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SCIENTIFIC MISSION SUPPORT FOR EXTENDED LUNAR EXPLORATION

Final Report

Volume 3

Detailed Technical Report

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NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

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FOREWORD

This document contains the detailed technical report concerning the results of a study of scientific mission support for extended lunar exploration. The study was performed by the Space and Information Systems Division of North American Aviation, Incorporated for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration, under Contract NAS8-20258.

The study was performed under technical direction of Dr. N. C. Costes of the Research Projects Laboratory of NASA-MSFC, during a 7-1/2 month period beginning on 13 December 1965. The general guidelines of the study were delineated in DCN 1-5-21-00019 (1F).

The complete results of the study are presented in the following volumes:

Volume 1 - Condensed Summary Report

Volume 2 - Task Summary Report

Volume 3 - Detailed Technical Report

Volume 4 - Appendix A, Experiment Sequences - Computer Printouts

Volume 5 - Appendix B, Master Data Report - Computer Printouts

Volume 6 - Appendix C, Computer Program

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GLOSSARY OF TERMS

AAP	Apollo Applications Program (formerly AES, Apollo Extension Systems) — A concept for continuing the exploration of the Moon and near-earth space through maximum utilization of the existing Apollo hardware.
ALSEP	Apollo Lunar Surface Experiment Package—A package of geophysical instruments to be carried on early Apollo manned lunar flights which will be emplaced by the astronauts on the lunar surface and left there to record and transmit to Earth lunar geophysical data for periods up to 1 year.
ALSS	Apollo Logistics Support System — A concept for extended lunar exploration based on the LEM-TRUCK logistics system.
Apollo	The total system for accomplishing the initial manned lunar landing.
Apollo Spacecraft	The vehicle required to perform the Apollo mission after separation of the final launch stage. It consists of the command module (CM), the service module (SM), the lunar excursion module (LEM), and the spacecraft adapter.
Base	The location on the lunar surface serving as the focal point for the execution of a mission. This generally corresponds to the location of one or more personnel shelters.
Baseline System	A set of system requirements that holds for all system concepts and serves as a reference point of departure for parametric analyses.
Bev	1 billion electron-volts
COBOL	A computer language or technique commonly used to encode business computer programs usually related to financial data.

Discipline Area	A principal division of science or engineering. The SMS-ELE Discipline areas are: (0) Lunar Atmospheres (1) Geodesy (2) Geology (3) Geochemistry (4) Geophysics (5) Particles and Fields (6) Biology (7) Astronomy (8) Mission Support Investigations (9) Miscellaneous Basic and Applied Research
ELMS	Engineering Lunar Model Surface — Standard representative lunar surface profiles, typical of Maria and Uplands regions, formulated from twenty 100-kilometer traverses to establish a baseline for determining lunar roving vehicle requirements and evaluating the performance capabilities of proposed designs.
ESS	Emplaced Scientific Station — A geophysical observatory containing a complex of instruments similar to the ALSEP but of larger size.
Experiment	A series of measurements or observations intended to yield specific information required to accomplish part of an investigation. An experiment may have one or more replications. Example: (1) measurement of material density; (2) observation of petrologic character, e.g., crystalline, amorphous, sedimentary, igneous, metamorphic, etc.
Experiment Location	The point or region on the Moon or in space at, or within which, the experiment is performed. For example, the location for a photographic experiment relative to the Moon may be in a lunar orbit or at a particular site on the lunar surface or from a flying vehicle hovering over a particular region of the Moon.
Exploration Equipment	All hardware and systems utilized in a lunar exploration program.
Exploration Phase	A period of exploration involving a general scope of exploration with a given level of system capability.

Exploration System	A hardware assembly that contains sufficient number and types of subsystems to perform an essential set of tasks for a given mission. Systems categories include personnel shelters, LRV's, LFV's, launch vehicles, logistics spacecraft, personnel spacecraft, and others.
GSFC	NASA Goddard Space Flight Center
Guideline	One of a series of instructions that define desirable goals and objectives which the study effort should strive to achieve.
Investigation	An exercise involving a group of closely related experiments performed concurrently and/or sequentially with the intent of acquiring a specified amount of a particular kind of information within a technical area. Example: (1) determination of the number and relative amounts of different minerals in a given area; (2) photographic survey of the lunar equatorial region with a specified degree of optical resolution. An investigation can consist of one experiment only in which case the terms "Experiment" and "Investigation" are synonymous.
LEM	Lunar Excursion Module of the Apollo
LEM-SHELTER	A LEM modified to permit lunar landing and up to a three-month quiescent lunar surface storage, followed by a two-week manned occupancy as a lunar base and laboratory.
LEM-TAXI	A LEM modified to permit up to a two-week unmanned storage on the lunar surface after landing by crew adjacent to the LEM-SHELTER and prior to return to Earth.
LEM-TRUCK	A LEM descent stage modified to operate as an unmanned payload carrier. Reaction control systems must be added to permit this flight profile. Such a logistics carrier could deliver as much as 10,000 pounds of payload to the lunar surface using the basic Apollo mission profile.

