panchromatic and color film)	Spectral radiance of scene	W/M^2-st-μ	20 - 400		40 W/M^2-st-μ	10% (sensitometry)		Atmosphere	
3. Surface temperature of ice and snow	Thermal IR scanner	Spectral radiance of scene	W/M^2-st-μ	0 - 10			1°K (relative)	5% (radiometry)	Detector noise (background and internal) Atmosphere	
4. Areal extent of snow and ice pack	Radar imager	Linear extent of snow and ice	17 mi.	0 - 40	200 ft			50 feet		
5. Apparent radiometric surface temperature of snow and ice	Microwave scanner radiometer	Apparent radiometric surface temperature	K°	110 - 240			1°K	1°K	Preamp. noise Atmosphere	

Table 2

HYDROLOGY
INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment.

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner	X	One band only (10. 2-12. 6 microns)
4.	Radar Imager	X	
5.	Absorption Spectrometer	X	
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-H-4	-1	Checkout Equipment		4			5-C	1/wk	15-45	1		1 yr	
	-2	Clean Lenses		5	EVA		21-B	1/wk	1-2 hr	1			
	-3	Prepare Equipment - Load Cameras, prepare TV scanners, chilldown IR scanner & MW scanner, instrument checkout & periodic calibration & preparation of telescope scan.		3			5-B	5-6 Orb/wk	20-40	1			
	-4	Operate Equipment - Sensor selection, cycling, switching, frame control & ancillary logic test equipment; photo development equipment imagery comparison, data display & image data transmission systems.		3			15-B	5-6 Orb/wk	20-70	1			
	-5	Visual Observations - Visual scan of target areas along with optical scan telescope & required day-night TV.		2			15-B	5-6 Orb/wk	10-30	1			
	-6	Monitor Equipment - Experiment data status, information transmission-image (non-real time) comparison. Instrument status & experiment progress.		1			15-B	5-6 Orb/wk	10-30	1			
	-7	Adjust Equipment - Internal sensor adjustments, camera replenishment, cryo preparation & instrument boresighting, minor maintenance.		1			5-B	1-2 orb	10-30	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

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LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS--HYDROLOGY

6-H-5 Survey of Soil Moisture in Selected Areas of the North American Continent

1. Research Objectives

The basic objective of this research cluster is to identify the distinguishing spectral, spatial, and temporal characteristics of moisture in the soil. This experiment will satisfy the critical issue that asks, "How can soil moisture be measured?" The results of the experiment can be used to provide information on the global distribution of soil moisture. In particular, methods developed here can be used to provide periodic surveys of the agricultural areas of the North American continent, the major river basins during flooding season, and sporadic and discontinuous permafrost in Canada and Alaska.

The proposed experiment will yield valuable information regarding the areal distribution and seasonal variation of soil moisture in the liquid and frozen states. Because of limitations in remote and ground platform sensing capabilities, however, it will not yield absolute data on total soil moisture content.

2. Background and Current Status

The amount of moisture in the soil of the Earth, although estimated to be only 0.06 percent of the total fresh water budget, is approximately one-fifth of the amount of fresh water contained in lakes and 75 percent greater than that contained in the rivers of the Earth.

Soil moisture and temperature are important to both agriculture and hydrology. Without sufficient soil moisture, which permits cooling of vegetation by evapotranspiration, the temperature of the exposed parts of plants may rise excessively, resulting in destruction of the vegetation. In agricultural areas, excessive soil moisture due to irrigation will result in concentration of salts on the surface and the destruction of crops. In urban areas, excessive infiltration of the soil by water may make areas unsuitable for development. In major river basins, moisture that is frozen in the soil will impede the downward flow of water and contribute to regional flooding conditions. In the arctic regions, continuously frozen moisture in the soil (permafrost) presents difficult engineering problems during construction. Thawing of the soil by the construction of dams or pipelines will cause instability with progressive differential settlement in summer and excessive heaving in winter.

3. Description of Research

High-resolution photography, using panchromatic and false-color film, will be used to determine soil types, texture, areas of water infiltration, vegetation patterns, standing water, and ground patterns indicative of permafrost. Thermal infrared imagery will be used to obtain temperature distribution patterns of the terrain. Radiometric brightness temperature of the terrain, strongly dependent upon soil moisture content, will be measured with a scanning microwave radiometer. Measurements of soil moisture and temperature will be obtained by data collection from surface-based sensors for correlation with infrared and microwave measurements. Additional hydrologic data will consist of air temperature, relative humidity, and wind velocity and direction.

4. Impact on Spacecraft

To completely fulfill the objective of this research cluster, the spacecraft orbit should be polar. Data storage, readout, and analysis facilities are necessary including processing of panchromatic and color film. Correlation of the photographs with the infrared and microwave imagery and subsequent comparison with ground truth data comprise much of the preliminary analysis. The photographs and imagery of good quality will be returned to the ground for later analysis.

5. Required Supporting Technology Development

To evaluate the microwave radiometry data, ground truth data describing radiometric properties of various soil types as a function of water content above and below freezing will be needed. To support the research, platforms to collect ground truth data will have to be developed along with a spacecraft data-collection system.

6. References

1. Richard R. Anderson. The Use of Color Infrared Photography and Thermal Imagery in Marshland and Estuarine Studies. Second Annual Earth Resources Aircraft Program Status Review. NASA Manned Spacecraft Center, September 1969.

2. J. T. Smith, Jr. Manual of Color Aerial Photography. American Society of Photogrammetry, Falls Church, Virginia, 1968.

RESEARCH CLUSTER
NO. 6-H-5

Critical Issues Addressed by Research Cluster

6-H-5

SURVEY OF SOIL MOISTURE IN SELECTED AREAS OF THE NORTH AMERICAN CONTINENT

6.2.1.1.3.3
What is the moisture content, porosity and permeability of the soil?

6.3.2.3.4.1
How can areas of drought and flood be more effectively controlled?

6.5.1.1.1.6
What is the areal extent of precipitation?

6.5.1.1.2.6
How can soil moisture be measured?

6.5.1.2.1.3
What is the extent of the loss of water along irrigation canals?

6.5.1.2.1.4
What are the effects of changes in vegetation patterns on the run-off of precipitation?

6.5.1.2.1.5
What are the location where excessive irrigation is increasing the saline content of soil?

6.5.2.1.1.5.2
What is the global distribution of soil moisture?

6.5.2.2.1.1
What is the effect of cultural changes of the surface of the Earth on the elements of the hydrologic cycle?

RESEARCH CLUSTER NO. 6-H-5

TABLE 1

EARTH OBSERVATIONS - HYDROLOGY PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp.	Measurement Precision	Predominant Noise Source	
1. Soil types, texture, vegetation, water infiltration, permafrost	Metric Camera (panchromatic and false color film)	Linear Extent of objects on terrain	n. mi.	0-300	100 ft.			0.02 to 0.05%	Film Stability	Ground measurements of soil moisture and surface temperature for correlation with infrared and microwave measurements.
2. Terrain Surface Temperature Patterns	Thermal IR Scanner	Spectral radiance of terrain	w/m^2-st-μ	0-10			1°K (relative)	± 5% (radiometry)	Detector Noise (Background and internal)	
3. Radiometric brightness temperature of terrain	Microwave Scanner Radiometer	Apparent Radiometric Surface Temperature	K°	130 to 280			1°K	1°K	Preamp. Noise atmosphere	

Table 2

HYDROLOGY INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment.

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner	X	One band only (10. 2-12. 6 microns)
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-H-5

Table 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY
6-H-5	-1	Checkout Equipment		4			5-B	1/wk	5-20	1			
	-2	Clean Lenses		5			21-B	1/wk	1-2 hrs	1			
	-3	Prepare Equipment - Load metric camera, childown scanners (2), power up instruments (cycle several times), calibrate as nece-sary.		3			5-B	6-8 Orb/wk	30-70	1			
	-4	Operate Equipment - Operate a complex of switching & sequencing controls & viewing optics.		3			5-B	6-8 Orb/wk	10-30	1			
	-5	Visual Observations - Visual & contextual cues, voice recorded.	Optical Scanner	2			15-B	6-8 Orb/wk	10-30	1			
	-6	Other Measurements - Online monitoring of data receipt, sensor status image quality & experiment progress.		2			15-B	6-8 Orb/wk	10-30	1			
	-7	Monitor Equipment - Data receipt, sensor status image quality, experiment progress.		1			5-B	6-8 Orb/wk	10-30	1			
	-8	Adjust Equipment - Internal calibrations, boresighting & minor maintenance.		1			5-B	6-8 Orb/wk	10-30	1			

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-H-6

LOCATION OF UNDERGROUND WATER SOURCES IN SELECTED AREAS

RESEARCH CLUSTER SYNOPSIS--HYDROLOGY

6-H-6 Location of Underground Water Resources

1. Research Objectives

The objective of this research cluster is to identify the distinguishing spectral, spatial, and temporal characteristics of significant features that relate to underground water resources. A secondary objective is to evaluate thermal infrared imaging, and color or false-color photography for locating these underground water resources and their discharge onto the surface. This research will provide information to satisfy critical issues concerned with the utilization of water resources.

2. Background and Current Status

A primary objective of the science of hydrology is optimum utilization of the fresh water resources of the earth. Eleven percent of the earth's fresh water resources are contained in ground water at depths less than 2, 500 ft, compared to only 0. 3 percent in lakes and 0. 03 percent in rivers. Undiscovered sources of ground water represent a significant untapped resource.

Underground sources of water can be identified by locating the areas of ground water discharge to surface water bodies. This can be accomplished by the use of thermal infrared imagery and radiometry. Several previously unknown ground water sources have been located by this method (References 1 and 2). In arid regions, areas of ground water discharge can be identified by observing the character and density of vegetation.

Identification of areas of ground water discharge is important because it gives clues to areas underlain by productive aquifers that are capable of supplying large amounts of water for municipal, industrial, and irrigational use. Identification of these areas from orbiting spacecraft will simplify the exploration and evaluation of ground water resources. The synoptic coverage from orbital altitude will offer the advantage of observing large areas in a short period of time, and will also permit repetitive coverage to observe the seasonal changes in the flow of ground water discharge.

3. Description of Research

A thermal infrared imaging scanner will be used to obtain images of temperature discontinuities in areas of ground water discharge into surface water bodies. In semi-arid regions, black and white and false color photography will be used to study characteristics of vegetation in areas of ground water discharge. Passive microwave radiometric measurements of brightness temperature will also be evaluated for application in areas where cloud cover prevents the use of optical and infrared sensors.

Initial observations should be obtained in areas of the southern United States and Mexico bordering the Gulf of Mexico and in semi-arid regions of the southwestern United States and Northern Mexico, between 20 and 35 degrees north latitude. Subsequent observations should be obtained along the major river systems of the United States, extending to 48 degrees north latitude.

4. Impact on Spacecraft
Film development processing and analysis is most important for this research. Annotated supplemental observations by scientists will be helpful.

5. Required Supporting Technology Development
The development of high-resolution infrared and microwave imaging scanners is a necessary part of this research. Models relating vegetation to ground water characteristics must also be developed.

6. References

1. W. Fisher, et al. Fresh Water Springs of Hawaii from Infrared Images. USGS Atlas HA-218, 1966.

2. Kennan Lee. Infrared Exploration for Shoreline Springs at Mono Lake, California, Test Site. Proceedings of the Sixth International Symposium on Remote Sensing of the Environment, Vol. II. Willow Run Laboratories, the University of Michigan, October 1969, pp. 1075-87.

7. Bibliography

Barnwell, W. W. Color Infrared and Thermal Infrared Sensing of Hydrologic Features in Northern Cook Inlet, Alaska. Second Annual Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, September 1969.

Hun, J. D. and R. N. Cherry. Remote Sensing of Offshore Springs and Spring Discharge Along the Gulf Coast of Central Florida. Second Annual Earth Resources Aircraft Program Status Review. NASA Manned Spacecraft Center, September 1969.

Critical Issues Addressed by Research Cluster

6-H-6

LOCATION OF UNDERGROUND WATER SOURCES IN SELECTED AREAS

6.2.1.2.3.4
What is the location and amount of ground water?

6.5.1.1.1.5
What is the level and movement of groundwater?

6.5.1.1.2.5
How can the location and extent of underground water sources be identified?

TABLE 1 - EARTH OBSERVATIONS - HYDROLOGY PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temperature	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Water Circulation Patterns	Metric Camera (Panchromatic and False Color Film)	Spectral Radiance of Water	W/M^2-st-μ	5 to 75	50 ft			± 10% (Sensitometry)	Atmosphere	Meteorological Data at Truth Sites - Air Temperature, Wind Direction and velocity, cloud cover, relative humidity.
2. Spectral Characteristics of vegetation	Metric Camera (False Color Film)	Spectral Radiance of Vegetation	W/M^2-st-μ	20 to 400	50 ft			± 10% (Sensitometry)	Atmosphere	
3. Thermal Gradients and patterns	Thermal IR Imager	Spectral Radiance of Water	W/M^2-st-μ	5 to 10	100 ft		1 °K (Relative)	± 5% (Radiometry)	Detector Noise (Background and internal)	

Table 2

HYDROLOGY
INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment.

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner	X	One band only (10.2-12.6 microns)
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System		
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-H-6

Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-H-6 -1	Checkout Equipment		4			5-C	1/wk	15-45	1	*	1 yr	
-2	Clean Lenses		5	EVA		21-C	1/wk	1-2 hrs	1			
-3	Prepare Equipment - Camera loading, IR imager preparation, calibration, energizing data recording & optical instruments.		3			5-B	3-6 Orb/wk	20-80	1			
-4	Operate Equipment - programming & sequencing equipment (select data modes), photographic reduction/interpretation, optical scan equipment.		3			15-B	3-6 Orb/wk	30-80	1			
-5	Visual Observation - Utilize optical equipment for closely examining contextual features, vegetation & growth patterns & geologic formations.		2			15-B	3-6 Orb/wk	20-80	1			
-6	Other Measurements - Photogrammetric measurements & stereoscopic measurements of interim imagery.		2			15-B	1/wk	2-4 hr	1			
-7	Monitor Equipment - Sensor system operation experiment status, image quality, indicative patterns within imagery context.		1			15-B	1/wk	2-4 hrs	1			
-8	Adjust Equipment - Internal calibrations (boresighting & focussing), calibration against cold bodies, maintenance.		1			5-B	3-6 Orb/wk	30-70	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

* Late Spring & Fall (twice/yr)

C-6-175

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS--HYDROLOGY

6-H-7 Survey of Hydrologic Features of Major River Basins

1. Research Objectives

The basic research objective of this cluster is to evaluate the use of satellites to provide information on topography for a number of critical issues relating to the utilization of water resources. A secondary objective is to provide data for the routing of canals and waterways.

To provide this information, seasonal observations will be made of major river basins of North and South America, using high-resolution photograph, supplemented by infrared radiometry and radar imagery to define the shape, size, and drainage patterns of bodies of water and watercourses. Data will be used to provide maps at a scale of 1/250,000. Supplementary hydrologic data will be obtained by surface-based sensing platforms where available.

2. Background and Current Status

Periodic surveys of the drainage characteristics of major river basins, lakes, and estuaries are important in water system management, flood control, hydroelectric power generation, control of soil erosion, wildlife protection, and recreation. In semi-arid regions where flash flooding occurs, the courses of rivers can change annually. Surveys of the hydrologic features of major river basins in underdeveloped regions of South America can be of value in the development of water resources.

3. Description of Research

In areas of high terrain relief, topographic information will be obtained, using wide-angle stereometric camera photography. Inasmuch as metric topography from orbital altitudes using stereo-photography may be limited to the order of tens of feet, topography in areas of low terrain relief will be determined on the basis of inference by photographic interpretation. Panchromatic film will be used with a red filter to obtain high contrast among water, landforms, and clouds.

Multispectral film photography will be used as follows. Panchromatic film will be used with a green filter for water penetration to determine patterns of bottom topography. Color film will be used to emphasize tonal contrasts of water, landforms, and vegetation. False-color infrared film will enable determination of types of aquatic plant life and surrounding vegetation. Infrared film will give high contrast between water and land interfaces.

Thermal infrared imagery will be used to observe thermal patterns indicative of well-drained and poorly-drained areas. High-resolution radar imagery will permit identification of topographic characteristics in areas with a high percentage of cloud cover.

Supplementary hydrologic data will be obtained by surface-based sensing platforms and a data-collection system. These data will consist of precipitation, streamflow rate, river stage, soil moisture and temperature, air temperature, relative humidity, and wind velocity and direction.

4. Impact on Spacecraft

Large-capacity film development and processing equipment will be needed. A great deal of film will have to be scanned, and poor-quality and high-cloud-cover film sets will be rejected.

5. Required Supporting Technology Development

Photocomparator and cross-correlation techniques will have to be developed to compare photographs from various cameras and to extract pertinent data.

6. References

1. R.C. Culler and R.M. Turner. Relation of Remote Sensing to Transpiration of Flood Plain Vegetation. Second Annual Earth Resources Aircraft Program Review. NASA Manned Spacecraft Center, September 1969.

2. D.J. Belcher and S.E. Maftenyi. Discharge Properties of Drainage Basins Observable from Aerial Photographs, Paper 70-145. Proceedings of the American Society of Photogrammetry, March 1970.

Critical Issues Addressed by Resource Cluster

6-H-7

SURVEY OF HYDROLOGIC FEATURES OF MAJOR RIVER BASINS

6.3.1.1.1.1.1
How can the natural water supplies of remote wildlands, marshes, and other bird/animal sanctuaries be monitored?

6.3.1.1.1.1.2
How can natural snow and watershed capacities be increased and the runoff controlled and monitored?

6.3.1.1.1.1.3
How can topography be used more effectively for the generation of electrical power and control of silting of major dam and reservior systems?

6.3.1.1.1.1.4
How can potential irrigation water be located and possibly transferred to remote and reclaimed land areas?

6.3.1.1.2.4.3
How can natural river systems be more expeditiously exploited as transport media, and how can these systems be effectively monitored, managed and controlled?