LESA	Lunar Exploration System for Apollo — A post-Apollo modular lunar base concept accommodating from 3 to 18 men with lunar surface stay-time capabilities ranging from 3 months to more than 2 years.
LFV	(Lunar Hopper) (MFS) Lunar Flying Vehicle — A manned flying system capable of performing LRV abort missions or action as a lunar surface mobility adjunct.
LLV	Lunar Logistics Vehicle — A logistics spacecraft concept designed to maximize the lunar soft-landing payload capability of the Transportation Systems.
LOR	Lunar Orbit Rendezvous — A lunar mission mode during which rendezvous is accomplished in Lunar orbit.
LRV	Lunar Roving Vehicle
LSSM	Local Scientific Survey Module — A short-range (action radius 8 to 10 km, maximum range of single traverse 25 km), open-cabin surface vehicle, carrying 1 or 2 astronauts and containing neither environmental control nor life support systems. Portable backpacks are the sole provision for life support with this mobility.
Lunar Exploration Program	A scheduled plan of lunar exploration involving both lunar surface and lunar orbit operations and extending over a significant time span (the time span under consideration in this study will extend from the Apollo landing through the decade of the 1970's and into the decade of the 1980's). A lunar exploration program accomplishes a given scientific program and is described by: (1) a particular array of exploration concept modes utilizing a set of exploration equipment derived in a specific evolutionary manner, (2) a schedule controlled by resource restraints and development lead times.
Mev	1 million electron volts.

MHz	Megahertz (1 million cycles per second)
MIMOSA	Mission Modes and System Analysis for Lunar Exploration. MSFC study contract NAS8-20262 with Lockheed Missiles and Space Company.
Mission	Those operations and experiments specified to be performed at a particular location within a designated time interval.
Mission Equipment	Major system and support equipment hardware other than flight systems used in the lunar exploration program to support, sustain, and aid man in the accomplishment of lunar exploration: i.e., LRV, LFV, Lunar Shelter, Lunar Power Stations, etc.
Mission Sequence	A specified order of mission accomplishment within a lunar exploration program.
MOLAB	A concept for a long range mobile laboratory. The concept was initially associated with the Apollo Logistics Support System concept.
MSC	NASA Manned Spacecraft Center, Houston, Texas.
MSFC	NASA Marshall Space Flight Center, Huntsville, Alabama.
NAA	North American Aviation, Inc.
NAS	National Academy of Sciences
NASCOM	NASA Communications System
OART	NASA Office of Advanced Research and Technology.
OCE	Office of the Chief of Engineers, Department of the Army
OMSF	NASA Office of Manned Space Flight
Orbiter	The Lunar Orbiter Project satellite designed for lunar surface photography (unmanned).
OSSA	NASA Office of Space Sciences and Applications

Radius of Operation	Maximum radial distance from home base permitted on a lunar traverse.
Range	The total path distance which a vehicle may travel on a single traverse.
RMS	Root Mean Square — A statistical technique of analysis. In this case it is related to lunar terrain roughness.
RTG	Radioisotope Thermoelectric Generator — Energy sources connected with the ALSEP and ESS.
Scientific Equipment	Mission equipment associated directly with the scientific investigation program including scientific instruments and their immediate support ancillaries; i.e., lunar drill, emplaced scientific package, seismometers, gravimeter, etc.
S&ID	Space and Information Systems, Division of North American Aviation, Inc.
SMS-ELE	A Study of Scientific Mission Support for Extended Lunar Exploration (this study).
Subsystem	A major hardware assembly within a system that performs a specified function. Subsystem categories include structure, power, life support, environmental control, fuel, and others.
Traverse	Scientific excursion on or over the lunar surface for the purpose of obtaining measurements or observing scientific phenomena.
USGS	United States Geological Survey

1.0 TECHNICAL APPROACH

1.1 INTRODUCTION

This report presents the results of a study conducted to determine the probable spectrum of investigations to be performed during extended lunar exploration and to provide an estimate of experimental systems and operational requirements for typical lunar surface and lunar-orbital programs so that scientific mission requirements can be established sufficiently early to influence the definition of future exploration systems.

1.2 BACKGROUND

The Apollo program has the immediate objective of landing two men on the lunar surface and returning them safely to Earth. With this operational capability approaching reality, one of NASA's major tasks is the most satisfactory use of this operational capability or of some combination of its elements. Because of the long leadtimes required for upgrading the existing capability, modifying existing space systems, or developing advanced systems, it is expedient to study various missions and the associated scientific investigation support requirements at this time.

The Scientific Mission Support Study for Extended Lunar Exploration is a second-generation study which builds on the results of previous first-generation studies that examined potential missions for the specific system concepts of LEM/SHELTER—LEM/TAXI (References 46 and 47), ALSS/MOLAB (Reference 45), and LESA (Reference 3). This study differs from the preceding studies in that it is not subject to the restraints of a single candidate system; however, the general system and subsystem capabilities anticipated for the applicable phase of lunar exploration are considered.

The results of this study provide information to be used for the Mission Modes and Systems Analysis for Lunar Exploration (MIMOSA) study, currently being performed under a separate NASA contract to Lockheed, as well as other studies.

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1.3 STUDY GUIDELINES

The initial guidelines provided by NASA for conduct of the study were as follows:

1. Scientific guidelines should be derived from the report of a study conducted by the Space Science Board entitled "Space Research—Directions for the Future" and from the report of the NASA 1965 Summer Conference on Lunar Exploration and Science (References 1 and 2). Fundamental experiments (see Section 2.1) should be compiled from References 1 and 2 and other NASA source documentation.

2. Use should be made of the results of previous scientific mission support studies relating to single-point candidate systems for extended lunar exploration that are pertinent to the expanded scope of this study.

3. Scientific mission definition should not be tailored to constraints imposed by a specified transportation mode for a particular time period, nor should they be restricted to missions associated with specific lunar base candidate systems.

4. Some understanding of the practical limits and general utility of the proposed AAP effort should be acquired in order to assess the extent that the early effort of lunar exploration can influence the later phases of the program.

5. An assessment of the penalty to the scientific effort by the lack of adequate personnel mobility should be made.

6. A reasonable effort should be made to understand, and factor into this study, the relationship between scientific exploration growth and the possible growth patterns and development modes that will comprise the personnel and logistics transportation and the lunar base system capability.

7. The study results should serve as an input to the concurrent Mission Modes and System Analysis study.

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1.4 STUDY APPROACH

For purposes of facilitating the exchange of information between the study and the Lockheed MIMOSA study, the effort was organized into two phases, Phase 1 consisted mainly of the compilation of experiments and supporting requirements and the development of an experiment data management system. Phase 2 was primarily concerned with the development of experiment sequences, evolutionary scientific programs, earth support scientific personnel requirements, exploration program factors, and special system/subsystem considerations.

During the initial phase of the program, source documents supplied by NASA were screened for identification of potential experiments. Typical source documents consisted of contractor NASA reports, conference proceedings, scientific subgroup meetings, and NASA inhouse study reports. NASA supplied objectives and guidelines were used as selection criteria. Key guideline documents included the report of the Space Science Board of the National Academy of Sciences, "Space Research-Directions for the Future" (Reference 1), and the results of the "NASA 1965 Summer Conference on Lunar Exploration and Science" (Reference 2). These documents were also used as source material for experiments.

The initial review of source documents and guidelines was translated into scientific objectives, experiments, and operational support requirements. Equipment parameter definition also resulted from the source document review, as well as the identification of mission support experiments and miscellaneous basic and applied research experiments. The experiments were arranged by scientific discipline area and submitted to NASA-MSFC for review. Figure 1 shows the review process and the reviewing agencies and groups. The results and comments of this review were factored into the final data presentation by NAA through the NASA MSFC. With the information gained from the activities previously delineated as well as NAA experience in lunar scientific and operational studies, a data handling procedure was developed which evolved into an experiment data management system as shown in Figure 2. Figure 2 also illustrates the generation of the master experiment list, the subsystem support requirements, equipment performance requirements, and the mission support requirements as a second-level effort with its gradual evolution into the experiment cataloging activity, consisting of the formulation of various sequences. The second-level effort essentially completed Phase 1 activities, although continuous updating of experiments was conducted through Phase 2 as more information became available.

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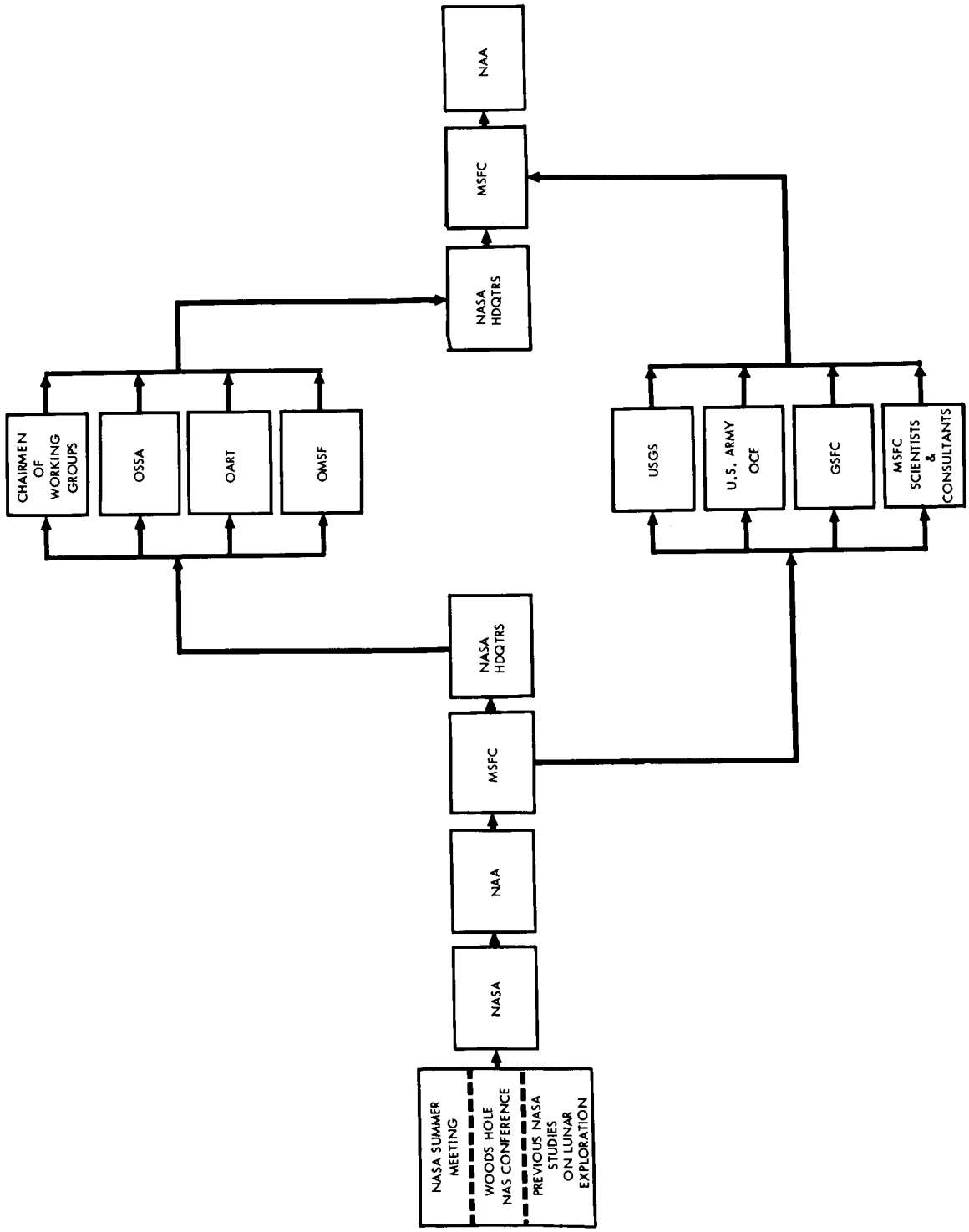