6.3.1.2.1.2
What aspects of river dynamics can be explored to aid in the effective control of flood condition discharge?

6.3.1.3.4.1
How can the mapping of dynamic features and processes be accomplished? What is the time frame?

6.3.1.3.4.2
What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.:

Land use
Crop-timber
Hydrologic
Political
Population migration
Urban development
Economic
Climatic
Physical/chemical
Cultural

6.3.1.3.4.3
How can maps displaying time variant entities be effectively produced and distributed for use?

6.3.2.1.1.3
What effect did river systems have on the land and man's cultural development?

6.3.2.3.4.1
How can areas of drought and flood be more effectively controlled?

6.3.3.2.2.3
What is the rate of depletion of natural water supplies in areas of population pressure?

6.3.3.2.3.5
What are the effects of urban development on erosion of the land?

6.4.1.1.3.2
How can dam sites for flood control and other controlling structures sites be identified?

6.4.2.3.3.3
What are the rates of flow of the major river systems?

6.5.1.1.3.1
What is the topography, geologic structure, and soil cover in underdeveloped regions of the world?

6.5.1.1.3.2
What are the hydrologic features of coastal regions and large inland lakes?

6.5.1.1.3.3
What are the geomorphological characteristics of river basins?

6.5.1.1.3.4
How can the best routing for canals and artificial waterways be determined?

6.5.1.2.3.2
What are the effects of streamflow and wastes upon coastal waters?

6.5.2.2.1.2
How is the watershed affected by changes in use of land?

TABLE 1
EARTH OBSERVATIONS - HYDROLOGY
PARAMETERS TO BE MEASURED

RESEARCH CLUSTER NO. 6-H-7

		Characteristics of Parameters Measured by Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predomnant Noise Source	Control Measurements at Truth Site or on Spacecraft
					Spatial	Spectral	Temp.			
1. Drainage basin topography in areas of high terrain relief	Metric Cameras (stereo)	Relative elevation	feet	Q-21, 000	100 feet			200 feet	aerotriangulation accuracy	
2. Drainage basin topography in areas of low terrain relief	Metric Cameras	Relative elevation	feet	Q-21, 000	100 feet			Precision Photo-interpretation	N/A	
3. Bottom topography, tonal contrasts, vegetation types	Multispectral photography	Spectral radiance of terrain	w/m^2-st-μ	0-400	100 feet			±10% (sensitometry)	atmosphere	
4. Surface temperature of terrain	Thermal IR scanner	Spectral radiance of terrain	w/m^2-st-μ	0-10	100 feet			±5% (radiometry)	detector noise (background and internal)	
5. Drainage basin topography	Radar Imagery	Relative elevation	feet	Q-21, 000	200 feet			Precision of photo-interpretation	Atmosphere and perspective distortion	

Table 2

HYDROLOGY
INSTRUMENTS REQUIRED

The following instruments are applicable to this experiment. See Appendix A for

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	One band only (10.2-12.6 microns)
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY
6-H-7 -1	Checkout Equipment		4			5-C	1/wk	15-45	1	*	1 yr	
-2	Clean Lenses		5			21-B	1/wk	1-2 hrs	1			
-3	Prepare Equipment - Film change for three cameras (as required), scanner chilldown, powering electronic support equipment, instrument calibration.		3			5-B	10-12 Orb/wk	30-50	1			
-4	Operate Equipment - Operate switching, power selection, and rate controls & viewing optics. Monitor sensor electronics through status indication panel. Operate data collection system reviewing controls (data from ground station).		3			5-B	10-12 Orb/wk	30-50	1			
-5	Visual Observations - Evaluate previous imagery (Online comparisons through use of telescope) Assess data taking.		2			15-B	10-12 Orb/wk	20-50	1			
-6	Other Measurements - Receiving & processing measurement from ground stations to be correlated with orbital data.		2			5-B	10-12 Orb/wk	20-40	1			
-7	Monitor Equipment - Online monitoring of data receipt, sensor operation status, image quality (TV/Other) & experiment duration.		1			5-B	10-12 Orb/wk	20-40	1			
-8	Adjust Equipment - Internal calibrations, boresighting, & minor experiment maintenance.		1			5-B	2-5 Orb/wk	30-40	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

*Late Spring, Summer & Fall ([illegible] intervals)

TABLE 2

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
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Each code includes a number describing the discipline and a letter describing level of skill:

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7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
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12 - Meteorology
13 - Geography
14 - Cartography
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16 - Navigation
17 - Communications
18 - Radiology
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20 - Photography
21 - Astronaut
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A - Professional level, usually representing Master's degree or higher in discipline.

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Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER DESCRIPTION—OCEANOGRAPHY

6-O-1 Pollution Identification, Measurement and Effects

1. Research Objectives

The overall objective of this research cluster is to increase knowledge of the effects of pollution on the physical, chemical, and biological processes of the ocean so that pollution can be effectively monitored, controlled, and abated. This knowledge is necessary not only to evaluate the extent of the effects of pollution on marine ecology, but also to develop effective monitoring and abatement techniques. Although it has been observed that sewage pollution affects the neighboring population distribution and that thermal and toxic effects occur, very little appears to be known about the interaction between pollution and ocean ecological systems.

2. Background and Current Status

"Water pollution stems from many sources and exists in many forms to assail man's senses and hamper his activities. It may appear as oil slicks, as public health notices against swimming, or as masses of aquatic weeds making water undrinkable. More subtle are long-term changes in the aquatic life of a river--the decline of the sportsfish and the ascendance of carp, sludge worms, and other life forms tolerant of pollution."

This quotation from the First Annual Report of the Council on Environmental Quality (Reference 1) applies to inland, estuarine, and ocean pollution equally well. Water pollution affects health, esthetics, recreation, fishing, agriculture, and both industrial and municipal water suppliers. It stems from three main sources--industrial, municipal, and agricultural activities, although other minor sources exist (Reference 1). Ocean pollution results directly from sewer outfalls, runoff from land, boating or shipping activities and barging from land, and dumping. It also results from the inflow of rivers and the flushing of estuaries.

Pollution of the ocean is not as evident as that of rivers and lakes, but it is slowly and surely increasing. The single greatest universal ocean pollutant appears to be oil, which fouls birds, animals, plants, ships, boats, marine structures, harbors, and beaches. It affects or destroys animals or plantlife throughout the ocean, but particularly in the intertidal zone. It can suppress evaporation, after the reflectance (albedo) of the ocean surface, and change the surface-wave characteristics. Oil pollution results from the normal activities of shipping and boating as well as accidental discharge or breakup of ships. Recent research by Woods Hole Oceanographic Institution scientists has indicated that oil has a greater capacity for toxicity to ocean life than previously thought (Reference 2).

Other pollutants are soluble or insoluble organic materials that use up oxygen and other chemicals, or that release bacteria and viruses, inorganic nutrients (such as nitrates and phosphates) that may result in excessive blooms of plankton and algae or toxic materials from industrial processes, insecticides, and herbicides that may result in excessive mortality or affect reproduction and growth of some part of the ecosystem. If pollution is considered to be any detrimental effect to the environment resulting from man's activities, other factors can also be considered pollutants, such as increased water temperature (thermal pollution) or an increased sediment load. The thermal pollution results from producing electric energy and from industrial processes; and the sediment pollution results from increased erosion due to agricultural, forestry, and construction activities. These pollutants affect the color, odor, flavor, and feel of the water, but in particular, they alter the temperature, nutrients, and population dynamics. Although the extent is not known, massive plankton blooms and fish kills in the Gulf of Mexico, increasing levels of toxic materials in shell fish and the pelagic fisheries, and the changing fish population distribution are indicators that pollution is inceasing (Reference 3). It appears extremely desirable that remote methods be developed: (1) to detect and monitor oil, thermal, and chemical pollution; and (2) to measure and relate pollution to population dynamics and energy partition.

3. Description of Research

Since the type and the effects of marine pollutants are quite varied, the identification and measurement of the pollutants is complicated and difficult. Toxic materials may be present only in parts per million but still have a profound effect. Thus, the pollution is estimated by the means of physical, chemical, and biological parameters. The scope and nature of these parameters are discussed in detail in Pollution and Marine Ecology (Reference 4). Of the many parameters that are used for in-site investigations, only color, surface roughness, relative albedo, and temperature appear to be immediately useful as general remote-sensing parameters. Indirect effects on the spectral emmisivity and surface reflection characteristics of water, however, offer potential for advanced techniques. For example, it has been shown theoretically (Reference 5) that variations in salinity change the spectral emissivity of water. Laboratory studies (Reference 6) have indicated the possibility of using spectral reflectance as a parameter to identify pollution types. The Fraunhofer line absorption (Reference 7) is another such technique. Also simulated emission (luminesence), using a laser as a light source, should be considered. Oil in particular appears to be identifiable by spectral reflectance characteristics in the optical and infrared spectral bands (Reference 8).

4. Impact on Spacecraft

Flexibility in experiment sequencing and crew duty cycles is desirable so that observations may be made in response to occurrence of specific pollution episodes. The ability to initially reduce data, including photographic development along with readout of nonimaging data, is necessary. Such data processing and subsequent analysis will allow insight into the processes and relationships involved, and allow early development or modification of descriptive and mathematical models.

The Space Research Facility activities would be mainly concerned with instrument operation and selective data acquisition when cloud cover or visibility warrant. Voice annotations of interesting or unusual features would be utilized to develop or test analytical models.

5. Required Supporting Research and Technology
Of the many techniques, analysis of ocean color and temperature appear to be the most useful at present. The approach here would be to evaluate the currently available multispectral scanners, ocean color sensors, and microwave radiometers by mounting them simultaneously in an aircraft and overflying test sites where necessary ground truths are being accumulated. Parallel with these efforts, analytical models should be developed to relate the sensor outputs to the physical and chemical pollution parameters to be measured, and in turn to relate the parameters to information on type and concentration of pollutants. Through a comparison of the information obtained from these two approaches, the necessary characteristics of the space station instrument package and supporting ground truth sensors can be formulated. First, however, an improved prototype for aircraft tests has to be built.

6. References

1. Environmental Quality, Report of the Council of Environmental Quality, GPO, 1970.

2. Dr. Max Blumer, Oil Pollution Can Be Invisible and Odorless--but It's Deadly. Los Angeles Times, Section G, August 23, 1970, p. 3.

3. Wesley Marx. The Frail Ocean. Ballentine Books, 1967.

4. T. A. Olson and F. J. Burgess, editors. Pollution and Marine Ecology. Interscience Publications, 1967.

5. H. Hyatt. Emission, Reflection, and Absorption of Microwaves at a Smooth Air-Water Interface, Journal of Quantitative Spectroscopy and Radiative Transfer, Vol. 10, 1970, pp. 217 to 247.

6. J. P. Scherz, W. C . Boyle, and D. P. Graff. Photographic Characteristics of Water Pollution. Instruments and Control Systems, Vol. 42, November, 1969.

7. W.R. Hemphill, Geologic Applications Program--Summary of Recent Progress and Plans. Presented at Spacecraft Oceanography Project Workshop on Earth Resources Satellite Applications, Washington, D.C., December 1969.

8. P.G. White. An Ocean Color Mapping System. TRW Systems, Proceedings of the Fifth Annual Symposium of the Marine Technology Society, 1969.

7. Bibliography

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Steller, D.D. Multisensor Mapping of Coastal Effluents. Proceedings of the Fourteenth Annual Technical Symposium, Society of Photo-Optical Instrumentation Engineers, 1969.

Strandberg, Carl H. Aerial Discovery Manual. John Wiley and Sons, New York, 1967.

Barringer, A.R. Remote Sensing of Marine Effluents, Oceans from Space, Gulf Publishing Co., Houston, 1969.

Lowe, D.S., and P.G. Hasell. Multispectral Sensing of Oil Pollution. Proceedings of the Sixth International Symposium on Remote Sensing of the Environment, Vol. II, 1969.

Aukland, J.C., and W.H. Conway, Detection of Oil Slick Pollution on Water Surfaces with Microwave Radiometer Systems. Proceedings of the Sixth International Symposium on Remote Sensing of the Environment, Vol. II, 1969.

Burnett, E.S., and P.G. White. Water Pollution--The Role of Remote Sensing. Journal of Remote Sensing, June/July 1970.

Critical Issues Addressed by Research Cluster

6-O-1

OCEAN POLLUTION IDENTIFICATION, MEASUREMENT, AND EFFECTS

6.3.2.2.2.2
What general aspects of man's progress induce pollution and changes in topography and river systems?

6.3.2.3.1.5
How can pollution and waste from large population centers be effectively controlled?

6.3.2.3.3.1
How can pollution from industrial expansion be controlled, i.e., atmospheric/hydrologic?

6.3.2.3.3.2
How is pollution related to the Earth's topography and climate?

6.3.2.3.3.4
How is pollution affecting the coastal ecological environment?

6.3.3.1.2.4
How do man's activities affect the long term climate pattern?

6.3.3.1.3.2
How does man's modification of the environment affect local climate?

6.3.3.1.3.3
How do great population centers affect local climates?

6.3.3.3.1.1
What effect is exerted on the coastal and inland water body ecologic environments by industrial warm water waste?

6.6.1.1.2.2
How are the physical properties affected by ocean pollution?

6.6.1.1.3.2
How does ocean pollution affect electromagnetic emission from the sea surface?

6.6.1.1.3.3
How does ocean pollution affect the chemical reactions and salinity in the oceans?

6.6.1.1.3.4
How does tidal flushing patterns affect salinity and pollution characteristics?

6.6.1.1.5.2
How is the productivity of the oceans related to ocean pollution?

6.6.1.1.5.4
How can knowledge of the surface slicks be improved?

6.6.1.2.1.4.3
How is the population dynamics affected by ocean pollution?

6.6.1.2.1.4.6
How are surface slicks related to population dynamics?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in communications are needed?

6.6.1.2.2.3.4
What improvements in display facilities are needed?

6.6.1.2.3.3.1
How are population dynamics affected by ocean pollution?

6.6.1.2.3.3.3
How can pollution of the ocean be effectively controlled?

TABLE 1

EARTH OBSERVATIONS - OCEANOGRAPHY
PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
					Spatial	Spectral	Temp.			
1. Sea surface temperature (thermal pollution)	Radiometry, Infrared Microwave Multispectral scanners	Spectral radiance of scene	W/m^2 st-μ W/m^2 st-μ	5 to 10 0. 01 to 0. 1	100 m 100 m		0. 5°C 0. 5°C	5% 5%	Atmosphere Atmosphere	Aircraft over flights with same suite of instruments
2. Spectral characteristic of scene (Pollutants, chloroph.)	Multichannel ocean color sensor	Spectral radiance of scene	W/m^2 st-μ	20 to 80	100 m	150 A		5%	Atmosphere	
3. Spectral characteristics of scene (sedimentation, bottom topography)	Multispectral scanner	Spectral radiance of scene	W/m^2 st-μ	20 to 400	100 m			5%	Atmosphere	
Spectral characteristics of scene (Pollutants)	Absorption spectrometer	Spectral radiance of scene	W/m^2 st-μ	20 to 400	100 m			5%	Atmosphere	
5. Surface roughness	Multispectral microwave scanner	Spectral radiance of scene	W/m^2 st-μ	0. 01 to 0. 1	100 m			1%	Atmosphere	
6. Tonal contrasts, areal extent, clouds	Metric camera, Pan film	Spectral radiance of scene	W/m^2 st-μ	20 to 400	100 m			10% Sensitometry	Atmosphere	

Table 2

EARTH OBSERVATIONS–OCEANOGRAPHY INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10-Band Multispectral Scanner	X	
4.	Radar Imager		
5.	Absorption Spectrometer	X	
6.	Multichannel Ocean Color Sensor	X	
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	Additional frequency bands may be required.
9.	Sferic Detector, UHF		Study under SR &T required.
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

Table 3.

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START	DURATION†	TASK CONCURRENCY
6-0-1	-1	Checkout Equipment		4			15-C	1/wk	15-45	1			
	-2	Clean Lenses		5	EVA		21-B	1/wk	1-2 hrs	1			
	-3	Prepare Equipment - Load Camera, warm-up (& childdown) of non-imaging sensors; prepare data recording & associated display equipment; reference flight plan/ weather advisories.		3			15-B	10-12 Orb/wk	30-70	1			
	-4	Operate Equipment- Experiment sequencing equipment slewing controls, associated electronics, scan optics, data entry & reduction equipment & (monitor) status displays.		3			15-B	10-12 Orb/wk	30-70	1			
	-5	Visual Observations - telescope scan of oceans & major bodies of water - locate targets.		2			8-B	10-12 Orb/wk	30-70	1			
	-6	Other Measurements - Ground truth measurements (Scripps & Galveston Beach). Distance & area measurements via scan optics.		2			8-B	10-12 Orb/wk	30-70	1			
	-7	Monitor Equipment - Monitor camera & non-imaging sensor operation observing sensor status, data collection, time remaining & other experiment parameters.		1			15-B	10-12 Orb/wk	30-70	1			
	-8	Adjust Equipment - Internal camera & sensor adjustments, calibrate instruments with ground truth sites, boresighting & other (maintenance).		1			15-B	3-5 Orb/wk	10-50	1			

C-6-193

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
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0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER
NO. 6-O-2

RESEARCH CLUSTER SYNOPSIS—OCEANOGRAPHY

6-O-2 Solar Thermal Energy Partition and Heating of the Sea Surface Layer

1. Research Objectives
The overall objective of this research cluster is to improve understanding of the physical processes and transformations of energy that occur in the ocean. To achieve this objective, improved knowledge is required of the nature of the partition of the incoming solar energy in the atmosphere and at the air-sea interface. In particular, information is required to determine what part of the total energy is used to heat the surface layer of the sea.

Improvements in our knowledge of the energy partition at the sea surface will allow better forecasts of the temperature changes in the surface layer, heat and water vapor exchange with the atmosphere, and photosynthetic potential of the oceans. These forecasts in turn should lead to improvements in our forecasts of the weather, overall biological productivity of the ocean, distribution of fish population, and propagation of sound waves in the ocean.

Precise data on the solar energy partition and surface heating are basic to determining what fraction of the solar energy is supplied to the atmosphere, what fraction is used to heat the ocean, and what fraction is available for photosynthesis. It is also important in determining the intensity and spectral nature of the radiance that upwells into space from the ocean and atmosphere. This upwelling radiation must be considered in accounting for the total global heat budget and thermal balance of the earth.

The understanding of the energy partition is further complicated by considerations of scattered and reflected radiation from (1) molecules and aerosols in the atmosphere; (2) clouds; (3) the ocean surface; (4) sea water molecules, suspended particles, pollutants, plankton, and other biota; and (5) bottom features. Bioluminescence and other stimulated emission of materials caused by solar and skylight as well as by mechanical excitation are also involved.

2. Background and Current Status
Current theories and descriptive models used by research oceanographers hold that a certain fraction of the incoming radiation arriving at the sea surface is reflected and scattered. This fraction is known to be a function of the incident angle of the sun and the state of the sea surface influenced by roughness, foaminess, slicks, suspended material, etc. Part of the energy causes the surface sea water to evaporate. The amount evaporated depends on the micrometeorological state of the atmosphere adjacent to the surface. Part of the energy heats the surface layer, and part is transmitted into the depths. As

this transmitted energy penetrates into the ocean depths, it is progressively scattered and absorbed by sea water molecules and suspended matter. Some of this absorbed energy is used in photosynthesis, but the larger part is used in heating the turbid sea water. At the surface of the sea a radiative exchange of long-wave thermal energy takes place with the atmosphere. Current theories consider that there is a net loss of thermal energy from the sea to the atmosphere and space; under certain conditions of cloud cover and temperatures aloft, surface energy may be gained. Finally the models describe how energy is exchanged with the sea surface by molecular and eddy conductivity from the atmosphere and from beneath the ocean surface.(1) Clearly the theories that describe energy partition are complicated and consider many interrelated features of both the ocean and atmosphere. These theories describe the true physical dynamics and interactions to only a restricted degree. The researchers require advances in theories and models to describe the real world to greater fidelity. Precise knowledge of the exact nature of the energy partition, however, is basic to the correct interpretation of measurements of parameters (such as sea surface temperature) made by remote sensors from spacecraft and aircraft. In a physical sense, this knowledge is basic to the ability to improve forecasts of the future states of both the atmosphere and the oceans.

The three-dimensional temperature distribution in the surface layers of the sea can be explained by the energy partition characteristics.(2) This temperature distribution is continually changing, from hour to hour, from day to day, and from year to year. The characteristics of the temperature distribution as determined by the energy partition is thought to be modified by the ocean motions, particularly turbulence associated with surface waves, convection from cooling, and upwelling caused by wind-induced currents. This temperature structure is most important to researchers for a number of reasons, such as determining (1) fish population distribution, (2) heat and water-vapor exchange with the atmosphere, (3) pollution and nutrient diffusion in the ocean and (4) sound-wave propagation in the ocean.

The energy partition estimates used by oceanographers at present are determined mainly by indirect methods using an energy balance equation and averaged measured values of the parameters. It is used for diagnostic purposes in studies of the larger-scale aspects of air-sea interaction and the temperature changes in the ocean.

3. Description of Research

Central to an advance in understanding of the nature of the energy partition are data on the net heat flux at the ocean surface. A technique to measure this has been researched by E. D. McAlister at Scripps Institution of Oceanography.(3) With this technique the infrared radiation intensities in two closely spaced bandwidths in the 4 to 5μ region are measured, from which the vertical temperature gradient of a thin (a few microns) sea surface layer as well as the surface temperature can be determined. By considering the heat-transfer phenomena, this temperature gradient can be used to estimate the total heat flux at the sea surface. Water vapor and clouds in the atmosphere, by absorbing the radiation, limit the usefulness of this measurement from altitude. However, a similar remote sensing technique using the microwave region of the spectrum has the potential to overcome these atmospheric effects, and instrument developments in this area would lead to all-weather capabilities. Further research in this area is required to determine more precisely the optical properties of sea water in the microwave region of the spectrum and to extrapolate the infrared techniques studies by McAlister to microwave hardware.

The Earth orbital activities required to support this research cluster will initially involve dual-channel microwave radiometric measurements of sea surface temperature and total heat flow, probably using the 8-mm and 3-cm wavelengths. Exact wavelength selection would follow extensive laboratory investigations relative to the optical properties of water in these microwave regions. These surface investigations would be followed by airborne trials to further develop a microwave capability from remote platforms. Space platforms will provide the only acceptable means of obtaining the needed real-time synoptic data on a global scale.

The initial flight instruments should have the flexibility for adjusting and selecting the channel wavelength and polarization during the mission. During these activities, the onboard scientists would direct their attention toward proving out the optimal channels to be employed for routine data collection.

Initially, air-temperature and water-vapor profiles near the sea surface must be measured from buoys or ships. Verification data for wind, sea surface temperature, and sea roughness should also be obtained from these platforms. Potentially the vertical air temperature and water vapor profiles can also be measured by the use of dual-channel techniques. One of the research objectives would be to develop and evaluate such a technique, using the data collection system, onboard data processing and displays.

Later missions would serve to provide research oceanographers with the precise data required to refine the descriptive and quantitative models of energy partition and total global heat budget. In addition to the heat flow data, absolute measurements of incoming solar radiation and albedo of the atmosphere would be needed. World-wide synoptic knowledge of the energy interchange will eventually lead to improved long-range forecasts of both weather and ocean surface conditions.

In summary, Earth orbital activities are essential to provide researchers with the synoptic global data required to gain fuller understanding of the solar thermal-energy partition. This improved understanding leads directly to increased knowledge of the sun-atmosphere-Earth heat engine, which determines geographic climate and weather. Space-based research requires evolutionary support from both ground-based investigations and airborne trials.

4. Impact on Spacecraft

Facilities for rapid computation of heat flux from measurements are desirable. This would allow assessment of experiment procedures and equipment functioning.

These space activities would also require close coordination with surface-based activities to gather the required in situ truth site measurements for remote-sensing data interpretation. These early missions would serve to develop a statistical base of data over varying conditions of sea state, surface winds, and cloudiness; and over a series of selected geographical regions.

5. Required Supporting Research and Technology

To achieve the research objectives of this cluster, several research and technology development items are required. Basically, existing microwave radiometers were not designed specifically for heat-flow measurements. They could be used, however, and compared with other techniques and instruments to help determine the desired characteristics of a heat-flow microwave radiometer. From this research, an advanced microwave radiometer that can measure temperature with a precision of 0.01° C with a resolution ultimately of 100 meters from the spacecraft altitude (250 = 300 mmi) would be developed.

To utilize this data, models relating heat flow to sea surface temperature have to be developed. Such models have to take pertinent atmospheric and oceanographic parameters into account.

6. References

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Critical Issues Addressed by Research Cluster

6-O-2

SOLAR ENERGY PARTITION AND HEATING IN THE SEA SURFACE LAYER

6.1.2.4.1
What are the energy dissipation mechanisms in the ocean?

6.3.2.3.2.4
What effect would be produced on the ecology of coastal areas supporting atomic power stations?

6.3.3.1.1.1
How does the global heat balance affect world climate?

6.3.3.1.2.1
How does the regional heat balance affect regional climates?

6.3.3.1.2.4
How do man's activities affect the long term climate pattern?

6.3.3.1.3.1
How does the local heat balance affect local climates and can this be controlled?

6.3.3.1.3.2
How does man's modification of the environment affect local climate?

6.3.3.1.3.3
How do great population centers affect local climates?

6.4.2.3.2.2
What is the rate of heat loss from the Earth's crust (en toto)?

6.4.3.1.2.2
How does the radiant temperature of the Earth contribute to the control of weather?

6.5.2.1.1.4.3.2
How can anomalies in the sea ice pack be related to climatic or subsurface causes?

6.6.1.1.2.3
What are the relations between enery partition at the ocean surface and atmospheric and ocean characteristics and phenomena?

6.6.1.1.3.2
How does ocean pollution affect electromagnetic emission from the sea surface?

6.6.1.2.1.2.1
How is the partition of solar energy at the sea surface affected by the roughness, foaminess, oiliness, etc., of the surface?

6.6.1.2.1.2.2
How is the emission of microwave and infrared radiation of the sea surface affected by the roughness, foaminess, oiliness, etc., of the surface?

6.6.1.2.1.2.5
What is the rate and mechanism of energy dissipation in the ocean?

6.6.1.2.1.4.2
How is the productivity modified by short-term variations in the solar radiation that penetrates the ocean boundary?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.2.16
How can forecasts of sea surface temperature fields be improved?

6.6.1.2.2.2.17
How can forecasts of sea temperature with depth be improved?

6.6.1.2.2.2.18
How can forecasts of mixed layer depths be improved?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in communications are needed?

6.6.1.2.2.3.4
What improvements in display facilities are needed?

6.6.1.2.3.1.1
How much effect does a sea surface film of oil have on evaporation, sensible heat flux and gas exchange?

TABLE 1
EARTH OBSERVATIONS - OCEANOGRAPHY
PARAMETERS TO BE MEASURED

RESEARCH CLUSTER NO. 6-0-2

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial	Spectral	Temp.			
1. Sea Surface temperature	Radiometry Infrared Microwave	Spectral radiance of water	W/m^2-st-μ	5-10 0.01-.1	100 m		0.5° F	5%	Detector, Atmosphere	Simultaneous aircraft overflights with same suite of instruments.
2. Sea surface heat flux	Same as 1.	Spectral radiance of water	W/m^2-st-μ	Same	100 m		0.01° C	5%	Detector, Atmosphere	
3. Sea surface roughness	Microwave radiometry	Spectral radiance of water	W/m^2-st-μ	0.01-.1	100 m			5%	Atmosphere	
4. Sea color	Multispectral color sensor	Spectral radiance of water	W/m^2-st-μ	20-400	100 m	100 A		5%	Atmosphere	
5. Cloud cover	Metric camera (panchromatic film)	Areal features	kilometers	0.1-300	100 m			5%	Sensor	
6. Precitation	Microwave radiometry	Same as 1	W/m^2-st-μ	0.01-.1	100 m			5%	Background	

Table 2

EARTH OBSERVATIONS—OCEANOGRAPHY

INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10-Band Multispectral Scanner	X	(10.2 - 12.6 u band only)
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	X	
7.	Radar Altimeter/ Scatterometer	X	
8.	Microwave Scanner Radiometer	X	Additional frequency bands may be required. Study under SR&T required.
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-O-2

Table 3 -3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE ‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-0-2 -1	Checkout Equipment		4			15-C	1/wk	15-45	1			
-2	Clean Lenses		5	EVA		21-C	1/wk	1-2	1			
-3	Prepare Equipment - Load Cameras, Warm-up electronics, checkout experiment systems, monitor associated electronics and displays & update flight plan.		3			15-B	5-6 Orb/wk	30-70	1			
-4	Operate Equipment - Experiment sequencing equipment, Sensor slewing controls, associated electronics, scan optics, data entry and reduction, monitor status displays.		3			15-B	5-6 Orb/wk	30-70				
-5	Visual Observations - Observe sea state, cloud cover, cloud type, etc.		2			8-B	5-6 Orb/wk	30-70				
-6	Other Measurements - Ground-truth measurements over five sites.		2			15-B	5-6 Orb/wk	30-70				
-7	Monitor Equipment - Camera & non-imaging sensor operations, observing sensor status data collection, time remaining & other equipment operation parameters.		1			15-B	5-6 Orb/wk	30-70				
-8	Adjust Equipment - Internal Adjustment to cameras & sensing equipment, calibrating instruments over ground truth sites.		1			15-B	5-6 Orb/wk	30-70				

C-6-2 /

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-0-3

OCEAN POPULATION DYNAMICS AND FISHERY RESOURCES

RESEARCH CLUSTER
NO. 6-O-3

RESEARCH CLUSTER SYNOPSIS—OCEANOGRAPHY

6-O-3 Population Dynamics and Fishery Resources

1. RESEARCH OBJECTIVES. The overall objective of this research cluster is to improve understanding of the population dynamics to determine and improve the maximum sustainable yield of the world's fisheries. To achieve this objective, more knowledge is needed on the interaction of the marine population with its environment. Chapman(1) points out that the natural fluctuations in fishery yield can be quite large from year to year and that the causes of the variation are not well enough known, but that environmental factors appear to play a significant part. He also says that". . . the major overall problem in the development and management of the fisheries of the world ocean is to riddle out the natural processes causing variability in the ocean and the effect of this variability on the variability in abundance and availability of resources supporting major fisheries."

   In particular, Flittner(2) in discussing the forecasting of the availability of albacore tuna in the eastern Pacific Ocean points out that "our problem is threefold: we must know the relation of the albacore population to its environment; we must be able to forecast environmental change accurately to anticipate the responses of albacore tuna to these changes; and we must know the relationship of the fishery to the resource upon which it depends."

2. BACKGROUND AND CURRENT STATUS. The fisheries of the oceans are very important as a primary source of food in some countries and as a supplemental protein source in many others. The potential fisheries, it has been determined, are concentrated in about 10 percent of the ocean's area; the other 90 percent of the ocean, nearly three-quarters of the earth's surface, produces only a negligible fraction of the world's fish catch and appears to have little potential for an increase in yield.(3) The greatest potential yield, about half of the fish supply, occurs in upwelling regions totaling about 1 percent of the surface. The remaining fish yield is caught in coastal waters and a few offshore regions of relatively high fertility.

   The need to develop the yield of the world fisheries increases daily. This need arises from the continually increasing demand for food for a continually expanding population. Chapman(1) has estimated that by the year 2000, the demand for fish will be from five to ten times greater than in 1960, i.e., 200 to 400-million metric tons. However, the NAS/NRC Committee on Resources and Man(4) develops a maximum sustained yield estimate of 150 to 160 million tons; a yield of 100-million tons appears quite possible, but another doubling to 200 million tons is questionable. Higher yields, in theory, may be attained if plankton are harvested. Harvesting plankton at a reasonable cost, however, has yet to be demonstrated, and processing them for general use may be far in the future. It appears that much research is needed to improve the maximum sustainable yield and to develop or improve models for forecasting overall fish production and yield for a particular species or a give area.

Predictions of the overall fish production are derived from analytic models of the population (food chain) dynamics of the ocean, which use estimates of primary (photosynthetic) organic production as inputs. Large variations in these predictions can occur because of the inadequate knowledge (models) of the population dynamics in the various regions and the uncertainties associated with estimates of the primary production used as inputs. This knowledge and associated models, also need to consider the effects (1) of the loss of population from fishing and (2) of pollution in altering the reproductive, growth, and death rates within the population.

3. DESCRIPTION OF RESEARCH. An intermediate research objective in this area is to improve the relationship between the potential productivity and the actual fish catch. A measure of this potential productivity is the abundance of phytoplankton in a region. Phytoplankton abudance is the result of the primary (photosynthetic) organic production process. This photosynthetic production is determined primarily by the sunlight penetrating down through the surface layer, the nutrients available and the amount of CO_2 dissolved in the water. Phytoplankton use the sunlight, CO_2, and nutrients to reproduce and grow. They form the basis of the food chain that supports the species of interest to man. The photosynthesis process, the subsequent population distribution among the species, and the overall productivity are a consequence of the population dynamics and the local physical, chemical, and biological conditions.

The sunlight that is incident on and penetrates into the ocean is reflected and scattered back to space from the atmosphere, the water surface, the ocean interior, and the ocean bottom. The interior scattering may be due to the water inself, the phytoplankton, other biochromes, suspended sediment, or pollution. It has been found by measurements from aircraft that the spectra of the reflected solar radiation (radiance) from the sea can be used as a measure of the chlorophyll concentration in the sea.(5) An increase of chlorophyll concentration causes a relative increase in the green and a decrease in the blue part of the spectrum. Since chlorophyll is associated with living plants (phytoplankton), this measurement can be used as an index of phytoplankton abundance. The second objective, then, is to determine from space whether the spectral radiance signal due to chlorophyll can be determined from the solar radiation that is scattered and reflected from the sea. If this can be done with enough precision, the resulting index of phytoplankton abundance can then be used as basic data for improving productivity forecasts.

Ground truth data from ships, which is required to support these two objectives, are direct samples of phytoplankton abundance, simultaneous measurements of the spectral distribution of solar irradiance, surface roughness, suspended sediments, and pollutants. Some measure of fish yield is also needed. If the technique is feasible, these data will be required on a regular schedule of at least once a week for a period of several years.

4. IMPACT ON SPACECRAFT. Facilities for data processing are desirable, including readout of data and development of film. Computer facilities are also needed to check simple models for chlorophyll concentration and fish distribution.

5. REQUIRED SUPPORTING TECHNOLOGY DEVELOPMENT. To improve the use of remote sensing for population dynamics and fishery resources, several supporting research and technology items are needed. An analytical model is needed to relate the spectral distribution of reflected radiance quantitatively to chlorophyll concentrations and other population parameters. This model can then be used to test and evaluate ocean color sensors and multispectral scanners for the measurement of these population dynamic parameters. From this research, improved instruments for aircraft and spacecraft can be designed. Another model that is required to take full advantage of the chlorophyll-concentration measurements is an analytical model that relates photosynthesis (as indicated by chlorophyll concentration) to current and future fish population distributions.

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5. G. L. Clarke, G. C. Ewing, and C. J. Lorenzen. Spectra of Backscattered Light from the Sea Obtained from Aircraft as a Measure of Chlorophyll Concentration. Science Vol. 167. 1970, pp. 1119-1121.

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Critical Issues Addressed by Research Cluster

6-O-3

OCEAN POPULATION DYNAMICS AND FISHERY RESOURCES

6.6.1.1.5.1
What is the population dynamics of the ocean?

6.6.1.1.5.2
How is the productivity of the oceans related to ocean pollution?

6.6.1.1.5.3
How is the population distribution of the biota affected by cloud cover and precipitation?

6.6.1.2.1.4.1
How is the nutrient distribution affected by turbulence in the ocean?

6.6.1.2.1.4.2
How is the productivity modified by short-term variations in the solar radiation that penetrates the ocean boundary?

6.6.1.2.1.4.3
How is the population dynamics affected by ocean pollution?

6.6.1.2.1.4.4
How is the biota distribution affected by temperature and salinity changes?

6.6.1.2.1.4.5
How is the population distribution affected by kelp beds?

6.6.1.2.1.4.6
How are surface slicks related to population dynamics?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.2.4
How can forecasts of nutrients be improved?

6.6.1.2.2.2.5
How can forecasts of fish population be improved?

6.6.1.2.2.2.14
How can forecasts of upwelling be improved?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in communications are needed?

6.6.1.2.2.3.4
What improvements in display facilities are needed?

6.6.1.2.3.3.2
How does changing the sea color affect ocean heating and photosynthesis?

Table 1

EARTH OBSERVATIONS – OCEANOGRAPHY

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp.	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Sea surface temperature	Multispectral scanners I. R. Microwave	Spectral radiance of scene	W/m^2-stn-	5 to 10 .01 to .1	180 m. 100 m.		0.5°C 0.5°C	5% 5%	Atmosphere Atmosphere	Aircraft overflights with same suite of instruments
2. Spectral characteristics of scene	Multi channell ocean color sensor	Spectral radiance of scene	W/m^2-stn-	20 to 80	100 m.	150 A		5%	Atmosphere	
3. Spectral characteristics of scene	Multispectral scanner	Spectral radiance of scene	W/m^2-stn-	20 to 400	100 m.		0.5°C	5%	Atmosphere	
4. Surface roughness	Multispectral microwave scanner	Spectral radiance of scene	W/m^2-stn-	.01 to .1	100 m.			5%	Atmosphere	
5. Clouds	Metric camera	Areal extent	kilometers	.1 to 100	100 m			"	"	

Table 2
EARTH OBSERVATIONS – OCEANOGRAPHY
INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner	X	(10.2 - 12.6 u band only)
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor	X	
7.	Radar Altimeter/Scatterometer		
8.	Microwave Scanner Radiometer	X	Additional frequency bands may be required. Study under SR&T required.
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-0-3

Table 3 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-0-3 -1	Checkout Equipment		4			15-C	1/wk	15-45				
-2	Clean Lenses		5	EVA		21-C	1/wk	1-2 hrs				
-3	Prepare Equipment - Camera loading, electronics warmup (and chilldown) of non-imagery sensors, preparation of data recording equipment & associated display equipment & referencing flight plan updates from ground sources.		3			15-B	8-10 Orb/wk	30-70				
-4	Operate Equipment - Experiment sequencing equipment, slewing controls, associated electronics, scan optics, & data entry & display equipment, monitor sensor status.		3			15-B	8-10 Orb/wk	30-70				
-5	Visual Observations - Visual description & voice supplementary data annotations in conjunction with the use of optics & displays.		2			8-B	8-10 Orb/wk	30-70				
-6	Other Measurements - Ground truth measurements; location information using optics.		2			15-B	8-10 Orb/wk	30-70				
-7	Monitor Equipment - Camera & non-imaging sensor operation (observing sensor status) data collection, time remaining & other experiment parameters.		1			15-B	8-10 Orb/wk	30-70				
-8	Adjust Equipment - Internal camera & sensor adjustment, calibrate instruments in conjunction with ground-truth site overfly. Boresighting & other (maintenance).		1			15-B	3-5 Orb/wk	30-70				

C-6-214

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

Do not Reproduce

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER—6-0-4

OCEAN CURRENTS AND TIDE FORECASTING

RESEARCH CLUSTER SYNOPSIS--OCEANOGRAPHY

6-O-4 Ocean Currents

1. Research Objectives

The overall objective of this research cluster is to improve knowledge and forecasts of the ocean currents. To achieve this objective, more information is needed of the variations of the height of the sea surface relative to the equipotential surface, which is at or close to the geoid.

2. Background and Current Status

Knowledge of the ocean currents is important in determining heat, mass, and momentum transport in the ocean. In particular, this knowledge is needed to assist in the research on population dynamics, dispersion and transport of pollutants and energy balance for forecasting the ocean and atmospheric parameters.

Ocean currents may result from many physical processes, among which are wind drag, differences in density, tides, and internal waves. It is generally assumed that the large-scale quasi-permanent currents are associated with differences in mean sea surface height relative to the equipotential or level surface. This height difference may be caused by dynamic balance or variations in the density field. In the former case, the height difference is a result of the currents; in the latter case, the density and distribution cause the height difference and hence the currents. These types of currents are known as geostrophic currents. In both cases, it is actually the slope of the sea surface that is the pertinent parameter. The variation of the density field, however, is basically determined by the temperature field. Thus some currents and their variation may be estimated by the temperature field. (1, 2)

In general, these geostrophic currents are slowly varying in depth, width, and speed. Once these currents are known, transports of mass and heat can be estimated. The current structure beneath the surface can also be estimated if the density field is known. The density field can be determined if temperature and salinity data are available from hydrographic soundings. At present, these surface currents are estimated from the hydrographic data by assuming a surface of no motion at some depth in the ocean. This depth is never known; it is only estimated. Consequently, the estimates of the current structure of the ocean are inaccurate. Thus, knowledge of the sea surface height variations would improve knowledge of the surface current and subsurface current distribution. (3)

To improve forecasting of the currents, it is necessary to first improve the estimates of the currents, either directly through measurement or indirectly by calculation from other data.

3. Description of Research

To estimate the variations in the sea-surface mean height, a radar altimeter would be used to determine the distance from the spacecraft to the sea surface. The distance from the spacecraft to the center of the Earth's coordinate system would be estimated from the spacecraft track obtained from the inertial platform data. The difference then would be the height of the sea surface from the center of the coordinate system. Thus the satellite altimeter would provide an estimate of a topographic map every 24 hours. To be most useful in oceanographic applications, however, this surface must be referred to an equipotential surface at, or close to, the geoid; and the surface height measurement must be as precise as possible, at least within ±3 centimeters.