Figure 1. Experiment Review Process

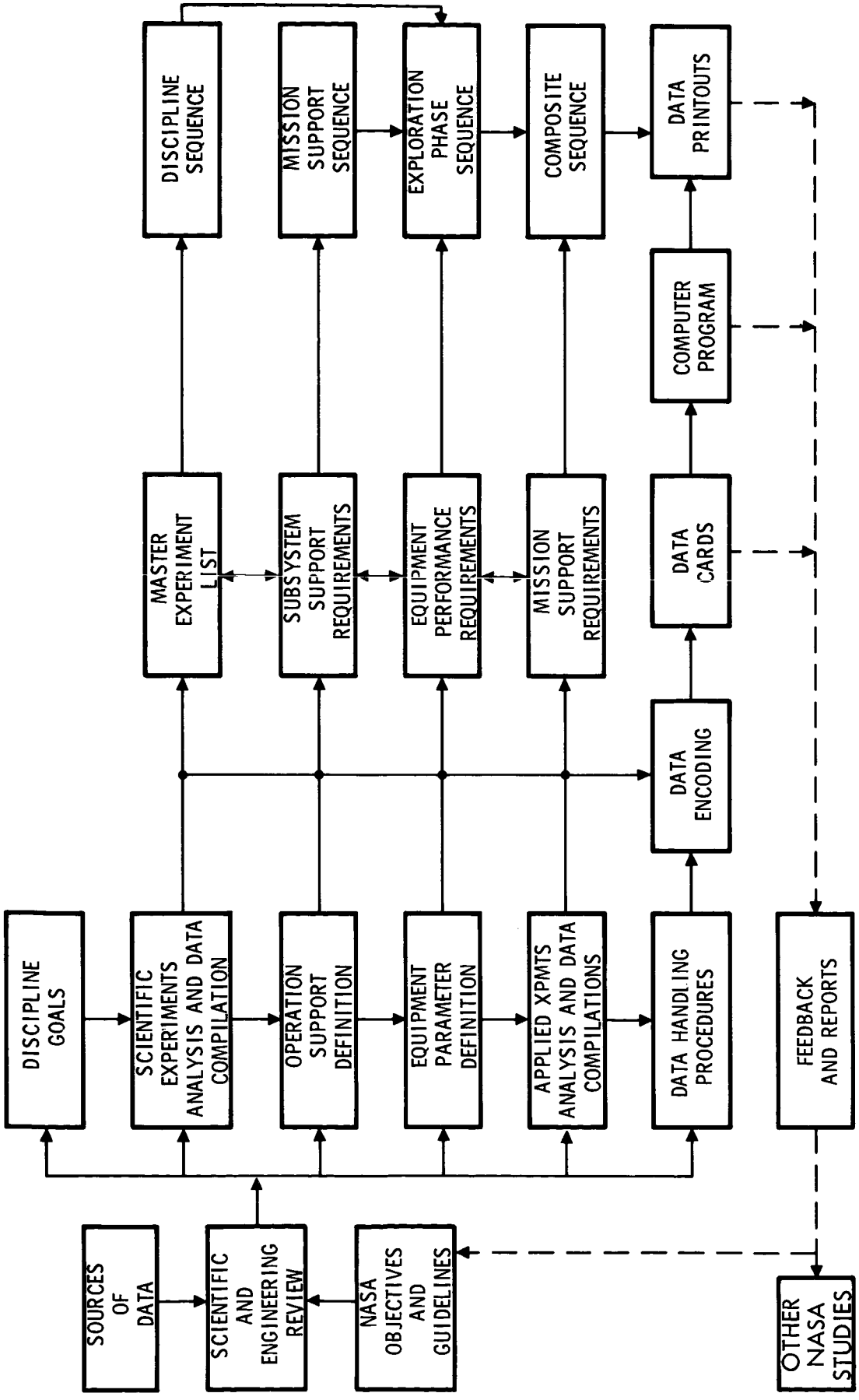


Figure 2. Project Data Flow

1.5 PROJECT ORGANIZATION

The project organization for this study is shown in Figure 3. The scientific staff was responsible for compiling the fundamental experiments and investigations. The group, headed by Dr. E.R. Cohen of the NAA Science Center, was selected and organized to be compatible with the scientific discipline areas initially identified at the beginning of the study effort, and was comprised mostly of personnel who had participated in previous scientific mission studies. S&ID capability was augmented by Dr. M. Blander of the NAA Science Center and by participants outside North American Aviation, including Dr. J. Verhoogen of Stanford University (Geosciences), Dr. K. Pierce of the University of Arizona (Solar Physics), and Dr. D.H. McNamara of Brigham Young University (Astronomy). The Engineering functions were divided into two basic areas of activity: Operations Analysis, which was responsible for formulation and implementation of the experiment data management system, analysis of the experiment support requirements, and formulation of the experiment sequences; and Applied Science and Engineering, which was responsible for identification of Mission Support, and Miscellaneous Basic and Applied Research experiments as well as systems and subsystems and other engineering support.