To achieve this precision, the sources of error must be reduced to a minimum. One error will arise from the measurement of the time that the return signal arrives. This occurs because the wave front is curved and the sea surface is rough, which means that a gating and averaging technique must be developed. To develop these techniques, a scientist would use an oscilloscope to observe the return wave. Variations in the gating and averaging would be performed to reduce the signal fluctuations caused by the wind waves; swell; and if possible, clouds; perturbations of the spacecraft; and inhomogenieties of the atmosphere. In addition, different power-levels, wave lengths, pulse durations, and repetition rates would be tried to achieve better precision and accuracy.

Ground truth needed will include data on the sea surface temperature, roughness, gravity field, ocean currents, and wind velocity.

4. Impact on Spacecraft.

Laboratory facilities will be required to monitor, test, and modify the radar altimeter scatterometer system. Development facilities for film will also be necessary for evaluating altimeter data.

5. Required Supporting Research and Technology

To determine the relative sea surface heights to within ±10 cm by 1972 and ±3 cm by 1975(4) requires several developments in research and technology. In addition to improved instrument sensitivity and signal processing, an analytical model must be developed, that relates signal characteristics to sea surface' heights and which includes atmospheric absorption, reflection, and refraction effects. Another model is required that will transform the relative mean distance from sea surface to spacecraft into mean sea surface height relative to the geoid. Time and space variations of this mean sea surface height must then be related to expected current.

6. References

1. G. Warnecke, L. M. McMillin, and L. J. Allison. Ocean Currents and Sea Surface Temperature Observations from Meteorological Satellites. NASA, TN-D 5142, 1969.

2. Raymond D. Nelson. The Potential Application of Remote Sensing to Selected Ocean Circulation Problems. Oceans from Space, 1969.

3. J. A. Greenwood, A. Nathan, G. Neumann, W. J. Pierson, F. C. Jackson, and T. E. Pease. Oceanographic Applications of Radar Altimetry from a Spacecraft. Remote Sensing of the Environment, Vol. 1, 1969, pp. 71-80.

4. W. Kaula, editor. The Terrestrial Environment: Solid Earth and Ocean Physics. NASA CR-1579, April 1970.

7. Bibliography

Laevastu, T. The Causes and Predictions of Surface Currents in Seas and Lakes. Hawaii Institute of Geophysics Report No. 21, 1962.

Von Arx, W. S. Introduction to Physical Oceanography. Addison-Wesley Publishing Co., New York, 1962.

Critical Issues Addressed by Research Cluster

6-O-4

OCEAN CURRENTS AND TIDE FORECASTING

6.3.1.2.1.3
How can abnormally high water conditions in the coastal environment be controlled for sustained periods?

6.3.2.3.2.4
What effect would be produced on the ecology of coastal areas supporting atomic power stations?

6.4.2.3.1.1.4
What is the effect of lunar cycle on Earth tides?

6.5.1.1.2.8
What is the location of large icebergs which can be used as a source of fresh water?

6.5.2.1.1.4.3.1
How is sea ice movement related to climatic and ocean current patterns?

6.6.1.1.1.1
How does the sea surface height vary because of variations in the Earth's gravitational potential?

6.6.1.1.2.4
What are the relationships between distribution of ocean variables on the small scale and ocean turbulence and other motion?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.2.2
How can forecasts of movements of silt and sand be improved?

6.6.1.2.2.2.6
How can forecasts of tides be improved?

6.6.1.2.2.2.7
How can forecasts of storm surges be improved?

6.6.1.2.2.2.8
How can forecasts of tidal waves be improved?

6.6.1.2.2.2.10
How can forecasts of icebergs and ice movement be improved?

6.6.1.2.2.2.12
How can forecasts of mean sea surface height be improved?

6.6.1.2.2.2.13
How can forecasts of ocean currents be improved?

6.6.1.2.2.2.14
How can forecasts of upwelling be improved?

6.6.1.2.2.2.15
How can forecasts of diffusion be improved?

6.6.1.2.2.2.21
How can forecasts of convergence zones be improved?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in communications are needed?

6.6.1.2.2.3.4
What improvements in display facilities are needed?

6.6.1.2.3.1.2
How much effect does an oil film have on the character of wind stress and momentum flux on the ocean surface?

TABLE 1

EARTH OBSERVATIONS - OCEANOGRAPHY
PARAMETERS TO BE MEASURED

RESEARCH CLUSTER
NO. 6-0-4

		Characteristics of Parameters Measured By Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution Spatial	Instrument Resolution Spectral	Instrument Resolution Temp.	Measurement Precision	Predominant Noise Source	Control Measurements At Truth Site Or On Spacecraft
1. Sea surface mean height	Radar altimeter	Sea surface height	cm.	0 to 100	3 cm			3%	Surface roughness, Precipitation	Overflights with aircraft
2. Clouds and sea surface	Metric camera	Clouds, glitter pattern	Areal extent Areal extent Km.	0. 1 to 100	100 to 500m			10%	Atmosphere	

Table 2

EARTH OBSERVATIONS—OCEANOGRAPHY

INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner		
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer	X	
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		

Table. 3 - 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER
NO. 6-O-4

(58)

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-0-4	-1	Checkout Equipment		4			15-C	1/wk	15-45				
	-2	Clean Lenses		5	EVA		21-C	1/wk	1-2 hrs				
	-3	Prepare Equipment - Load Camera, prepare electronics, checkout & test, reference flight plan; input ephemeris.		3			15-B	8-10 Orb/wk	30-70				
	-4	Operate Equipment - Scan optics, ancillary electronics, sensor platform slewing controls, experiment sequencing equipment & voice magnetic tape recorders, computational & data processing equipment.		3			15-B	8-10 Orb/wk	30-70				
	-5	Visual Observations - provide supporting data on sea-state, color, & cloud cover.		2			8-B	8-10 Orb/wk	30-70				
	-6	Monitor Equipment - Camera operation sensor operating status, data processing equipment. Reference flight plan.		1			15-B	8-10 Orb/wk	30-70				
	-7	Adjust Equipment - Internal sensors (cameras, etc.), calibrate with ground-truth sites.		1			15-B	1-2 Orb/wk	30-70				

C-6-22[illegible]

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS--OCEANOGRAPHY

6-0-5 Physical Properties

1. Research Objective

The overall objective of this research cluster is to improve knowledge of the physical and chemical properties of the ocean, in particular, the density structure and variations which are basic to determining many of the characteristics. To achieve these objectives, a more systematic monitoring of the salinity and temperature structure is needed. This information on the density is required to utilize and check the theories regarding current distribution in the ocean, ice formation and dissipation, fish population distribution, and energy exchange between the ocean and the atmosphere.

Increased knowledge of the physical and chemical properties of the ocean is important for determining not only density variations but also for understanding turbulent mixing and corrosion, estimating sound and light wave scattering, and formulating models of the marine ecological system.

2. Background and Current Status

Density variations in the ocean are fundamental factors in determining the relative heights of pressure surfaces, including the sea surface, and hence the large scale (geostrophic) currents. Density is determined by the temperature, pressure, and composition of the sea water; this, however, is not a simple relationship. The basic relationship is fairly well known, but there are nonlinear interrelationships that require further research.

Composition is represented by salinity. In general, it has been found that the individual components of the composition have the same percentage relationship regardless of the location and the overall salinity in parts per thousand. This does not hold true along coasts where river runoffs are significant. This also may not hold true where heavy precipitation has occurred or where pollution is a significant factor. Turbulent mixing is an important factor in determining the uniformity of composition, as well as the distribution of salinity and temperature. Turbulent mixing may be caused by wave action, sea surface cooling, and spatial variations of currents.

Density is usually determined from measurements of temperature and salinity as a function of pressure (depth). Although these data are determined by hydrographic casts, surface variations of salinity, temperature, and hence density could be estimated from remote sensing techniques. Variations of density with time at a given point, therefore, may be due to variations of salinity and temperature from turbulent mixing, advection, and heating or cooling.

3. Description of Research

Density at the sea surface is determined mainly by the salinity and temperature of the water. Salinity variations cause variations in the dielectric constant of the water and hence emissivity, especially in the microwave frequency band.(1) Temperature determines the intensity of the emitted radiation, but it also influences the value of the emissivity in the microwave frequency band. Theoretically, therefore, it is possible to remotely measure salinity by sensing the polarized microwave radiation at wavelengths longer than 10 cm. On the other hand, at these wavelengths emissivity is little affected by the temperature; consequently, the total radiation flux is proportional to the temperature of the water. Thus, one of the first sets of experiments should be oriented toward verifying whether or not variations in salinity can be detected remotely.

Since density is a function of temperature and salinity, it is necessary to compare the variations of each separately with variations of atmospheric and other ocean parameters, such as current and upwelling, to understand the variations in density. Some of these atmospheric parameters that need to be considered are wind velocity, cloud cover, precipitation, temperature, and humidity. Thus, over a test site the multichannel microwave radiometer would record data from which the temperature, salinity, seastate, and rainfall could be determined. A radar imager should also be tested to determine utility for obtaining rainfall data. A metric camera would be used to obtain fine detail of the areal characteristics of the sea surface and cloud cover. Buoys and ships would be used to obtain the necessary ground data, such as sea surface roughness, sea surface and atmospheric temperature, atmospheric humidity, ocean salinity, wind velocity, and ocean currents.

4. Impact on Spacecraft

Facilities are desirable for processing and analyzing selected data. The ability to record the descriptions of visual surface characteristics on tape will also be necessary.

5. Required Supporting Research and Technology

In general, other techniques and instruments should be developed to use reflectance and thermal radiance from the sea surface and overlying clouds to determine the physical properties of the ocean. Basically, an improved mathematical model is needed that relates the physical, biological, and chemical processes to the spectral reflectance, emission, and polarization of radiation from the ocean. Such a model could be used as a guide to develop improved instrumentation for the remote measurement of salinity. In addition a forecast model that relates ocean and atmospheric parameters to ice distribution is also needed.

6. References

1. H. A. Hyatt. Emission, reflection and absorption of microwaves at a smooth air water interface. Journal of Quantitative Spectroscopy and Radiative Transfer, Vol. 10, 1970, pp. 217-47.

7. Bibliography

Hill, M. N., editor. The Sea, Vols. I and II. Interscience Publishers, New York, 1963.

Sverdrup, H. V., M. W. Johnson, and R. H. Fleming. The Oceans. Prentice Hall, New York, 1942.

Critical Issues Addressed by Research Cluster

6-O-5

OCEAN PHYSICAL PROPERTIES

6.5.1.2.2.1
What are the water circulation patterns in coastal waters, estuaries, and large lakes?

6.5.1.2.2.2
What are the effects of currents and tidal flows upon harbors and estuaries?

6.6.1.1.3.1
How is the salinity field of the ocean surface affected by precipitation, evaporation and runoff from land?

6.6.1.1.3.3
How does ocean pollution affect the chemical reactions and salinity in the oceans?

6.6.1.1.3.4
How does tidal flushing patterns affect salinity and pollution characteristics?

6.6.1.1.4.2
How does aeolian transport affect the composition of sea water and sediments.

6.6.1.1.5.2
How is the productivity of the oceans related to ocean pollution?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.2.1
How can forecasts of the density be improved?

6.6.1.2.2.2.3
How can forecasts of salinity be improved?

6.6.1.2.2.2.10
How can forecasts of icebergs and ice movement be improved?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in communications are needed?

6.6.1.2.2.3.4
What improvements in display facilities are needed?

TABLE I

EARTH OBSERVATIONS—OCEANOGRAPHY

—PARAMETERS TO BE MEASURED

SPACE-DETECTABLE PHENOMENON	TYPE OF INSTRUMENT (AND FILM)		CHARACTERISTICS OF PARAMETERS MEASURED BY INSTRUMENTATION							CONTROL MEASUREMENTS AT TRUTH SITE OR ON SPACECRAFT
		PARAMETER DESCRIPTION	UNITS	DYNAMIC RANGE (min/max)	SPATIAL	SPECTRAL	TEMP.	MEASUREMENT PRECISION	PREDOMINANT NOISE SOURCE	
1. Ice surface characteristics	Radar Side looking	Height Areal extent	Meters Kilometers	0 to 10 0 to 1000	1 m 10 m			5% 5%	Instrument Instrument	Aircraft overflights with same suite of instruments.
2. Salinity at sea surface	Multichannel Active/passive microwave radiometer	Radiance	W/m^2-sr-μ	.01 to 0.1	100 m			5%	Instrument	
3. Sea surface temperature	Same as 2	Radiance	W/m^2-sr-μ	.01 to 0.1	100 m		0.5°C	5%	Instrument	

Table 2

EARTH OBSERVATIONS – OCEANOGRAPHY

INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner		
4.	Radar Imager	X	
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer		
8.	Microwave Scanner Radiometer	X	Additional frequency bands may be required. Study under SR&T required.
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-0-5

Table 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-0-5 -1	Checkout Equipment		4			15-C	1/wk	15-45				
-2	Clean Lenses		5	EVA		21-C	1/wk	1-2 hrs				
-3	Prepare Equipment - Load camera, prepare electronics, checkout & test; reference flight plan, input ephemeris.		3			15-B	8-10 Orb/wk	30-60				
-4	Operate Equipment - Scan optics, ancillary electronics, sensor platform slewing controls, voice recording, computational & data processing equipment.		3			15-B	8-10 Orb/wk	30-70				
-5	Visual Observation - Describe ground conditions (wave height, sea color, wave-length, surface roughness), supplement non-imaging data.		2			15-B	8-10 Orb/wk	30-60				
-6	Monitor Equipment - Camera operation, sensor status, data processing equipment; reference flight plan (assure data collection).		1			15-B	8-10 Orb/wk	30-60				
-7	Adjust Equipment - Calibrate internal sensors (cameras and other instruments) with ground measurements/ground-truth stations.		1			15-B	8-10 Orb/wk	10-20				

C-6-232

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

TA [illegible] 2

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

Do not Reproduce

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER–6-0-6

OCEAN SOLID BOUNDARY PROCESSES

RESEARCH CLUSTER SYNOPSIS—OCEANOGRAPHY

6-O-6 Solid Boundary Processes

1. RESEARCH OBJECTIVES. The overall objective of this research cluster is to improve knowledge of the processes that change the character and shape of the coastlines and the adjacent ocean bottom. To achieve these objectives, information is needed on the nature and rates of erosion and sedimentation of the coastline; the effect of harbor and coastline construction and modification activities on currents and flushing patterns; and the relationship of high swells, tsunami's, and tidal waves to bottom topography and coastline shape.

   The shape and nature of the coastlines is determined by the erosion and sedimentation characteristics. These in turn are regulated by the longshore currents. Ersosion is primarily caused by windwaves and the breaking of swells on the coast. The material loosened is carried out to sea by the undertow and transported along the shore by the currents induced by tides, wind, waves, and swells.

2. BACKGROUND AND CURRENT STATUS. The major problems are the anomalous erosion of beaches and sedimentation of harbors, both of which may be caused by man's activities. One of the major causes of beach erosion appears to be the reduction of sediment load from rivers due to the presence of flood control dams.(1) Another cause is the construction of jetties, which trap the sand and hence reduce the sediment load downstream. Sedimentation of harbors may be caused by construction that changes the currents.

   Excess erosion and deposition can be caused by anomalous weather conditions that change the usual swell and longshore currents. The worst conditions are caused by tsunamis and tidal waves of non-earthquake origin. These phenomena can cause excessive damage, and are difficult to predict. Tidal waves caused by meteorological patterns are much easier to predict than tsunamis. Both, however, are affected by the bottom topography, as are the swell and longshore currents. Therefore, the bottom depths and the coastline shape are continually changing and the changes must be monitored continually, so that knowledge about them can be kept up to date.

3. DESCRIPTION OF RESEARCH. To predict the changing nature of the coastline, particularly beaches and harbors, relationships between coastal currents, their sediment load and tide, wind, and swell need to be developed among other things. This means an extensive measurement program in

a particular area to acquire data on (1) the variation of longshore and ripcurrents with wind velocity, sea roughness and tides, (2) variation of the sediment load of the currents and rivers, (3) the changing shape and nature of the coastline and adjacent ocean bottom, (4) construction and dredging activities, and (5) the biota and pollutant characteristics.

A high-resolution radar or metric camera should be able to provide the necessary data on the coastline shape. For bottom topography, it has been proposed that multispectral photography be used.(3) Sediment load pollutants, and biota, however, affect the spectral characteristics.(4) It would appear that a model to determine the various components, such as sediment, bottom depth, and pollutants, must first be developed. This model could then be tested for usefulness by acquiring data with a multispectral camera or scanners mounted in an aircraft. In this respect, lidar appears to be useful for measuring bottom topography at least to tens of meters depth.(5) Such flights would also help define the needed ground truth requirements (described above).

4. IMPACT ON SPACECRAFT. Facilities and equipment will have to be provided to develop, process, and analyze film as needed. Storage, readout, and analysis facilities for imagery will be required as necessary, and a telescope for visual scanning is desirable. Flexibility of experiment sequencing and crew duty cycles is desirable to assess the results of unusual storm conditions, and the occurrence of tsunamis or earthquakes.

5. REQUIRED SUPPORTING TECHNOLOGY DEVELOPMENT. To use the techniques described above, it is necessary first to develop a computational model that relates spectral radiance to the depth of the ocean floor and takes into account the scattering in the atmosphere and ocean by all types of pollutants and life forms. The scattering and reflection at air-to-sea interfaces must also be considered. This model, in conjunction with data provided by the currently available instrumentation, could be used to evaluate the techniques and to determine the improved instruments that are needed for space use. Models relating erosion and deposition to other oceanographic and meteorological parameters also need development.

6. REFERENCES

1. Wesley Marx. The Frail Ocean. Ballentine Books, 1967.

2. T. Saville. Paper presented at Spacecraft Oceanography Project Workshop, December 16 to 18, Washington, D.C., 1969.

3. D. S. Ross. Color Enhancement for Ocean Cartography in Oceans From Space. Gulf Publishing Co., Houston, 1969.

4. Dr. Pierce. Paper presented at the Spacecraft Oceanography Project Workshop, December 16 to 18, Washington, D.C., 1969.

5. Dr. D. Hickman. Paper presented at the Spacecraft Oceanography Project Workshop, December 16 to 18, Washington, D.C., 1969.

7. BIBLIOGRAPHY

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Critical Issues Addressed by Research Cluster

6-O-6

OCEAN SOLID BOUNDARY PROCESSES

6.3.2.3.3.4
How is pollution affecting the coastal ecological environment?

6.3.3.3.1.1
What effect is exerted on the coastal and inland water body ecologic environments by industrial warm water waste?

6.4.2.2.3.2
What are the positions of land masses, polar ice sheets, and ocean basins?

6.4.2.2.4.3
What evidence is there that the continents are drifting?

6.4.2.2.4.4
What evidence is there of sea floor spreading?

6.4.2.3.2.5
What is the relative rate of drift of the continents?

6.4.2.3.2.9
What are the rates of sea floor spreading?

6.5.1.1.3.2
What are the hydrologic features of coastal regions and large inland lakes?

6.5.1.2.3.2
What are the effects of streamflow and wastes upon coastal waters?

6.6.1.1.1.5
What are the relationships between bottom topography and tsunamis?

6.6.1.1.2.1
How are tidal flushing patterns affected by coastline construction?

6.6.1.1.2.5
How can knowledge of the bottom topography be improved?

6.6.1.1.4.1
How do the volcanological characteristics of the ocean relate to the occurrence of tsunamis?

6.6.1.1.4.2
How does aeolian transport affect the composition of sea water and sediments.

6.6.1.1.4.3
What are the erosion and sedimentation characteristics of the coastlines?

6.6.1.2.1.5.1
How does turbulence affect the transport of particulate matter?

6.6.1.2.1.5.2
How do turbidity currents affect the bottom topography of the ocean?

6.6.1.2.1.5.5
How do the biological processes affect the depositional characteristics?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in computational facilities are needed?

6.6.1.2.2.3.4
What improvements in communications are needed?

6.6.1.2.3.2.1
How do jetties and land fill affect longshore transport?

TABLE 1

EARTH OBSERVATIONS - OCEANOGRAPHY PARAMETERS TO BE MEASURED

RESEARCH CLUSTER
NO. 6-0-6

		Characteristics of Parameters Measured By Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp.	Measurement Precision	Predominant Noise Source	Control Measurements At Truth Site Or On Spacecraft
1. Coastline, areal extent	Radar imager	Distance	meters	10 to 1000	10 m			less than 1%	Instrument Precipitation	Aircraft over-flights with same instruments
2. Sea surface pollutants and sediment load	Multi-spectral scanner	Radiance	W/m^2-μ sr.	20 to 400	100 m			5%	Instrument Precipitation	
3. Bottom topography	Multi-spectral camera	Radiance	W/m^2-μ sr.	0 to 400	100 m			5%	Instrument Precipitation	

Table 2

EARTH OBSERVATIONS—OCEANOGRAPHY

INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera	X	
3.	10 Band Multispectral Scanner	X	
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/Scatterometer	X	
8.	Microwave Scanner Radiometer		
9.	Sferic Detector, UHF		
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Temperature Profile Radiometer		
21.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-0-6
6-0-6

3

FORM 30-1033-1 (REV. 10-67)

Table 3. CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-0-6 -1	Checkout Equipment		4			15-C	1/wk	15-45				
-2	Clean Lenses		5	EVA		21-C	1/wk	1-2 hrs.				
-3	Prepare Equipment - Load camera, prepare electronics, checkout & test, reference flight plan from Space Station or other source.		3			15-B	8-10 Orb/wk	30-60				
-4	Operate Equipment - Scan Optics, ancillary electronics, sensor platform slewing contorls, voice recorder, computational & data processing equipment.		3			15-B	8-10 Orb/wk	30-70				
-5	Visual Observations - Visually-aided observations of coastlines including slewing of instruments & indexing photography; describe cloud cover, water color, sea-state.		2			8-B	8-10 Orb/wk	30-60				
-6	Monitor Equipment - Camera, sensor status, data processing, reference flight plan.		1			15-B	8-10 Orb/wk	30-60				
-7	Adjust Equipment - Calibrate cameras & other sensors with ground measurement/ truth stations.		1			15-B	1-2 Orb/wk	10-20				

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—OCEANOGRAPHY

6-O-7 Sea Surface Roughness

1. Research Objectives

The basic objective of this research cluster is to improve forecasts of the sea surface roughness and the resulting heavy swell on the coastline. To achieve this objective, improved prediction models are needed that relate the temporal variations of the wind stress on the sea surface to the spectral distribution of resulting wave heights. To improve prediction models and the predictions, however, improved information on the distribution of the sea surface roughness is needed. Thus, techniques and instruments have to be developed that can measure the sea-surface roughness parameters. Two basic techniques that require testing have been proposed:

1. Relating the backscattered radar signal to the sea surface roughness. (1)

2. Relating the naturally emitted and reflected microwave radiation to the roughness. (2,3)

This research is required to reduce the time and cost of ship movements on the ocean's surface and to improve the safety of ships at sea, as well as industrial and recreational activities along coastlines and adjacent waters. Improved prediction models are also needed for estimating erosion and transportation processes along coastlines from swells and breakers.

2. Background and Current Status

Sea surface roughness or the spectra of the wave heights is determined principally by the wind stress on the sea surface, the period of time over which it acts, and the distance or fetch over which it is effective. Swells are the remnants of the wave distribution after the waves have traveled out of the area of formation or after the wind has decreased. Swell characteristics are determined basically by the initial wave characteristics, the distance over which it travels from the area of formation, and the bottom topography.

The theory relating the sea surface roughness characteristics to the wind field is quite well developed. Further development and use are limited by the observations. Most observations of the sea surface roughness and wind velocity are taken from ships, and a few from buoys and platforms. One of the areas that requires further study and additional data is the effect of the wind on surface stress characteristics, and the effect of the vertical temperature profile in the sea near the surface on the wave characteristics. Problems areas related to sea surface roughness are involved with:

1. Energy partition at the sea surface.

2. Ocean currents.

It is not known, for example, exactly what determines the partition of wind stress between waves and currents, or the transfer of energy from waves into current.

3. Description of Research

The information necessary to improve the observation and forecasts of the sea surface roughness is fourfold, consisting of:

1. Estimates of the sea surface roughness.

2. Average and variance (RMS gusts) of the wind over the sea surface.

3. Air-sea temperature difference.

4. Surface layer temperature profile.

Ground truth data from buoys or ships will be needed of each of these items. Data from remote sensors will be needed to define the sea surface roughness parameters. Various technique and instrument combinations will be tried, such as the radar or lidar altimeter scatterometer, active/passive radar, multichanneled passive microwave radiometer, and optical imagery.

Although radar scatterometry has been investigated the most extensively of these techniques, it does not give the required RMS sea-state height nor any information on the spectral distribution of waves. That this technique may not be precise enough for wave measurement has been indicated by a recent naval research laboratory study. (4) Measurements taken with a four-frequency radar system indicated only a small variation in the scattering coefficient curve with wind speed frequency. Thus, a further evaluation of the various techniques appears desirable.

4. Impact on Spacecraft

Since the prime purpose of the experiment is comparison and evaluation of different instruments and techniques, facilities for data storage, readout, and analysis are needed. A computer and other equipment for utilizing numerical forecast models are desirable for use in verifying forecasts and modifying these models. A telescope for making visual observations and a tape recorder for annotation are also desirable.

5. Required Supporting Research and Technology

To resolve the conflict indicated above and to better evaluate the other techniques proposed, improved or extended mathematical models are needed. These models should relate the sea surface roughness parameters, atmospheric transmission parameters, and electromagnetic wave-reflection and emission parameters. These models can then be used in conjunction with the instrumentation now available on aircraft to determine the advantages of each system. This information could then be used to assist in the design of an active-passive multispectral microwave imager. Such a radiometer is needed that can provide sufficient information about the absorption, scattering, reflection and emission parameters from which required physical measurements can be derived.

6. References

1. R.K. Moore and G. Bradley. Radar and Oceanography. Proceedings of the Second Earth Resources Aircraft Program Status Review, NASA Manned Spacecraft Center, Houston, September 1969.

2. V.A. Sirounian. Passive Microwave Radiometry of the Sea State. Douglas Report DAC-60786, 1967.

3. A. Stogryn. The Apparent Temperature of the Sea State at Microwave Frequencies. IEEE Transactions on Antennas and Propagation, AP-15, 1967, pp. 278-286.

4. N.W. Guinard and J.C. Daley. An Experimental Study of a Sea Clutter Model. Proceedings of the IEEE, Vol. 58, 1970, pp. 543-550.

7. Bibliography

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Nordberg, W., I. Conaway, and P. Thaddeus. Microwave Observations of Sea State from Aircraft. Quarterly Journal of The Royal Meteorological Society, Vol. 95, 1969, pp. 408-13.

Soules, Stanley, D. Sunglitter Viewed from Space. Deep Sea Research (17), 1970, pp. 191-195.

Critical Issues Addressed by Research Cluster

6-O-7

OCEAN SURFACE ACTIVITY FORECASTING

6.6.1.1.2.4
What are the relationships between distribution of ocean variables on the small scale and ocean turbulence and other motion?

6.6.1.2.2.1.2
How can operational data be transmitted more quickly and accurately?

6.6.1.2.2.1.3
How can the representativeness of sea surface data be improved?

6.6.1.2.2.1.4
How can the time between data acquisition and processed results to the user be improved?

6.6.1.2.2.1.5
What ground truth data is needed to improve data accuracy?

6.6.1.2.2.2.11
How can forecasts of rough seas be improved?

6.6.1.2.2.2.20
How can forecasts of heavy swell on coasts be improved?

6.6.1.2.2.3.1
What oceanographic instruments need further development to improve data needed for prediction?

6.6.1.2.2.3.2
What improvements in computational facilities are needed?

6.6.1.2.2.3.3
What improvements in communications are needed?

6.6.1.2.2.3.4
What improvements in display facilities are needed?

TABLE 1

EARTH OBSERVATIONS - OCEANOGRAPHY PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp.	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Sea surface roughness characteristics	Radar altimeter	radiance	w/m^2-srμ	100 to 10^3	0. 5 km			less than 1%	Instrument Precipitation	Aircraft over-flights with same suite of instruments
2. Same	Active/ passive radar	radiance	w/m^2-srμ	.01 to 10^3	30m			less than 1%	Instrument Precipitation	
3. Same	Radar scatterbox	radiance	w/m^2-srμ	100 to 10^3	0. 5 km			less than 1%	Instrument Precipitation	
4. Same, also clouds	Metric camera pan film	radiance	w/m^2-srμ	20 to 400	50m			5%	Instrument Precipitation	

Table 2
EARTH OBSERVATIONS-OCEANOGRAPHY
INSTRUMENT REQUIRED

No.	Instrument	Applicable	Comments
1.	Metric Camera	X	
2.	Multispectral Camera		
3.	10 Band Multispectral Scanner		
4.	Radar Imager		
5.	Absorption Spectrometer		
6.	Multichannel Ocean Color Sensor		
7.	Radar Altimeter/ Scatterometer	X	
8.	Microwave Scanner	X	Additional frequency bands may be required.
9.	Sferic Detector, UHF		Study under SR&T required.
10.	Data Collection System	X	
11.	Star Tracking Telescope		
12.	Zero-g Cloud Chamber		
13.	Photo-imaging Camera		
14.	IR Interferometer/ Spectrometer		
15.	Multispectral Tracking Telescope		
16.	Selective Chopper Radiometer		
17.	IR Filter Wedge Spectrometer		
18.	IR Temperature Sounder		
19.	Satellite IR Spectrometer		
20.	Visible Wavelength Polarimeter		
22.	UV Imager/Spectrometer		

RESEARCH CLUSTER
NO. 6-0-7

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Table 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-0-7 -1	Checkout Equipment		4			15-C	1/wk	15-45				
-2	Clean lenses		5			21-C	1/wk	1-2 hrs				
-3	Prepare Equipment - Load camera, prepare electronics, checkout & test, reference flight plan & input ephemeris from Space Station or other source.		3			15-B	8-10 Orb/wk	30-60				
-4	Operate Equipment - Scan optics, ancillary electronics, sensor platform slewing controls, voice recorder, computational & data processing equipment.		3			15-B	8-10 Orb/wk	30-70				
-5	Visual Observation - Describe ground conditions, record instrument operation parameters, display outputs.		2			8-B	8-10 Orb/wk	30-70				
-6	Other Measurements - Roughness estimates (standard sea state designators aided by spacecraft optics.		2			8-B	2-3 Orb/wk	20-40				
-7	Monitor Equipment - Camera operation sensor operation, data processing; reference flight plan (assure data collection).		1			15-B	8-10 Orb/wk	30-60				
-8	Adjust Equipment - Calibrate cameras & other sensors with ground measurements/ground truth stations.		1			15-B	1-2 Orb/wk	10-20				

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—METEOROLOGY

6-M-1 Determination of Boundary Layer Exchange Processes Using IR Radiometry

1. Research Objectives

The experiment objective is to develop infrared radiometers and spectrometers that can provide measurements to assist in deriving the three-dimensional temperature and moisture fields and the character of the Earth's boundary layer and cloud layer of the atmosphere. This development is necessary to determine the exchange of momentum, heat, and moisture across the air-surface interface boundary and up through the lowest kilometer of the atmosphere. This development is a basic critical issue for improving the prediction of the atmospheric parameters. The experiments will test the hypothesis that radiometers and spectrometers operating in the vibration-rotation absorption bands of water vapor and carbon dioxide can be developed with resolution good enough to permit definition and study of small-scale phenomena. If these experiments are successful, remote sensors can then be used to fill an observational gap that is important for improving man's understanding of atmospheric processes, and improved global and regional forecasting.

2. Background and Current Status

The transfer of energy by heat and moisture across the air-land and air-water interfaces determines the primary heat sources and sinks for the atmospheric circulation. These are modified by the transfer of momentum between Earth and atmosphere or between water and atmosphere. These exchange processes depend critically on the vertical gradients of temperature, moisture, and wind in the atmosphere. They are nonlinear and intercoupled, however, and depend on the time and space variations of the land and ocean characteristics. Numerical prediction models have been developed by ESSA, but their efficient use awaits improvements in remote observation systems.

Improved weather forecasts as well as weather modification and control require improved numerical predictions. Improved models, in turn, require more-sophisticated observations. For this research cluster, the observations needed are principally in the lowest kilometer of the atmosphere and can be used for research and in numerical prediction models.

Remote atmospheric probing in the infrared from satellites began more than a decade ago with the launch of Explorer VII, which carried a simple wide-field infrared radiometer. Since then, more than a dozen radiometric instruments of increasing spectral and spatial resolution (and hence of increasing complexity) have been flown, or are scheduled to fly, on TIROS and Nimbus Satellites. Most recently, isobaric profile data have been generated by the Scanning Infrared Radiometer System (SIRS) on Nimbus 3 and Nimbus 4.

3. Description of Research

The basis for remote atmospheric probing in the infrared stems from the molecular absorption bands of the various atmospheric constituents. The principal IR absorber is H_2O, with strong vibration-rotation bands centered near 1.1, 1.38, 1.87, 2.7, and 6.3 microns, and with a rotation band becoming effective, through weak, near 12 microns, and intensifying increasingly out to about 60u. CO_2 is another important gaseous absorber with strong vibration-rotation bands centered near 2.7, 4.3, and 15 microns.

Particularly important to the concept of the remote determination of vertical temperature profiles (and subsequently, the remote determination of the vertical profiles of variable gases) is the observed nearly constant mixing ratio of CO_2 from the surface to approximately 70 to 80 km.

The determination of spheric vertical temperature profiles, therefore, is based on the measurement of atmospheric radiance in a number of narrow spectral intervals within the infrared absorption band of CO_2. The actual profile is then deduced by mathematical inversion of the radiative transfer equations. This has been successfully accomplished, using the Satellite Infrared Spectrometer (SIRS) 15-micron CO_2 band on Nimbus 3 and Nimbus 4. A marked improvement in the vertical resolution of the low-altitude temperature structure can be obtained by measurements in the 4.3-micron CO_2 band. (The 15-micron CO_2 band is more sensitive to temperature in the upper troposphere and lower stratosphere.) The high-frequency end of the 6.3-micron water band should give a more detailed low-altitude moisture profile than can be obtained from measurements in the rotational water band. The latter band (from 18 to 36 microns) is more sensitive to the upper-atmosphere water vapor. In addition measurements made in the window region, near 11 microns, contain information on the surface temperature, or if clouds are present, they contain information on the cloud-top temperature.

The system for this experiment, therefore, envisages measurements in all five bands, using several different radiometers and spectrometers to provide a basis for comparing the merits of the several instrument approaches. Testing of these instruments prior to possible incorporation of all measurements into one instrument (for unmanned operation) is particularly suited to manned operations.

Initially, these instruments and techniques should be tested and evaluated over a variety of surface types to provide sufficient data to develop a general model, or to determine whether a general model is possible from the data available. The ground-truth data needed include (1) vertical temperature, humidity, and wind profiles provided by instrumented towers or buoys and rawinsondes; (2) data on cloud types, height of base, and tops; and (3) surface characteristics, moisture content, and temperature.

4. Impact on Spacecraft

The major impact on the space vehicle will be due to the number of instruments to be tested simultaneously over the test sites, which will probably require maximum crew participation in readying and operating the equipment. The instrument operation will also result in a large data flow, which will require onboard processing, correction, and display.

5. Required Supporting Technology Development

Improved descriptive and mathematical models of the exchange processes at the boundary layer are needed to improve weather forecasting and weather and climate modification. The current prototype models are generally specialized to specific areas or processes. In particular, models are needed that relate small-scale and mesoscale processes to the large-scale general circulation models. The data generated in these experiments can be used in conjunction with field experiments on modification of the weather. In such experiments, variations in energy exchange can be effected by varying the albedo, moisture evaporation, surface roughness, and composition.

6. References

1. W. R. Bandeen. Experimental Approaches to Remote Atmospheric Probing in the Infrared From Satellites.

2. Oceanography and Meteorology: A Systems Analysis to Identify Orbital Research Requirements, Vol. II. Technical Report DAC 58121 Addendum to Contract NAS8-21064, McDonnell Douglas Astronautics Company, Huntington Beach, April 1968.

3. G. M. Hidy. Conference Summary, IUGG-1AMAP-AMS Conference on Planetary Boundary Layers. Bulletin of the American Meteorological Society, Vol. 51, June 1970, pp 518-527.

RESEARCH CLUSTER
NO. 6-M-1

Critical Issues Addressed by Research Cluster

6-M-1

DETERMINATION OF BOUNDARY LAYER EXCHANGE PROCESSES USING IR RADIOMETRY

6.3.2.3.2.2
How could microclimates be created and controlled by man?

6.3.2.3.2.3
How could solar radiation be effectively controlled for man's needs?

6.3.3.1.1.1
How does the global heat balance affect world climate?

6.3.3.1.2.1
How does the regional heat balance affect regional climates?

6.3.3.1.2.4
How do man's activities affect the long term climate pattern?

6.3.3.1.3.1
How does the local heat balance affect local climates and can this be controlled?

6.3.3.1.3.2
How does man's modification of the environment affect local climate?

6.3.3.1.3.3
How do great population centers affect local climates?

6.4.2.3.2.2
What is the rate of heat loss from the Earth's crust (en toto)?

6.4.3.1.1.1
What causes glaciation?

6.4.3.1.1.2
Are we entering interglacial epoch or is the glacial cycle completed?

6.4.3.1.2.1
How do ocean basins, continental masses control weather?

6.4.3.1.2.2
How does the radiant temperature of the Earth contribute to the control of weather?

6.5.2.1.1.1.3
How can the water vapor content within the atmosphere at the atmosphere — surface interface be determined?

6.5.2.1.1.2.2
How can long-range prediction of precipitation (rain and snow) be improved?

6.5.2.1.1.4.2.2
How can the thickness, temperature, and albedo of ice be determined?

6.5.2.1.2.2.1
What is the global distribution of the infrared radiance of the Earth's surface?

6.5.2.1.2.2.3
How can the diurnal variations in temperature of the surface of the Earth be determined?

6.5.2.1.2.3.1
What are the characteristics of the boundary layer at the interface between the atmosphere and the Earth's surface?

6.5.2.1.2.3.2
What is the rate of flow of thermal flux from the Earth into the turbulent atmosphere?

6.7.2.2.2.1
What knowledge of the present state of the physical characteristics is required?

6.7.2.2.2.2
What knowledge of the present state of the physical constituents is required?

6.7.2.2.3.1
What factors are involved in the current atmospheric momentum and mass fields?

6.7.2.2.3.2
What factors are involved in the current atmospheric radiation and temperature fields?

6.7.2.2.3.3
What factors are involved in the current atmospheric composition and structure?

6.7.2.3.1.1.1
What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity?

6.7.2.3.1.1.2
What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity?

6.7.2.3.1.2.1
What are the effects of the horizontal and vertical advection of temperature on the local time change of temperature?

6.7.2.3.1.2.6
What is the effect of diabatic heating by boundary layer heat transfer on the local time change of temperature?

6.7.2.3.2.1.1
What knowledge is required of the changes in the momentum, temperature and mass fields including local soil heating and radiation?