1.6 STUDY TASKS

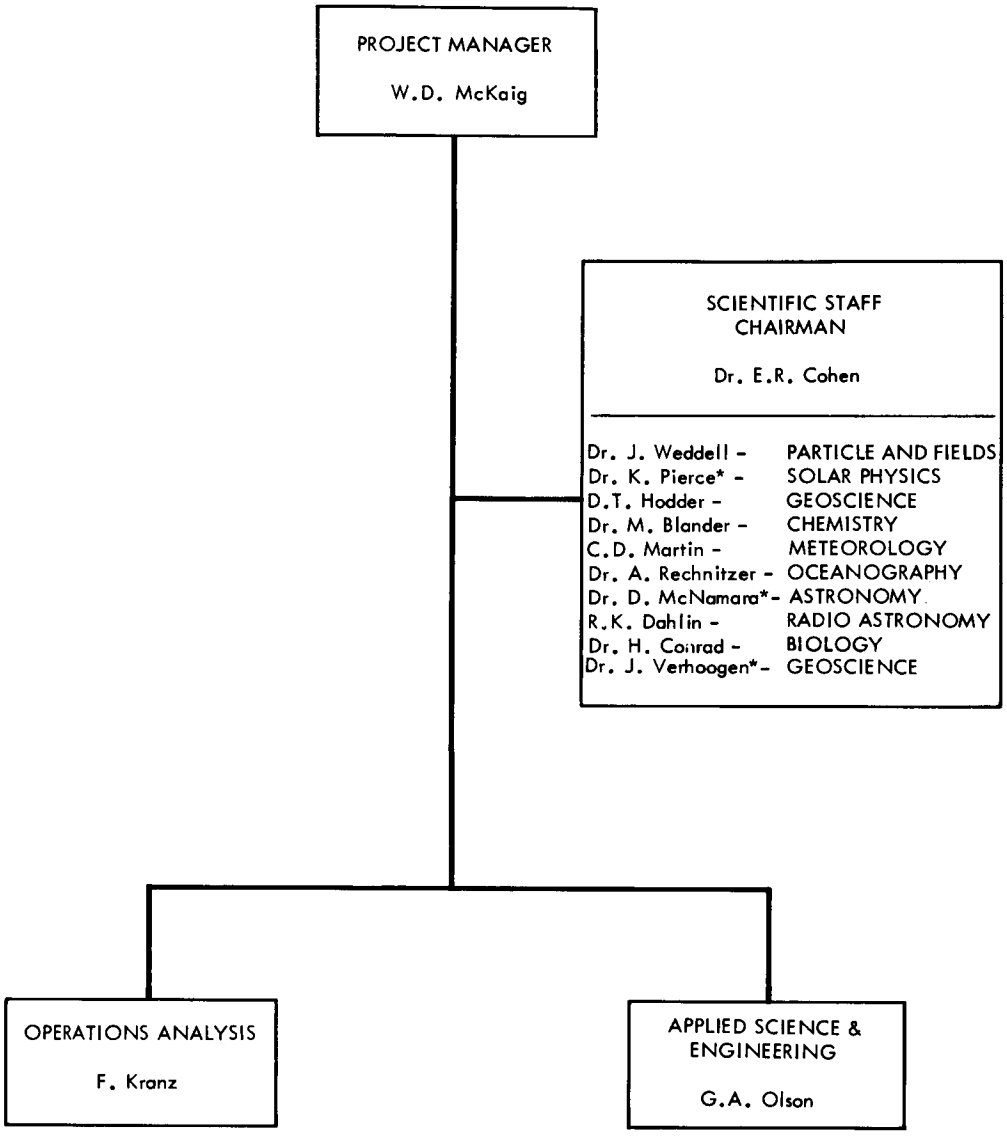
The following general study tasks have been accomplished:

1. A typical spectrum of Fundamental Investigations is extracted by reviewing existing suggested experiments and investigations, and analyzing presently approved programs (Section 2.0).

2. Mission Support and Miscellaneous Basic and Applied Research investigations and experiments are identified to ensure a more complete assessment of the total experiment support requirements (Section 3.0).

3. An experiment data management system is developed which allows rapid data retrieval for data pertinent to the experiment definition and associated support requirements (Section 4.0).

4. Equipment, personnel, and operational requirements are identified for each experiment or investigation (Section 5.0).



* Dr. K. Pierce - University of Arizona
* Dr. D.H. McNamara - Brigham Young University
* Dr. J. Verhoogen - Stanford University

Figure 3. Project Organization

5. A study is made of special systems and subsystems including the present capability of the suited astronaut, mobility requirements, and special large observatories (Section 6.0).

6. The fundamental experiments are cataloged by the following sequences (Section 7.0)

   a. Discipline Sequences within a particular scientific discipline in terms of logical accomplishment to allow an orderly progression of scientific knowledge.

   b. Mission Support Sequences within a particular scientific discipline in terms of ascending mission support parameters as a tool to aid the mission planner.

   c. Exploration Phase Sequences within a particular scientific discipline to identify logical phases of lunar exploration.

   d. Composite Sequence across scientific disciplines to aid in the delineation of an evolutionary program and in the relationship of interdisciplinary investigations with respect to support requirements.