6.7.2.3.2.2.1
What knowledge is required of the changes in the momentum, temperature and mass fields?

6.7.2.3.2.3.1
What knowledge is required of the changes in the momentum, temperature and mass fields?

6.7.2.3.3.1.1
What are the effects of changing the physical characteristics of the surface?

6.7.2.3.3.1.2
What are the effects of changing the surface albedo and emissivity?

6.7.2.3.3.1.3
What are the effects of changing the surface evaporation?

6.7.2.3.3.1.4
What are the effects of modifying the colloidal state of clouds or fog at the boundary?

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial[(a)]	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Reflected and emitted IR radiation originating at the surface of the earth, at cloud tops, and in the atmosphere.	Selective Chopper Radiometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	200-280°K	1.8 nmi	0.2% ($\Delta\nu$ = 1.3 cm^{-1} at 15u)	0.5C° below 3 nmi 2 C° between 10-20 nmi	< 1% of radiant intensity	Instrumental	Radiometric instrumentation is calibrated on board by viewing internal black body reference targets, reference calibration filters, and free space.
	IR Interferometer Spectrometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	near zero to 300°K	8 nmi	0.1u at 15u $\Delta\nu$ = 5 cm^{-1}	2C°	< 1% of radiant intensity	Instrumental	
	Satellite IR Spectrometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	40-190 ergs/(cm^2 sec strdn cm^{-1})	43 nmi	0.1u ($\Delta\nu$ = 5 cm^{-1} to 8 cm^{-1})	1C°	<1% of signal level[(b)]	Instrumental	
	Filter Wedge Spectrometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	TBD	3.5 nmi	$\lambda/\Delta\lambda$ =100 (0.05u at 5u)	TBD	Signal measured to 1 part in 500	Instrumental	
	IR Temperature Sounder	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	200-300°K	8.6 nmi	1% ($\Delta\nu$ = 10 cm^{-1} and 25 cm^{-1})	~1C°	~1% of measured radiance value	Instrumental	
	IR Temperature Profile Radiometer	Spectral radiance (transformable to temperature)	erg/cm^2 sec strdn cm^{-1})	0-200 ergs/(cm^{-2} sec strdn cm^{-1})	9 nmi	0.4u to 1.0u, depending on λ	~1C°	<1% of signal level[(b)]	Instrumental	
2. Cloud Cover	Metric Camera	Amount, size distribution, type	Amount in tenths; size in ft or nmi	Amt: 0/10 - 10/10 Size: 100's of ft to 10's of miles	150 ft	N/A	N/A	0.02 to 0.05%	Film stability	

(a) Horizontal resolution (on ground) at sub-satellite point.

(b) e.g., 0.3 ergs/(cm^2 sec strdn cm^{-1} represents an uncertainty of approximately 0.5% of signal level.

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1	Metric Camera	X	
2	Multispectral Camera		
3	Ten-Band Multispectral Scanner		
4	Radar Imager		
5	Absorption Spectrometer		
6	Multichannel Ocean Color Sensor		
7	Radar Altimeter-Scatterometer		
8	Microwave Scanner Radiometer		
9	Sferic Detector, UHF		
10	Data Collection System		
11	Star-Tracking Telescope		
12	Zero-Gravity Cloud Chamber		
13	Photo-Imaging Camera		
14	IR Interferometer-Spectrometer	X	
15	Multispectral Tracking Telescope		
16	Selective Chopper Radiometer	X	
17	IR Filter Wedge Spectrometer	X	
18	IR Temperature Sounder	X	
19	Satellite IR Spectrometer	X	
20	Temperature Profile Radiometer	X	
21	Visible Wavelength Polarimeter		
22	UV Imager-Spectrometer		

Table 3-3

RESEARCH CLUSTER
NO. 6-M-1

(58)

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-M-1 -1	Checkout Equipment	All	4			5-C	1/wk	5-20	1			
-2	Clean Lenses		5	EVA		21-B	1/wk	1-2 hrs	1			
-3	Prepare Equipment - Warm-up and chilldown of sensors & associated electronics, loading metrix & indexing camera & calibration of IR, radiometer, spectrometer instruments.		3			5-B	10-15 Orb/wk	30-95	1			
-4	Operate Equipment - All instruments, associated electronics, test controls, slewing/pointing/trading controls; scan optics & associated controls; data collection & recording equipment.	All	3			5-B	10-15 Orb/wk	30-95	1			
-5	Visual Operations - Observe via scan telescope to supplement sensor data for indexing photography, voice recorded.		2			12-B	10-15 Orb/wk	30-95	1			
-6	Monitor Equipment - Data receipt, sensor operation, imagery, & duration.		1			5-B	10-15 Orb/wk	30-95	1			
-7	Adjust Equipment - Internal calibrations, boresighting, minor experiment maintenance.		1			5-B	10-15 Orb/wk	30-95	1			

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—METEOROLOGY

6-M-2 UHF Sferics Detection

1. Research Objectives

The objective of this research cluster is to develop a technique to use ultrahigh-frequency (UHF) electromagnetic wave emissions from the atmosphere to provide data on the global distribution of connective (i.e., cumulus) cloud areas. These data are necessary to provide information on the spatial and temporal distribution of global thunderstorm activity in the atmosphere. Information on thunderstorm activity is not only important for aircraft routing, potential fire hazard detection, and hydrological forecasting, hydrological storm activity maintains the charge separation between the upper atmosphere and the ground. These data are also important for developing techniques to interpret atmospheric circulation processes from cloud photographs, and will also assist in developing thunderstorm forecasting techniques.

2. Background and Current Research

Information on the spatial and temporal variations of thunderstorm activity has both basic research and applied values. Among basic research problems are those of the general atmospheric circulation and the vertical distribution of atmospheric contaminants, since it is believed that the large cumulonimbus clouds of intense thunderstorms play a vital role in exchanges between the stratosphere and the troposphere.

Applications include location of electrical discharge as an aid in forestry management (fire hazard), in assessing the need for protecting electrical power transmission lines, in enabling optimum safe routing of aircraft, and in estimating atmospheric noise interference to radiocommunication. An especially interesting application is the remote location of tornadoes, identifiable since they may produce a very much higher, lightning flashing rate than do conventional thunderstorms.

Lightning is the visual indication of rapid and intense electric charge transfer through the atmosphere. This transfer activates electromagnetic wave pulses, which radiate through the atmosphere. These pulses cause static or atmospheric discharge (sferics) in radio transmissions. These may or may not necessarily be associated with classic anvil-shape thunderstorms. Lightning has been known to occur in clear air, and weak discharges occur between water drops. However, the rate of occurrence of lightning in an area (and hence, the sferics) is an indicator of the intensity of the connective; i.e., thunderstorm activity.

During the past several years, a number of studies have dealt with the feasibility of detecting sferics from Earth-orbiting satellites. Recent observations of UHF emissions from cumulus clouds from both airborne and ground-based equipment indicate that there is adequate power in UHF sferics for detection at satellite altitudes.

3. Description of Research
For detection of sferics from space, the UHF portion of the spectrum seems to be most promising because:

1. The frequency is high enough for the ionosphere to be transparent and nonrefracting.

2. At higher frequencies, the antennas are smaller and easier to install on spacecraft.

UHF emissions in the 610-MHz region from appropriate targets will be measured by equipment onboard the spacecraft. This equipment consists of an antenna system, a low-noise UHF receiver (2-kHz bandwidth), a signal processing unit, a data tape recorder, and a control panel. The experiment will be operated with supporting observations by the astronaut. During the daytime, they will include cloud-scene information (e.g., type, form, distribution, and amount). In addition to photographing the scene, the spacecraft will also monitor lightning, using a viewer fitted with a narrow spectral-band filter around the hydrogen-alpha line (6, 563 A), which is practically absent in the solar spectrum because of absorption in the solar atmosphere. During the nighttime visual observation of lightning (e.g., bolts, and frequency and length of discharge) will be made. Simultaneous aircraft, ground, and meteorological satellite observations will also be obtained for postflight correlation and analysis.

The ground instrumentation is twofold and consists of:

1. A portable ground station, consisting of a radio transmitter, pulser, and antenna, for sending calibration signals to spacecraft.

2. Sferics-detecting equipment associated with weather radar. This equipment is available at numerous locations (e.g., Cape Kennedy).

4. Impact on Spacecraft
Because of nature of this experiment, a continuous monitoring of predicted thunderstorm areas may be desirable, resulting in extended crew-duty cycles. Observations require a significant amount of crew participation in voice annotations and in recording data and calibrations over ground truth sites. Frequency selection and antenna optimization may also require significant crew participation.

5. Required Supporting Technology Development
Descriptive and mathematical models need to be developed from the experimental data and from theory, which relate the sferics signature to the different sources and dynamic processes. It is generally considered that different states of convective activity, such as nonprecipitating cumulus, mild thunderstorms, severe thunderstorms, and tornado producing clouds, have different sferics characteristics and signatures.

6. References

1. J. A. Chalmers. Atmospheric Electricity. Pergamon Press, New York, 2nd Edition, 1967.

2. E. T. Pierce. Monitoring of Global Thunderstorm Activity in Planetary Electrodynamics. S. C. Coroniti and J. Hughes, editors. Gordon and Breach Science Publishers, New York, 1969.

3. M. A. Uman. Lightning. McGraw-Hill Books Co., New York, 1969.

Critical Issues Addressed by Research Cluster

6-M-2

UHF Sferics Detection

6.7.2.2.1.1
What chemical constituents are present in the atmosphere?

6.7.2.2.1.2
Where are the chemical constituents located and how do they vary?

6.7.2.2.1.3
What terrestrial and extraterrestrial factors affect the distribution of chemical constituents?

6.7.2.2.2.1
What knowledge of the present state of the physical characteristics is required?

6.7.2.2.2.2
What knowledge of the present state of the physical constituents is required?

6.7.2.2.3.1
What factors are involved in the current atmospheric momentum and mass fields?

6.7.2.2.3.2
What factors are involved in the current atmospheric radiation and temperature fields?

6.7.2.2.3.3
What factors are involved in the current atmospheric composition and structure?

6.7.2.3.1.1.1
What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity?

6.7.2.3.1.1.2
What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity?

6.7.2.3.2.1.1
What knowledge is required of the changes in the momentum, temperature and mass fields including local soil heating and radiation?

6.7.2.3.2.2.1
What knowledge is required of the changes in the momentum temperature and mass fields?

6.7.2.3.2.3.1
What knowledge is required of the changes in the momentum, temperature and mass fields?

RESEARCH CLUSTER
NO. 6-M-2

Table 1

PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial	Spectral	Temp			
1. UHF Sferics radiated from the Earth and its environs.	UHF Sferics Detector	UHF emissions from clouds (peak amplitude frequency and duration of sferics)	Microvolts/meter (field strength) Frequency and duration of pulse (in micro-seconds)	Receiver has a maximum noise of 3 db; antenna gain is 6 db Pulse durations from 1.2u sec to 10's of usec	N/A	N/A	N/A	S/N 17.5 to 27.5 db	Source/sensor; urban area noise; switching transients from s/c equipment	Calibration signals from ground station to spacecraft. Event marking by astronaut.
2. Cloud Convective activity	Metric camera	Clouds	Type, amount pattern, distribution	Daytime light levels	200 ft	Black and white photography	N/A	N/A	N/A	Cloud observations from applicable surface world-wide meteorological network.

Table 2
INSTRUMENTS REQUIRED

No.	Instruments	Applicable	Comments
1	Metric Camera	X	
2	Multispectral Camera		
3	Ten-Band Multispectral Scanner		
4	Radar Imager		
5	Absorption Spectrometer		
6	Multichannel Ocean Color Sensor		
7	Radar Altimeter-Scatterometer		
8	Microwave Scanner Radiometer		
9	Sferic Detector, UHF	X	
10	Data Collection System		
11	Star-Tracking Telescope		
12	Zero-Gravity Cloud Chamber		
13	Photo-Imaging Camera		
14	IR Interferometer-Spectrometer		
15	Multispectral Tracking Telescope		
16	Selective Chopper Radiometer		
17	IR Filter Wedge Spectrometer		
18	IR Temperature Sounder		
19	Satellite IR Spectrometer		
20	Temperature Profile Radiometer		
21	Visible Wavelength Polarimeter		
22	UV Imager-Spectrometer		

RESEARCH CLUSTER
NO 6-M-2 -2

Table 3 3

CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-M-2 -1	Checkout Equipment		4			5-C	1/wk	5-10	1			
-2	Prepare Equipment - Power-up Sferics detector, checkout, input ephemeris to experiment data recorder, note ground weather updates, reference experiment plan.		3			12-B	6 or more orb/wk	20-40	1			
-3	Operate Equipment - Cycle experiment sequencing equipment - timers, frame rate controls, data selection equipment & electronic logic test equipment.		3			12-B	6 or more Orb/wk	20-40	1			
-4	Visual Observations - Locate targets (closed formations, storm activity; initiate rapid data taking & supporting activities; monitor signal receiving/processing.		2			12-B	12-14 Orb/wk	20-50	1			
-5	Other Measurements - Annote via voice recorder supplemental measurements.		2			12-B	6 Orb/wk	10-30	1			
-6	Monitor Equipment - Data receipt, storage and/or processing; camera & equipment observation.		1			5-B	12-14 Orb/wk	20-50	1			
-7	Adjust Equipment - Calibrate Sferics detectors with ground truth stations & on occasion locations where Sferics exists. Adjust metric camera, as required.		1			12-B	1-2/wk	20-30				

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
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CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

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3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

DO NOT REPRODUCE

EARTH ORBITAL EXPERIMENT PROGRAM AND REQUIREMENTS STUDY

EARTH OBSERVATIONS

RESEARCH CLUSTER–6-M-3

ATMOSPHERE DENSITY MEASUREMENTS BY STELLAR OCCULTATION

RESEARCH CLUSTER SYNOPSIS—METEOROLOGY

6-M-3 Atmospheric Density Measurements by Stellar Occultation

1. Research Objectives

The primary objective of this research cluster is to test methods of remotely measuring the density of the Earth's atmosphere. Such methods are needed to provide data on the mass distribution of the atmosphere. These data are needed for determining the refraction and scattering of electromagnetic waves in the atmosphere and for improving forecasts of meteorological parameters. Two proposed methods should be tested. If these or other methods are successful, the resultant data will be useful in filling a major gap in our knowledge.

2. Background and Current Status

Most weather prediction models depend on a knowledge of the initial flow and mass distribution of the atmosphere, and use primarily the height field of standard pressure surfaces. The usual way to obtain the mass distribution of the atmosphere is to measure, in situ, by radiosonde balloons, the temperature as a function of pressure; and to integrate upward from the surface to obtain pressure as a function of height. From a spacecraft, the desired pressure-height field can be derived from accurate density and absolute height data. The vertical temperature profiles can be derived by measuring the atmospheric radiance in a number of narrow spectral intervals within the infrared absorption band of a uniformly mixed atmospheric constituent, such as CO_2.

At the present time, numerical weather forecasting is accomplished routinely for periods of 3 to 4 days, and covers about one-third of the Earth. Further extension of forecasting in time and area will require knowledge of the initial state of the atmosphere on a hemispheric, and eventually on a global basis.

The potential of a global system of measuring density from space, for such programs as the World Weather Watch and the Global Atmospheric Research Program, has been examined by individual researchers and groups under the sponsorship of NASA, ESSA, and COSPAR. To date, only analytical and feasibility studies have been completed. The next step requires orbital testing.

3. Description of Research

Measurement of atmospheric density from space can be inferred from stellar occultation by the atmosphere. May be in this experiment, stars will be acquired slightly above the horizon and tracked with a star-tracking telescope until occultation occurs. The refraction angle measured as a function of time during occultation can be determined as a function of the ray-path constant at the point of tangency. This will permit inversion of the data to deduce the atmospheric density profile in the lower stratosphere, and at times, in the upper troposphere.

Stars, upon which refraction measurements are to be made, will be acquired with an acquisition telescope a few degrees above the horizon. When the star is tracked to within 1 minute of arc of the center, control will be shifted to a data telescope, which tracks to its center (within a few seconds of arc). Gyros mounted on the telescope measure the telescope's motion as the star is automatically tracked, until finally the light from the star is occulted by clouds or the Earth. Refraction angles to be measured range from 4 arc-sec at 50-km tangent height to 40 min at 5 km. Tracking time, depending on the altitude of acquisition and the azimuth angle, will be 20 to 40 sec per star. Stars having azimuths within about 30 degrees of directly aft will be used in this experiment.

Given the refraction angle measured as a function of time during occultation, together with satellite ephemeris data, the refraction angle will be known as a function of the ray-path constant at the point of tangency. The vertical atmospheric density profiles derived from the refraction angles may allow derivation of the vertical profiles of pressure and temperature. The data will be compared with radiosonde data taken over meteorological truth sites. As an adjunct to this experimental approach, data will be gathered to supply information on background radiance near the horizon and starlight attenuation in the atmosphere for use in evaluating the performance and to optimize further development of the star tracker.

These measurements will represent averages over an almost horizontal path about 1,000 km long near the lowest part of the ray path. This experiment requires accurate orbital and attitude data.

4. Impact on Spacecraft

The density occultation experiment will require a trained scientist to derive densities and profiles from knowledge of the star, its brightnes magnitude, and the speed and degree of occultation. The success of this experiment will depend critically on the performance of the crew in providing supporting observations.

Telemetry of initial data to the ground station for rapid processing is important in assessing initial performance of instruments in both experiments. Ground-based data will be needed immediately for this comparison.

5. Required Supporting Technology Development

Attitude-control and attitude-measuring systems with accuracies of the order of 1 arc-sec must be developed for the occultation experiment. The effects of varying air masses, moisture and aerosol contents, and the influence of temperature and scintillation must be accurately determined. The effect of scattered moonlight must also be studied and measured.

6. References

1. Star tracker development at University of Michigan.

2. Numerical experiments in long-range weather prediction at ESSA, Princeton, and UCLA.

Critical Issues Addressed by Research Cluster

6-M-3

ATMOSPHERE DENSITY MEASUREMENTS BY STELLAR OCCULTATION

6.7.2.2.1.1
What chemical constituents are present in the atmosphere?

6.7.2.2.1.2
Where are the chemical constituents located and how do they vary?

6.7.2.2.1.3
What terrestrial and extraterrestial factors affect the distribution of chemical constituents?

6.7.2.2.2.1
What knowledge of the present state of the physical characteristics is required?

6.7.2.2.2.2
What knowledge of the present state of the physical constituents is required?

6.7.2.2.3.1
What factors are involved in the current atmospheric momentum and mass fields?

6.7.2.2.3.2
What factors are involved in the current atmospheric radiation and temperature fields?

6.7.2.2.3.3
What factors are involved in the current atmospheric composition and structure?

6.7.2.3.1.1.1
What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity?

6.7.2.3.1.1.2
What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity?

6.7.2.3.2.1.1
What knowledge is required of the changes in the momentum, temperature and mass fields including local soil heating and radiation?

6.7.2.3.2.1.4
How can frequent and detailed local and hemispherical observations of the initial state of the time-dependent atmospheric variables be obtained and used?

6.7.2.3.2.2.1
What knowledge is required of the changes in the momentum temperature and mass fields?

6.7.2.3.2.2.4
How can global observations of initial state of all the time-dependent atmospheric variables be obtained and used?

6.7.2.3.2.3.1
What knowledge is required of the changes in the momentum, temperature and mass fields?

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
					Spatial	Spectral	Temp			
1. Stellar refraction along 2 axes (azimuth and elevation)	Star-tracking telescope	Apparent Angular Displacement	Minutes of arc	0-75 minutes of arc	Acquisition telescope fov = 8 min, movable over 2 deg. Data telescope fov = 30 min movable over 5 min	Range 0.45-0.7 microns	N/A	2 arc sec rms	Differential refraction	
2. Stellar intensity reduction	Star-tracking telescope and image dissector phototube	Stellar brightness	Stellar magnitude	5 stellar magnitudes	N/A	N/A	N/A	TBD	Differential refraction, molecular scattering	

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1	Metric Camera		
2	Multispectral Camera		
3	Ten-Band Multispectral Scanner		
4	Radar Imager		
5	Absorption Spectrometer		
6	Multichannel Ocean Color Sensor		
7	Radar Altimeter-Scatterometer		
8	Microwave Scanner Radiometer		
9	Sferic Detector, UHF		
10	Data Collection System		
11	Star-Tracking Telescope	X	
12	Zero-Gravity Cloud Chamber		
13	Photo-Imaging Camera		
14	IR Interferometer-Spectrometer		
15	Multispectral Tracking Telescope		
16	Selective Chopper Radiometer		
17	IR Filter Wedge Spectrometer		
18	IR Temperature Sounder		
19	Satellite IR Spectrometer		
20	Temperature Profile Radiometer		
21	Visible Wavelength Polarimeter		
22	UV Imager-Spectrometer		

RESEARCH CLUSTER
NO. 6-M-3

Table 3 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASKS CONCURRENCY†
6-M-3 -1	Checkout Equipment	All	4			5-C	1/wk	15-30	1			
-2	Clean Lenses		5	EVA		21-B	1/wk	1-2 hrs	1			
-3	Prepare Equipment - Occultation instruments - focussing optics, cycling tracking controls, warm-up electronics; prepare data.	All	3			5-B	8-10 Orb/wk	20-40	1			
-4	Operate Equipment (Initiated when star is chosen & acquired by telescope). Track (manual) for several seconds; initiate autotrack record radisonde, ephemeris & other data.		3			12-B	8-10 Orb/wk	15-30	1			
-5	Visual Observations - Initial star acquisition & tracking; qualitative evaluation of atmosphere, lighting, apparent density.		2			12-B	4-10 Orb/wk	15-30	1			
-6	Monitor Equipment - Data receipt, storage & star tracker; associated electronics.		1			5-B	8-10 Orb/wk	15-30	1			
-7	Adjust Equipment - Calibration & focussing of scan telescope, adjustment of optical tracker & gain adjustments for sensor electronics.		1			5-B	2-3 Orb/wk	15-30	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—EARTH PHYSICS

6-M-4 Cloud Physics Experiment in a Zero-G Environment

1. Research Objectives

It is necessary to understand the processes of evaporation, condensation, droplet growth, and other characteristics of atmospheric-moisture behavior to improve weather prediction and weather modification. This experiment is aimed at achieving a better quality of empirical data than has ever been developed in terrestial facilities or in atmospheric experiments. The data to be gathered in this test will be used to refine the theoretical models of the atmosphere used in numerical weather prediction and will also accelerate progress in modifying fog, convective-cloud development, and perhaps hurricanes and tornadoes.

2. Background and Current Status

Practically all atmospheric phenomena derive their energy from the moisture cycle; i. e., from the evaporation-condensation-rain series. In some cases, the reaction of the individual phenomena is almost immediate (e. g., hail and lightning development), while in others there is a less obvious relationship between the moisture cycle and the atmospheric phenomena (e. g., hurricane development). Accordingly, many scientists have striven to understand the detailed behavior and characteristics of the individual droplets, which are the basic factor in the moisture cycle.

To date, no terrestial facility has proven fully adequate as a test bed for droplet study. Such facilities as obsolete factory chimneys and mine shafts in the Alps have been tried, as have specially-built shafts, all instrumented to observe the behavior of droplets in a pseudo-natural environment. Momentary observations of a droplet as it falls from the top to the bottom of a mine shaft, however, have not provided the data needed to fully evaluate the phenomena of droplet development.

Experimental meteorologists have also used trial-and-error methods to discover ways to dissipate fog at airports, to preclude development of hail over Midwest wheat fields, and to influence the energy budget of hurricanes; but all of these experiments have been hampered by the lack of a way to isolate the effects of the experiments from the effects that occurred anyhow.

In summary, the zero-g experiment proposed here offers promise of a major step forward in a critical area of the atmospheric sciences. For the first time, individual droplets can be suspended without recourse to wires, glass surfaces, or probes, all of which might cause the droplets to act differently than they might in the free atmosphere.

3. Description of Research

A facility is proposed to permit observation and measurement of droplets and their characteristics while they are suspended in a zero-g condition. The capability to observe moisture particles for appreciable periods, from various points of interest and without use of disturbing support to hold the droplets will be exploited. To enhance the study, the facility will be equipped with equipment for varying such factors as temperature, electrical field, moisture, nuclei distribution, droplet size, and concentration.

The experimenter will be a trained scientist, and he will be augmented by technicians to maintain and calibrate equipment, record data, and participate in experiment procedures. Because of the high degree of specialization represented in this field of study, the astronaut-scientist will be expected to correlate the proposed series of individual experiments and test procedures with members of the meteorological community working in this field.

Basically, the experimenter will prepare and conduct a series of tests in which droplets will be minutely observed while ambient conditions in the test chamber are varied. Examination of early tests will lead to guidelines for subsequent tests; it would be premature to propose a complete program without allowing for use of early results in deciding which avenues of research warrant further study.

4. Impact on Spacecraft

As described by the title of this experiment, it is meant to operate in a zero-g environment; it is assumed that such an environment will exist in at least some portion of the spacecraft large enough to house two men, the test chamber, and associated equipment.

The zero-g chamber can measure about 1 by 1 by 1 ft. In this space, pressure, temperature, moisture, electric field, aerosal population, ionization, and gaseous composition can be controlled and monitored. Viewing ports are needed in every wall of the chamber, together, and light sources will be required for illuminating the droplet suitably for viewing and photographing. A low-range microscope-telescope is needed for viewing and for use in making high-speed time-lapse photographs. Tape recorders and a timing mechanism are needed to record the ambient data within the chamber and to index the photographs.

Housekeeping support must be provided for the equipment procedures described above.

5. Required Supporting Technology Development

Principal needs include (1) a scientific study of the initial tests and their priority, (2) an engineering definition of the individual components of the system, and (3) an interface investigation to interpret all parts of the system. It is essential that both U. S. and foreign specialists in cloud physics be made aware of this experiment to ensure that the most effective program plan will be selected prior to firm system definition.

6. References

1. Oceanography and Meteorology. A systems Analysis to Identify Orbital Research Requirements. Volume I, Executive Summary Report, DAC 58120; Volume II, Technical Report, DAC 58121. McDonnell Douglas Corporation, April 1968.

2. V. J. Schaefer. The Formation of Ice Crystals in the Laboratory and in the Atmosphere. Chemical Reviews, Vol. 44, 1949, pp. 2.

3. R. A. Schleusener. Hail Fall Damage Suppression by Cloud Seeding--A Review of the Evidence. Journal of Applied Meteorology, Vol 7, No. 6, December 1968, pp. 1004-1011.

4. R. G. Semonin and H. R. Plumlee. Collision Efficiency of Charged Cloud Droplets in Electric Fields. Journal of Geophysical Research, Vol. 71, 1966, pp. 4271-78.

5. B. J. Thompson, J. H. Ward, and W. R. Zinky. Application of Hologram Techniques for Particle Size Analysis. Applied Optics, 1967, p. 519.

6. C. L. Hosler. The Role of Extraterrestrial Surveillance in Cloud and Weather Modification. Presented to the Astronautical Society, 1969.

7. B. W. Wahl. Analysis of Selected Opportunities for Manufacturing in Space. McDonnell Douglas Astronautics Company, Paper 10119, February 1969.

8. F. H. Shepphird, M. Weinstein, W. W. Hildreth, and C. L. Hosler. Engineering Requirements Affecting Spacecraft Design Criteria to Support a Scientific Zero-G Cloud Physics Experiment. MDAC-WD 1140. Presented at The Fourth National Conference on Aerospace Meteorology, Las Vegas, Nevada, 1970.

9. American Meteorological Society. Conference on Cloud Physics, Ft. Collins, Colorado, August 1970.

Critical Issues Addressed by Research Cluster

6-M-4

CLOUD PHYSICS EXPERIMENT IN A ZERO-G ENVIRONMENT

6.7.2.3.1.1.1
What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity?

6.7.2.3.1.1.2
What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity?

6.7.2.3.1.3.3
How are the water droplet and ice crystal cloud fields changed by advection and eddy diffusion?

6.7.2.3.1.3.4
How are the water droplet and ice crystal fields changed by direct condensation, sublimation, and freezing?

6.7.2.3.1.3.5
How are the water droplet and ice crystal fields changed by collision, coalescence, and colloidal instability?

6.7.2.3.3.1.4
What are the effects of modifying the colloidal state of clouds or fog at the boundary?

6.7.2.3.3.2.4
What are the effects of modifying the colloidal state of clouds over large areas?

Table 1

PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial	Spectral	Temp			
1. Cloud elements (water droplets and ice crystals)	Zero-g cloud chamber, including associated environmental controls, microscope* and cameras *Possibly a long-range microscope using holography	Drop-size distribution	Diameter in microns	1-200u (water droplets)	0.5u			0.5u		
				20-100u (individual ice crystals)	0.5u			0.5u		
			number/cm^3	5-1000/cm^3 (water droplets)				±10%		
				0-<1/cm^3 (ice crystals)				±10%		
		Liquid-water content	g/cm^3	0-10^{-5}g/cm^3 (water droplets)				±20%		
				0-10^{-7}g/cm^3 (ice crystals)				±20%		
		Temperature	°C	-40° to +25°C			0.1 C°			
		Dew-point	°C	-40° to +25°C			0.1 C°			
		Pressure	psi	0 to 15 psi				±0.1%		
		Electric field strength	volts/cm	0-1000 y/cm				±1%		

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Table 2

METEOROLOGY INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1	Metric Camera		
2	Multispectral Camera		
3	Ten-Band Multispectral Scanner		
4	Radar Imager		
5	Absorption Spectrometer		
6	Multichannel Ocean Color Sensor		
7	Radar Altimeter-Scatterometer		
8	Microwave Scanner Radiometer		
9	Sferic Detector, UHF		
10	Data Collection System		
11	Star-Tracking Telescope		
12	Zero-Gravity Cloud Chamber	X	
13	Photo-Imaging Camera		
14	IR Interferometer-Spectrometer		
15	Multispectral Tracking Telescope		
16	Selective Chopper Radiometer		
17	IR Filter Wedge Spectrometer		
18	IR Temperature Sounder		
19	Satellite IR Spectrometer		
20	Temperature Profile Radiometer		
21	Visible Wavelength Polarimeter		
22	UV Imager-Spectrometer		

RESEARCH CLUSTER
NO. 6-M-4

Table 3
CREW ACTIVITY MATRIX

1500

RESEARCH CLUSTER NO.		TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-M-4	-1	Checkout Equipment	All	4			5-C	Daily	60	1			
	-2	Prepare Equipment - Purge & prepare chamber equipment & sample injecting equipment; load film, adjust camera.		3			12-A	1/wk	2-3 hrs				
	-3	Operate Equipment - Prepare samples, control temperature pressure, convection, droplet proximity, dew-point, & all other particulars, operate all equipment including still & time-lapse photography.	All	3			12-A	10-12 orb/wk	30-50	1			
	-4	Visual Observations - Observe for time, growth, rate, direction, shape, and measurables.		2			12-A	"	2-3 hrs	1			
	-5	Other Measurements - Voice annotation & tape recording & droplet behavior; notes including all experiment measurables.		2			12-A	"	20-40	1			
	-6	Monitor Equipment - Rate of growth of water droplets, ice crystals, phase transitions, collisions, coalescence & particle capture.		1			12-A	"	2-3 hrs	1			
	-7	Adjust Equipment - All data recording (photographic, TV, microscopic) equipment in addition to the experiment manipulative requirements.		1			12-A	3-5 orb/wk	30-60	1			

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†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS—METEOROLOGY

6-M-5 Detection and Monitoring of Atmospheric Pollutants

1. Research Objectives

The objective of this research cluster is to develop techniques and instrumentation to detect, identify, and measure pollutant concentrations in the atmosphere. This development is most important for monitoring and determining the spatial and temporal distribution of pollutants in the atmosphere. From this information, procedures can be developed to control the emission of pollutants. These data can also be used (1) to investigate the transport and diffusion properties of the atmosphere and (2) to determine the effect of pollutants on the absorption and scattering of solar radiation. Initially, the hypothesis that correlation spectrometry can be used to detect and measure SO_2 and NO_2 from space will be utilized. One of the gaps that needs to be investigated, however, is the effect that the atmospheric absorption and scattering, and the reflectance properties of the ground, have on the measurement technique.

2. Background and Current Status

Air pollution today has become a problem of national and international concern. The unintentional alteration of the environment by man is minor compared to what it will be in 10 or 20 years. As yet, the atmosphere's capacity is not known, nor how it might be measured. The overriding immediate need is for greatly improved and expanded methods of detecting and monitoring man-made alterations in the composition and energy budget of the atmosphere.

The influence of the weather and of diurnal and seasonal effects on the large-scale patterns of pollution are not known, and little is known about the effects of pollution on the weather and climate. For example, it is not yet clear whether the temperature is increasing because of the greenhouse effect of CO_2 pollution, or whether it is decreasing because of the addition of aerosol pollution, which intrcepts and reflects solar energy away from the Earth.

To date, the detection and monitoring of air pollution have been accomplished on a local basis. The most-used method has been direct point gas sampling and subsequent chemical or spectroscopic analysis. Optical remote-sensing techniques have been employed only sparsely, and no large-scale observations are currently being made over urban areas. These techniques take advantage of the fact that virtually all environmental pollutants exhibit characteristic optical absorption spectra, and that these spectra can be used to identify and quantitatively measure pollutant concentrations without resorting to wet chemistry or preconditioning.

Examination of the information and knowledge pertinent to the current detection and monitoring of atmospheric pollutants reveals numerous areas where research is needed before a significant remote-sensing capability is possible from space. A promising technique for obtaining some of the necessary information is that of correlation spectrometry. The technique has been demonstrated on the ground, in aircraft, and in a high-altitude (100, 000 feet) balloon, and is specific for SO_2 and NO_2. Other techniques that should be considered are resonance-Raman spectroscopy, using a tunable laser and an appropriate receiver.

3. Description of Research
Using the illumination from the sun as a source, two correlation spectrometers would be used to measure the amount of SO_2 and NO_2 in the field of view between the spacecraft and the Earth's surface over predesignated targets and targets of opportunity. Both sensors would scan the ground through a common mirror assembly driven in a bistable fashion from a position of vertical line-of-sight to a position ±15 degrees normal to the line of flight.

An independent determination of atmospheric-scattered and surface-reflected radiation will be required. For example, radiometric measurements of contrast ratios of the terrain at several wavelengths in the ultraviolet and visible portions of the spectrum would be useful. Given average values of reflectance and variations in this reflectance at several wavelengths, the ratio of apparent and actual contrasts would show how the target signal is diluted by backscattered radiation.

The three-dimensional distribution of the pollutants could be estimated from ground-based meteorological measurements, from which the depth of the atmospheric mixing layer and the wind speed in that layer could be determined. Supporting data would be derived from ground measurements of pollutant concentrations made by point-sampling and monitoring networks, from ground and aircraft traverses using correlation spectrometers with similar performance characteristics, from source emission data, from calculations using numerical models, and from spacecraft visual and photographic documentation of the scene.

4. Impact on Spacecraft
The scientific crew will augment data collection of sensors with voice annotations. Responsiveness to pollution episodes would be desirable.

5. Required Supporting Technology Development
Basic to the successful use of correlation spectroscopy is (1) a mathematical model that can separate the absorption due to the pollution from the radiance loss caused by the absorption and scattering by the atmosphere and the reflectance properties of the ground, and (2) further laboratory and field studies of the

signature for each gaseous pollutant. In particular, some pollutants are found in natural traces in the atmosphere; it is necessary therefore to not only detect the gases but also to measure their concentrations.

Another method that needs further study for its suitability and mode of operation in a spacecraft is resonance-Raman spectroscopy, using a tunable laser. Such a system offers potential of either a laser looking down and scanning the horizon, or of satellite-to-satellite propagation.

To utilize the data on air pollutants in emission control, improved models are needed (1) to relate concentration of pollutants to mesoscale and large-scale meteorological and geophysical parameters, and (2) to relate pollutant concentrations to the energy balance for the atmosphere.

6. References

1. A. A. Barringer, B. C. Newburg, and A. J. Moffat. Surveillance of Air Pollution from Airborne and Space Platforms. Proceedings of th Fifth Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, April 1968.

2. J. A. Fay and D. P. Hoult, editors. Aerophysics of Air Pollution. American Institute of Aeronautics and Astronautics, New York, 1969.

RESEARCH CLUSTER
NO. 6-M-5

Critical Issues Addressed by Research Cluster

6-M-5

DETECTION AND MONITORING OF ATMOSPHERIC POLLUTANTS

6.2.1.2.3.2
What are the sources of pollution?

6.2.1.2.3.3
What are the distribution mechanisms of pollution?

6.2.3.2.3.2
Where is pollutant emission in excess of standards?

6.3.2.2.2.1
What pollutants are evident in the atmosphere and in what percentage? What is their rate of change?

6.3.2.2.2.2
What general aspects of man's progress induce pollution and changes in topography and river systems?

6.3.2.3.1.5
How can pollution and waste from large population centers be effectively controlled?

6.3.2.3.3.1
How can pollution from industrial expansion be controlled, i.e., atmospheric/hydrologic?

6.3.2.3.3.2
How is pollution related to the Earth's topography and climate?

6.3.3.1.2.4
How do man's activities affect the long term climate pattern?

6.3.3.1.3.2
How does man's modification of the environment affect local climate?

6.3.3.1.3.3
How do great population centers affect local climates?

6.3.3.3.3.1
How are all ecologic systems affected by atmospheric pollution?

6.3.3.3.3.2
What aspects of population increase and migration most affect the airborne ecology?

6.3.3.3.3.3
What effect is exerted on the air ecologic system by the pollution of water and soil?

6.5.2.1.2.4.1
What are the effects of dust and contaminants in the Earth's atmosphere upon the energy budget?

6.5.2.1.2.4.2
What are the effects of air pollution upon the climate of urban areas?

6.5.2.2.2.1
What are the effects of contaminants in the atmosphere on the elements of the hydrologic cycle?

6.7.2.2.1.1
What chemical constituents are present in the atmosphere?

6.7.2.2.1.2
Where are the chemical constituents located and how do they vary?

6.7.2.2.1.3
What terrestrial and extraterrestrial factors affect the distribution of chemical constituents?

6.7.2.2.2.1
What knowledge of the present state of the physical characteristics is required?

6.7.2.2.2.2
What knowledge of the present state of the physical constituents is required?

6.7.2.2.3.1
What factors are involved in the current atmospheric momentum and mass fields?

6.7.2.2.3.2
What factors are involved in the current atmospheric radiation and temperature fields?

6.7.2.2.3.3
What factors are involved in the current atmospheric composition and structure?

6.7.2.3.1.1.1
What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity?

6.7.2.3.1.1.2
What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity?

6.7.2.3.1.3.8
How is the hygroscopic aerosol field changed by advection, eddy diffusion, and wind lifting of soil particles?

6.7.2.3.1.3.9
How is the hygroscopic aerosol field changed by evaporation of sea spray and sea bubbles?

6.7.2.3.1.3.10
How is the hygroscopic aerosol field changed by condensation scavenging and precipitation washout?

6.7.2.3.1.3.11
How is the nonhygroscopic aerosol field changed by advection, eddy diffusion, and wind lifting of soil particles?