7. Additional tasks accomplished are:

   a. An assessment of Earth-based scientific support requirements for the lunar scientific program (Section 8.0).

   b. A review of exploration program planning factors, including relation to planetary exploration and contingency planning. (Section 9.0).

2.0 FUNDAMENTAL INVESTIGATIONS

2.1 INTRODUCTION

The experiments and investigations that have been compiled under this study effort have been grouped into three main categories, namely "Fundamental Investigations"; "Mission Support Investigations"; and "Miscellaneous Basic and Applied Research." This section contains a typical spectrum of experiments and investigations under the category, "Fundamental Investigations." The latter two categories are presented in Section 3.0 of this volume.

For the purpose of this study, the term "Fundamental Investigations" designates collectively individual experiments or groups of experiments to be performed on the lunar surface or on lunar-orbiting spacecraft to obtain scientific information of a fundamental nature, i.e., information that will aid in answering fundamental questions relating to the origin, age, history, composition, gross-body properties, and environment of the Moon, the planets, including the Earth, and other celestial objects or phenomena. Individual experiments are denoted also as "Fundamental Experiments," in accordance with the definition of the more general terms, "experiment" and "investigation," adopted in the Glossary.

2.2 EXPERIMENT COMPILATION APPROACH

Fundamental experiments were compiled from a review of NASA source documentation, which included the results of previous studies of scientific missions planning and experiments suggested for lunar missions as well as system studies and equipment payload studies. Major contributions resulted from review of the results of the National Academy of Sciences 1965 Space Research Summer Study conducted at Woods Hole, Massachusetts and the NASA 1965 Summer Conference on Lunar Exploration and Science. NASA inhouse studies, reports from NASA-sponsored working groups, and suggestions from individuals as space experiment proposals to NASA comprised the bulk of the remaining review material. This material was also extremely helpful in providing the in-depth information needed to define experiment support requirements. The Bendix Systems Division, as subcontractor to the Lockheed MIMOSA Study, also provided material related to the geosciences (References 43 and 44). The source material utilized for the study, consisting of approximately 90 documents, is listed in the Bibliography.

The fundamental experiments were organized into eight discipline areas as follows:

Area	Title
0	Lunar Atmospheres
1	Geodesy
2	Geology
3	Geochemistry
4	Geophysics
5	Particles and Fields
6	Biology
7	Astronomy

All potential fundamental experiments extracted from the 90 documents supplied by NASA were initially listed. This initial listing produced approximately 660 experiments. Since these experiments came from many separate documents, it was inevitable that there would be duplications and redundancies. Duplicated experiments were removed. Overlapping experiments were combined by expanding the scope of one experiment so that it could accomplish the aims of two or three experiments with minor redefinition. These redundancy checks, commonality identifications, and revisions following the

midterm review resulted in 235 fundamental experiments. In the future, the number of experiments will undoubtedly change as additional knowledge becomes available concerning the Moon and system support capabilities.

2.3 SCIENTIFIC GUIDELINES

The scientific guidelines followed in the compilation of the Fundamental Investigations can be summarized as follows:

1. Obtain information from the Moon to determine its environment, composition, and gross body properties and ensure timely analysis of the data

2. Utilize the unique characteristics of the Moon to establish observatories and laboratories for long-term scientific investigations

3. Determine if lunar resources could be used for extended lunar operations, future interplanetary exploration, or terrestrial purposes

In 1965 the Space Science Board of the National Academy of Sciences, during its summer meeting at Woods Hole, Massachusetts, formulated the following 15 fundamental questions relating to the Moon as reported in "Space Research-Directions for the Future, Part One" (Reference 1).

1. Is the internal structure of the Moon radially symmetric, and if so, is it differentiated as the Earth is? Specifically, does it have a crust?

2. What is the geometric shape of the Moon? How does the shape depart from fluid equilibrium? Is there a fundamental difference in morphology and history between the subearth and averted faces of the Moon?

3. What is the present internal energy regime of the Moon? Specifically, what is the present heat flow at the lunar surface and what are the sources of this heat? Is the Moon seismically active and is there active volcanism? Does the Moon have an internally produced magnetic field?

4. What is the average composition of the rocks at the surface of the Moon and how does the composition vary from place to place? Are volcanic rocks present on the surface of the Moon?

5. What are the principal processes responsible for the present relief of the lunar surface?

6. What is the present distribution of tectonic activity on the Moon?

7. What are the dominant processes of erosion, transport, and deposition of material on the lunar surface?

8. What volatile substances are present on or near the surface of the Moon or in a transitory lunar atmosphere?

9. Is there evidence for organic or proto-organic materials on or near the lunar surface? Are living organisms present beneath the surface?

10. What is the age of the Moon? What is the range of age of the stratigraphic units on the lunar surface and what is the age of the oldest exposed material? Is a primordial surface exposed?

11. What is the history of dynamical interaction between the Earth and the Moon?

12. What is the thermal history of the Moon? What has been the distribution of tectonic and possible volcanic activity in time?