6.7.2.3.1.3.12
How is the nonhygroscopic aerosol field changed by precipitation washout?

6.7.2.3.3.2.3
What are the effects of changing the aerosol (dust) field in the atmosphere?

Table 1

PARAMETERS TO BE MEASURED

		Characteristics of Parameters Measured by Instrumentation								
					Instrument Resolution					
Space-Detectable Phenomenon	Type of Instrument (and Film)	Parameter Description	Units	Dynamic Range (min/max)	Spatial	Spectral	Temp	Measurement Precision	Predominant Noise Source	Control Measurements at Truth Site or on Spacecraft
1. Vertical burden of SO_2 and NO_2 in the lower layers of the atmosphere	Absorption spectrometer* *SO_2 center wavelength is 3100Å, w/150Å bandwidth; NO_2 center wavelength is 4400Å, w/200Å bandwidth	Ratio of energy contained in the absorption spectrum of the gaseous pollutant versus that contained in a reference spectrum (the output of the cross-correlation function as detected on the photodetector)	Volts, convertible to ppm-meter	2 to 20 volts peak-to-peak equivalent to 20-2000 ppm-meter	2-3 nmi	0.23%		±50% at 20 ppm-meter to ±10% at 2000 ppm-meter	Sensor; atmospheric parameters	Calibration will be required on a timely basis

Table 2

INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1	Metric Camera	X	
2	Multispectral Camera		
3	Ten-Band Multispectral Scanner		
4	Radar Imager		
5	Absorption Spectrometer	X	
6	Multichannel Ocean Color Sensor		
7	Radar Altimeter-Scatterometer		
8	Microwave Scanner Radiometer		
9	Sferic Detector, UHF		
10	Data Collection System		
11	Star Tracking Telescope		
12	Zero-Gravity Cloud Chamber		
13	Photo-Imaging Camera		
14	IR Interferometer-Spectrometer		
15	Multispectral Tracking Telescope		
16	Selective Chopper Radiometer		
17	IR Filter Wedge Spectrometer		
18	IR Temperature Sounder		
19	Satellite IR Spectrometer		
20	Temperature Profile Radiometer		
21	Visible Wavelength Polarimeter		
22	UV Imager-Spectrometer		

RESEARCH CLUSTER
NO. 6-M-5

Table 3 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-M-5 -1	Checkout Equipment		4			15-C	1/wk	15-45	1			
-2	Clean Lenses		5			21-B	1/wk	1-2 hrs	1			
-3	Prepare Equipment Checkout and warmup spectrometer and associated electronics loading cameras and cycling experiment control		3			15-B	10-12 ORB/wk	20-50	1			
-4	Operate Equipment Experiment cycling controls, pointing and tracking controls, and index photography; survey target areas via telescope		3			15-B	10-12 ORB/wk	30-50-	1			
-5	Visual Observations Voice annotations of measurements, sensory pointing, off-track pointing, indexing photography		2			12-B	"	30-50	1			
-6	Other Measurements Correlation measurements with similar equipped aircraft and update ground thrth measurements		2			15-B	"	"	1			
-7	Monitor Equipment Data receipt, sensor operation and sensor support system operations		1			15-B	"	20-50	1			
-8	Adjust Equipment Camera adjustments, spectrometer calibrations with ground truth sites, maintenance of associated sensor gear					15-B	3-5 ORB/wk	20-40	1			
									C-6-295			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
6 - Evaluate intermediate results
7 - Direct observation of phenomena
8 - Data handling
9 - Communications: initiate and receive transmissions (telemetry, voice)

CREW SKILL

Each code includes a number describing the discipline and a letter describing level of skill:

0 - No special skill required
1 - Medicine
2 - Biology
3 - Physiology
4 - Psychology
5 - Engineering
6 - Astronomy
7 - Physics
8 - Oceanography
9 - Forestry
10 - Agriculture
11 - Geology
12 - Meteorology
13 - Geography
14 - Cartography
15 - Hydrology
16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
21 - Astronaut
22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

B - Technician level, requiring several years of training in discipline but requiring no formal degree.

C - Cross-training to the specific task listed, which usually can be taught in three months or less.

START

Year of initial capability to perform task, if after 1974.

DURATION

1 - 1/2 year or less
2 - 1/2 to 1 year
3 - 1 to 2 years
4 - 2 to 3 years
5 - 3 to 4 years
6 - more than 4 years

TASK CONCURRENCY

Indicates other tasks that must be done concurrently with given task.

RESEARCH CLUSTER SYNOPSIS--METEOROLOGY

6-M-6 Support of Studies of Special Geographic Areas

1. Research Objectives

The objective of this research cluster is to investigate the potential of a manned spacecraft to provide intensive observational (visual and instrumental) meteorological support for the study of special geographic areas. In particular, the Global Atmospheric Research Program (GARP) has several special studies such as the Tropical Cloud Cluster Experiment, which will have special observational requirements. This experiment would provide information pertinent to many critical issues; in particular, those concerning the role of equatorial zones in the general circulation of the atmosphere. The experiment would test the hypothesis that a manned space laboratory can have a significant role in correlation of data from space with the ground-based systems in the equatorial zones.

2. Background and Current Status

The precise role of the equatorial regions of the Earth in the general circulation cycle consitutes one of the remaining problem areas in numerical weather prediction, because of the lack of synoptic observational data.

A combination of observing systems has been recommended to the international GARP for world data collection to alleviate this problem. They include satellite measuring systems, buoys, superpressure long-life constant-density balloons, and conventional surface-platform observations. Covering the globe will require four geosynchronous spacecraft, two sun-synchronous polar orbiters phased 90 degrees apart, thousands of balloons, and hundreds of buoys. Before the United States and GARP commit themselves to this large outlay, it is planned to conduct tests over a less-than-global area with one geostationary spacecraft, one polar orbiter, and a limited number of balloons and buoys. At the present time, an extensive test area is planned for the tropical Atlantic Ocean in the mid-1970's. An objective of the test will be to determine how well a composite system can quantitatively depict the state of the atmosphere under real weather conditions. In addition, several large-scale field experiments, such as the Tropical Cloud Cluster experiment and the popcorn cumulonimbus experiment, are being planned. Special studies and observations will have to be made by satellites, to fully reveal the physical processes responsible for the detailed structure of cloud clusters and the nature of their interactions with the field of motion. Both visual and infrared surveillance of the study area by satellites will be a major requirement of such studies.

Because meteorological research of this nature involves concentrated studies over specific areas, the resolution of the observation network will be much finer than normal, and the manned spacecraft program offers an opportunity for exceptionally close support of these area studies. The instrumentation required need not extend beyond that already contemplated for use in other Earth-observation experiments. The basic requirement will be close coordination between meteorological research programs and the manned spacecraft program.

3. Description of Research

Multiple-sensor, multiband radiometers and spectrometers would provide high-resolution (spectral and spatial) measurements of atmospheric radiation originating at the land and ocean surfaces, at the cloud tops, and within the atmosphere. These measurements would be used to derive and deduce vertical temperature and water vapor profiles, and surface and cloud-top temperatures. A measure of thermal convective activity in both thunderstorm and nonthunderstorm clouds would also be obtained by using the UHF sferics instrumentation specified in Experiment Group 6-M-2. High-resolution cloud photographs would be obtained by metric camera for correlation with the radiometric and sferics data, as well as for general meteorological referencing and research studies. Real-time visual observations of the scene would provide for close coordination with ground experimenters and would be valuable for correlation with data obtained in the manner described above.

4. Impact on Spacecraft

This experiment requires maximum participation by the scientific crew for short periods, since all meteorological instruments may be operating, and special voice annotations or written descriptions will be desirable. The great number of instruments in use will result in maximum data flow, processing, and temporary storage.

5. Required Supporting Technology Development

For this type of experiment to be successful, each proposed investigation needs an intensive and iterative systems analysis and simulation to optimize the observation system. In particular, the relationship of the spacecraft orbital characteristics to the study location and experiment objectives needs careful analysis to determine the best spacecraft instrument combination, necessary visual observations, and required ground truth.

6. References

1. Plan for U.S. Participation in the Global Atmospheric Research Program. National Academy of Sciences, Washington, D. C.

2. V. J. Oliver and R. K. Anderson. Circulation in the Tropics as Revealed by Satellite Data--GARP Topics. Bulletin of the American Meteorological Society, Vol. 50, September 1969, pp. 702-707.

RESEARCH CLUSTER
NO. 6-M-6

Critical Issues Addressed by Research Cluster

6-M-6

SUPPORT OF STUDIES OF SPECIAL GEOGRAPHICAL AREAS

6.1.2.2.1
What is the global heat balance within the Earth's crust?

6.2.1.3.2.4
What is the weather along distribution routes?

6.2.1.3.2.5
What is the climate of distribution areas?

6.3.1.3.4.1
How can the mapping of dynamic features and processes be accomplished? What is the time frame?

6.3.1.3.4.2
What types of maps would be most useful to scientists and what scales, accuracies and time frames are required, e.g.:

- Land use
- Crop-timber
- Hydrologic
- Political
- Population migration
- Urban development
- Economic
- Climatic
- Physical/chemical
- Cultural

6.3.1.3.4.3
How can maps displaying time variant entities be effectively produced and distributed for use?

6.3.2.3.2.3
How could solar radiation be effectively controlled for man's needs?

6.4.3.1.2.1
How do ocean basins, continental masses control weather?

6.4.3.1.2.2
How does the radiant temperature of the Earth contribute to the control of weather?

6.4.3.1.3.1
How do mountain chains affect local and regional climates?

6.4.3.1.3.2
How do plains provinces affect local and regional climates?

6.4.3.1.3.3
How do large geothermal anomalies affect local climates?

6.4.3.1.3.4
How do large population centers affect climate?

6.5.2.1.1.1.1
How can the amount of precipitable water within the Earth's atmosphere be determined?

6.5.2.1.1.1.2
What are the temporal variations in the fluxes of water vapor into and out of large drainage basins and lakes, and continental areas?

6.5.2.1.1.1.3
How can the water vapor content within the atmosphere at the atmosphere--surface interface be determined?

6.5.2.1.1.1.4
How can the occurrence and horizontal and vertical flow of water vapor over large areas be determined?

6.5.2.1.1.2.1
How can the global distribution of precipitation be determined on a frequent basis?

6.5.2.1.1.2.2
How can long-range prediction of precipitation (rain or snow) be improved?

6.5.2.1.1.3.1
How can reliable information on evaporation of water from the land and ocean be obtained?

6.5.2.1.1.3.2
What are the evaporation and transpiration losses along major river systems in arid environments?

6.5.2.1.2.3.3
What is the distribution of the horizontal vapor flux over the surface of the Earth?

6.5.2.1.2.4.2
What are the effects of air pollution upon the climate of urban areas?

6.5.2.1.2.5.3
What are the regional effects of changes in land use on the climate?

6.5.2.1.2.5.4
Can the characteristics of sand dunes be used to predict the climate in arid regions?

6.5.2.2.3.1
What is the effect of cloud seeding experiments on elements of the hydrologic cycle?

6.6.1.1.4.2
How does aeolian transport affect the composition of sea water and sediments?

6.6.1.1.5.3
How is the population distribution of the biota affected by cloud cover and precipitation?

6.6.1.2.2.2.11
How can forecasts of rough seas be improved?

6.6.1.2.2.2.20
How can forecasts of heavy swell on coasts be improved?

6.7.2.2.2.1
What knowledge of the present state of the physical characteristics is required?

6.7.2.2.2.2
What knowledge of the present state of the physical constituents is required?

6.7.2.2.3.1
What factors are involved in the current atmospheric momentum and mass fields?

6.7.2.2.3.2
What factors are involved in the current atmospheric radiation and temperature fields?

6.7.2.2.3.3
What factors are involved in the current atmospheric composition and structure?

6.7.2.3.1.1.1
What are the effects of the horizontal and vertical advection of velocity on the local time change of horizontal velocity?

6.7.2.3.1.1.2
What is the effect of the acceleration by the pressure gradient force on the local time change of horizontal velocity?

6.7.2.3.1.1.4
What is the effect of the acceleration by the frictional force due to internal eddy stresses on the local time change of horizontal velocity?

6.7.2.3.1.1.5
What is the effect of the acceleration by the frictional force due to boundary layer stresses on the local time change of horizontal velocity?

6.7.2.3.1.2.2
What is the effect of the transfer of heat by adiabatic processes due to the individual pressure change on the local time change of temperature?

6.7.2.3.1.2.3
What is the effect of diabatic heating by radiative transfer on the local time change of temperature?

6.7.2.3.1.2.4
What is the effect of diabatic heating by latent heat release on the local time change of temperature?

6.7.2.3.1.2.5
What is the effect of diabatic heating by internal eddy heat diffusion on the local time change of temperature?

6.7.2.3.1.2.6
What is the effect of diabatic heating by boundary layer heat transfer on the local time change of temperature?

6.7.2.3.1.3.1
How is the water vapor field changed by advection and eddy diffusion?

6.7.2.3.1.3.2
How is the water vapor field changed by evaporation and condensation?

6.7.2.3.1.3.3
How are the water droplet and ice crystal cloud fields changed by advection and eddy diffusion?

6.7.2.3.1.3.6
How is the ozone field changed by horizontal and vertical advection and eddy diffusion?

6.7.2.3.1.3.7
How is the ozone field changed by photochemical dissociation or reduction and recombination?

6.7.2.3.2.1.4
How can frequent and detailed local and hemispherical observations of the initial state of the time-dependent atmospheric variables be obtained and used?

6.7.2.3.2.2.4
How can global observations of initial state of all the time-dependent atmospheric variables be obtained and used?

6.7.2.3.2.3.2
How can the changes in the state of the ocean be used?

6.7.2.3.2.3.5
How can global observations of the initial state of the time-dependent atmospheric variables be obtained and used?

6.7.2.3.2.3.6
How can global observations of the initial state of the time-dependent land and oceanic variables be obtained and used?

6.7.2.3.3.1.1
What are the effects of changing the physical characteristics of the surface?

6.7.2.3.3.1.2
What are the effects of changing the surface albedo and emissivity?

6.7.2.3.3.1.3
What are the effects of changing the surface evaporation?

6.7.2.3.3.1.4
What are the effects of modifying the colloidal state of clouds or fog at the boundary?

6.7.2.3.3.2.1
What are the effects of changing the latent heat released by condensation and precipitation?

6.7.2.3.3.2.2
What are the effects of modulating the reflection, absorption, and emission of radiation by the atmosphere or clouds?

6.7.2.3.3.2.4
What are the effects of modifying the colloidal state of clouds over large areas?

Table 1

PARAMETERS TO BE MEASURED

Space-Detectable Phenomenon	Type of Instrument (and Film)	Characteristics of Parameters Measured by Instrumentation								Control Measurements at Truth Site or on Spacecraft
		Parameter Description	Units	Dynamic Range (min/max)	Instrument Resolution			Measurement Precision	Predominant Noise Source	
					Spatial(a)	Spectral	Temp			
1. Reflected and emitted IR radiation originating at the surface of the earth, at cloud tops, and in the atmosphere	Selective Chopper Radiometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	200-280°K	1.8 nmi	0.2% ($\Delta\nu$ = 1.3 cm^{-1} at 15u)	0.5C° below 3 nmi 2 C° between 10-20 nmi	< 1% of radiant intensity	Instrumental	Radiometric instrumentation is calibrated on board by viewing internal black body reference targets, reference calibration filters, and free space.
	IR Interferometer Spectrometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	Near zero to 300°K	8 nmi	0.1u at 15u ($\Delta\nu$ = 5 cm^{-1})	2C°	<1% of radiant intensity	Instrumental	
	Satellite IR Spectrometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	40-190 ergs/(cm^2 sec strdn cm^{-1})	43 nmi	0.1u ($\Delta\nu$ = 5 cm^{-1} to 8 cm^{-1})	1C°	<1% of signal level(b)	Instrumental	
	Filter Wedge Spectrometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	TBD	3.5 nmi	$\lambda/\Delta\lambda$ = 100 (0.05u at 5u)	TBD	Signal measured to 1 part in 500	Instrumental	
	IR Temperature Sounder	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	200-300°K	8.6 nmi	1% ($\Delta\nu$ = 10 cm^{-1} and 25 cm^{-1})	~1C°	~1% of measured radiance value	Instrumental	
	IR Temperature Profile Radiometer	Spectral radiance (transformable to temperature)	erg/(cm^2 sec strdn cm^{-1})	0-200 ergs/(cm^{-2} sec strdn cm^{-1})	9 nmi	0.4u to 1.0u, depending on λ	~1C°	<1% of signal level(b)	Instrumental	
2. Cloud Cover	Metric Camera	Amount, size distribution, type	Amount in tenths: size in ft or nmi	Amt: 0/10-10/10 Size: 100's of ft to 10's of miles	150 ft	N/A	N/A	0.02 to 0.05%	Film stability	
3. UHF Sferics Radiated from the Earth and its environs	UHF Sferics detector	UHF emissions from clouds (peak amplitude, freq and duration)	Microvolts/meter (field strength); duration in microseconds	Receiver has a max noise of 3 db; antenna gain is 6 db pulse duration from 1-2u sec to 10's of u sec	N/A	N/A	N/A			

(a) Horizontal resolution (on ground) at sub-satellite point. (b) e.g., 0.3 ergs/(cm^2 sec strdn cm^{-1}) represents an uncertainty of approximately 0.5% of signal level.

Table 2

METEOROLOGY INSTRUMENTS REQUIRED

No.	Instrument	Applicable	Comments
1	Metric Camera	X	
2	Multispectral Camera		
3	Ten-Band Multispectral Scanner		
4	Radar Imager		
5	Absorption Spectrometer		
6	Multichannel Ocean Color Sensor		
7	Radar Altimeter-Scatterometer		
8	Microwave Scanner Radiometer		
9	Sferic Detector, UHF	X	
10	Data Collection System		
11	Star-Tracking Telescope		
12	Zero-Gravity Cloud Chamber		
13	Photo-Imaging Camera		
14	IR Interferometer-Spectrometer	X	
15	Multispectral Tracking Telescope		
16	Selective Chopper Radiometer	X	
17	IR Filter Wedge Spectrometer	X	
18	IR Temperature Sounder	X	
19	Satellite IR Spectrometer	X	
20	Temperature Profile Radiometer	X	
21	Visible Wavelength Polarimeter		
22	UV Imager-Spectrometer		

RESEARCH CLUSTER 6-M-6
NO. 6-M-6

Table 3 3
CREW ACTIVITY MATRIX

RESEARCH CLUSTER NO.	TASK DESCRIPTION	EXPERIMENT EQUIPMENT	TYPE OF ACTIVITY†	PECULIAR ENVIRONMENTAL REQUIREMENTS	EXCLUSIVE‡	CREW SKILL†	FREQUENCY	TASK TIME (MIN)	NO. OF CREWMEN	START†	DURATION†	TASK CONCURRENCY†
6-M-6 -1	Checkout Equipment		4			15-C	1/wk	15-45	1			
-2	Clean Lenses		5			21-C	1/wk	1-2 hrs	1			
-3	Prepare Equipment Warm up and chill down of sensors and associated electronics, loading metric and index camera; calibrate IR, radiometer, spectrometer		3			15-B	10-15 ORB/wk	30-95	1			
-4	Operate Equipment All instruments and associated electronics, test controls, slewing/printing/tracking controls; scan optics and associated controls; data collection & recording equipment		3			15-B	"	"	1			
-5	Visual Observations Scan telescope used to supplement sensor data, indexing photography		2			15-B	"	"	1			
-6	Monitor Equipment Data receipt, sensor operation status, image quality, and experiment duration		1			12-C	"	"	1			
-7	Adjust Equipment Internal calibrations, boresighting, minor maintenance		1			15-B	"	"	1			

†See Legend of Codes, next page. ‡X (or other entry) indicates that time of crew member(s) cannot be shared with any other task.

C-6-307

LEGEND OF CODES USED IN TABLE 3

TYPE OF ACTIVITY

0 - Not covered below
1 - Experimental subject
2 - Spacecraft operations
3 - Preexperiment and post-experiment equipment preparation
4 - Maintenance of equipment
5 - Conduct of experiment
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7 - Direct observation of phenomena
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14 - Cartography
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16 - Navigation
17 - Communications
18 - Radiology
19 - Instrumentation
20 - Photography
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22 - Other

A - Professional level, usually representing Master's degree or higher in discipline.

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TASK CONCURRENCY

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