13. What has been the past flux of solid objects striking the lunar surface, and how has it varied with time?

14. What has been the flux of cosmic radiation and high-energy solar radiation over the history of the Moon?

15. What past magnetic fields may be recorded in the rocks at the Moon's surface?

In addition, scientific objectives for space-oriented, lunar-based investigations are contained in the following 18 additional fundamental questions formulated by NAA, as derived from Part Two of Reference 1:

16. Is the universe finite or infinite, and if it is finite, what is its size?

17. Is the universe in a steady state, and if not, how did it begin and how will it end?

18. Do the laws of physics, as deduced on Earth, apply without change for all times and over all distances? Alternatively, are there any fundamental physical laws or phenomena still undiscovered in terrestrial laboratories that are observable only on an astronomical scale?

19. Were the chemical elements that form all matter built up out of hydrogen, and if so, how?

20. How are stellar systems, stars, and planets formed?

21. What is the precise location, structure, intensity, time variation and spectral distribution of discrete X-ray sources?

22. What are the directional and spectral characteristics of diffuse X-ray radiation? What are the properties of the media in which it arises and through which it passes?

23. What are the directional and spectral characteristics of the diffuse gamma-ray flux? What is its intensity, origin, and production mechanisms?

24. What are the characteristics of the gamma-ray flux from strong radio sources? What is its origin and mechanism of production?

25. What are the characteristics of nuclear gamma rays from supernova remnants, and what does this imply about stellar evolution and collapse?

26. What is the mechanism of emission of long radio waves within the galaxy? To what extent does ionized hydrogen absorb galactic radio emissions? What is the distribution of ionized hydrogen in the galaxy?

27. What phenomena produce solar radio emission bursts? What is the relation of solar activity to terrestrial effects? What phenomena cause the Jupiter radio bursts?

28. What are the fluxes and spectral characteristics of galactic and extragalactic radio emissions?

29. What was the origin and development of the Sun? What is its structure and dynamics? What will be its future evolution?

30. What is the accuracy of the present theory of relativity?

31. What are the gross characteristics of earth terrestrial geophysical phenomena such as tidal heights, temperatures, energy emissions, etc. ?

32. What are the constituents of planetary geophysical phenomena such as atmospheric elements, temperatures, energy emission characteristics, etc. ?

33. Are there any unknown fundamental physical laws which are observable in the lunar environment?

In addition to the above general guidelines and fundamental questions, early post-Apollo lunar exploration objectives were delineated by the working groups of the NASA 1965 Summer Conference on Lunar Exploration and Science which took place at Falmouth, Massachusetts, July 19-31, 1965. The proceedings of this conference have been published as NASA Special Report 88 (Reference 2).

2.4 SCIENTIFIC OBJECTIVES

Specific scientific objectives were identified by NAA for each discipline area for later use in cataloging or formulating sequences of experiments. Initially, these objectives were identified from NASA source documentation. The objectives of each scientific discipline area are listed in Table 1. In some cases, the same objective may be listed under different scientific discipline areas because of the close relationship of the scientific disciplines and similarity of interests. Experiment data management encoding information is provided in Volume 6 (Appendix C).

For purposes of relating the objectives of the fundamental investigations identified by this study to the fundamental questions identified or derived from the National Academy of Sciences report, a matrix was formulated and is presented as Figure 4. The lunar-oriented experimental objectives of the geoscience discipline areas naturally show applicability to the NAS lunar-oriented fundamental questions, while the astronomy objectives are oriented toward the NAS space and planetary fundamental questions, except for experiments in particles and fields and radio astronomy which are equally applicable to both space and lunar-oriented scientific objectives.

Each discipline area is limited to ten objectives, which allows a single-digit numerical designation in the coding arrangement of the experiment data management system (see Volume 6, Appendix C.) This coding arrangement of objectives is adequate for the present program. Future expansion with an increased number of experiments may require two digits, allowing more than ten objectives per discipline, or the use of a common set of objectives across all disciplines.*

*The latter procedure could also use directly as scientific objectives the thirty-three fundamental questions delineated by the National Academy of Sciences Report, "Space Research - Directions for the Future" (Section 2.3) as experiment objectives. This advantage could not be foreseen when the data management system was formulated because the NAS report was not available at that time.

Table 1. Scientific Objectives

LUNAR ATMOSPHERES
Determine the composition and concentration of neutral species in the lunar atmosphere
Determine the mass and concentration of ionized species in the lunar atmosphere
GEODESY
Establish an accurate coordinate system and perform detail mapping of the Moon
Determine the size, shape, and motion of the lunar body
Determine the gravitational field of the Moon
GEOLOGY
Determine the characteristics and structure of the lunar surface and subsurface
Determine the characteristics and distribution of tectonic activity and geologic structure
Determine the principal processes responsible for lunar surface features, and the modes of erosion, transport, and deposition of lunar material
Determine the age of stratigraphic units and establish the presence of the oldest exposed material or primordial surface
GEOCHEMISTRY
Determine the geochemical, mineralogical, and petrological nature of lunar materials
Determine the extent of differentiation and segragation of lunar materials
Determine the characteristics of the sources of radioactive heat and the extent of segregation of radioactive elements

Table 1. Scientific Objectives (Cont)

GEOCHEMISTRY (Cont)
Determine the nature, extent, and relative importance of external and internal processes in shaping the present lunar topography
Determine the age of the Moon and its geomorphic features
GEOPHYSICS
Determine the characteristics and physical properties of the lunar surface and subsurface
Determine the nature of the internal lunar structure and its mechanics.
Determine the extent and location of lunar seismic activity
Determine the lunar moment of inertia, librations, and orbital perturbations
Determine the thermal state and thermal history of the lunar body
Determine the magnitude, time variations, and anomalies of the lunar gravity field
Determine the extent, time, and spatial variations of the lunar magnetic field
Conduct observations of selected terrestrial meteorological phenomena
Conduct observations of selected terrestrial planetary meteorological phenomena
Perform synoptic studies of Earth-ocean characteristics
PARTICLES AND FIELDS
Determine the cosmic solar particle radiation environment at the Moon
Determine the lunar interaction with the geomagnetosphere and solar wind

Table 1. Scientific Objectives (Cont)

PARTICLES AND FIELDS (Cont)
Conduct studies of the basic physics of high-energy particles in the natural vacuum of the Moon
Determine the composition and characteristics of active solar phenomena
BIOLOGY
Determine whether life on the Moon exists, did exist in the past, or could develop in the future
Determine the extent of Earth-originated contamination of the Moon
ASTRONOMY
Determine the suitability of the lunar surface as the site for an astronomical observatory
Investigate celestial objects utilizing optical telescopes in the UV, visual, and IR range
Investigate celestial objects in the X-ray and gamma-ray domain
Astronomical observations to test basic scientific hypotheses
Study of solar, planetary, galactic, and extra-galactic emissions
Study of lunar surface and subsurface electromagnetic properties
Study of the local lunar magnetoionic medium
Study of the cislunar medium and Earth-Moon-Sun-dynamics
Develop criteria for a lunar farside radio astronomy observatory

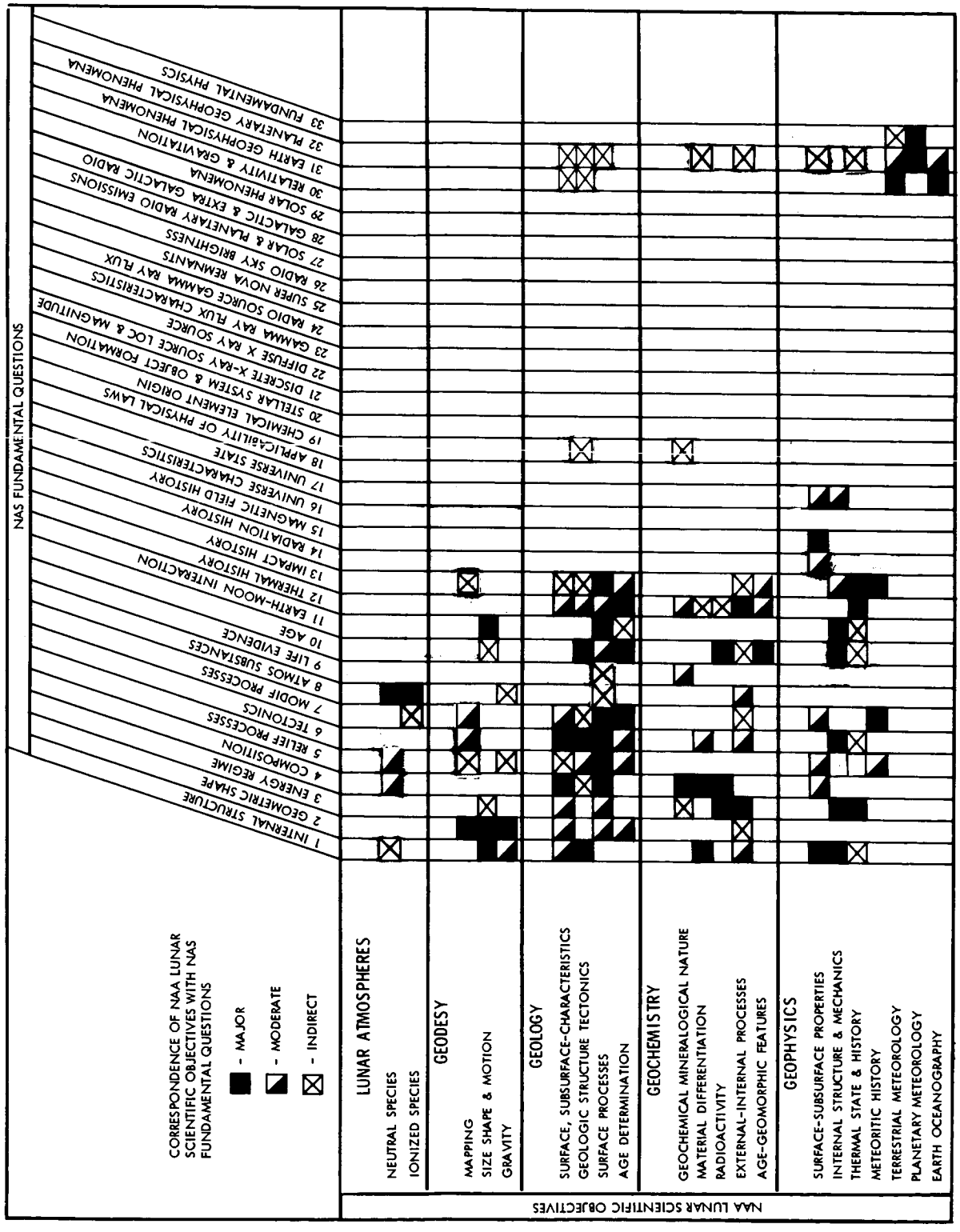


Figure 4a. Correlation of Scientific Objectives With Fundamental Questions Raised by Space Science Board National Academy of Sciences

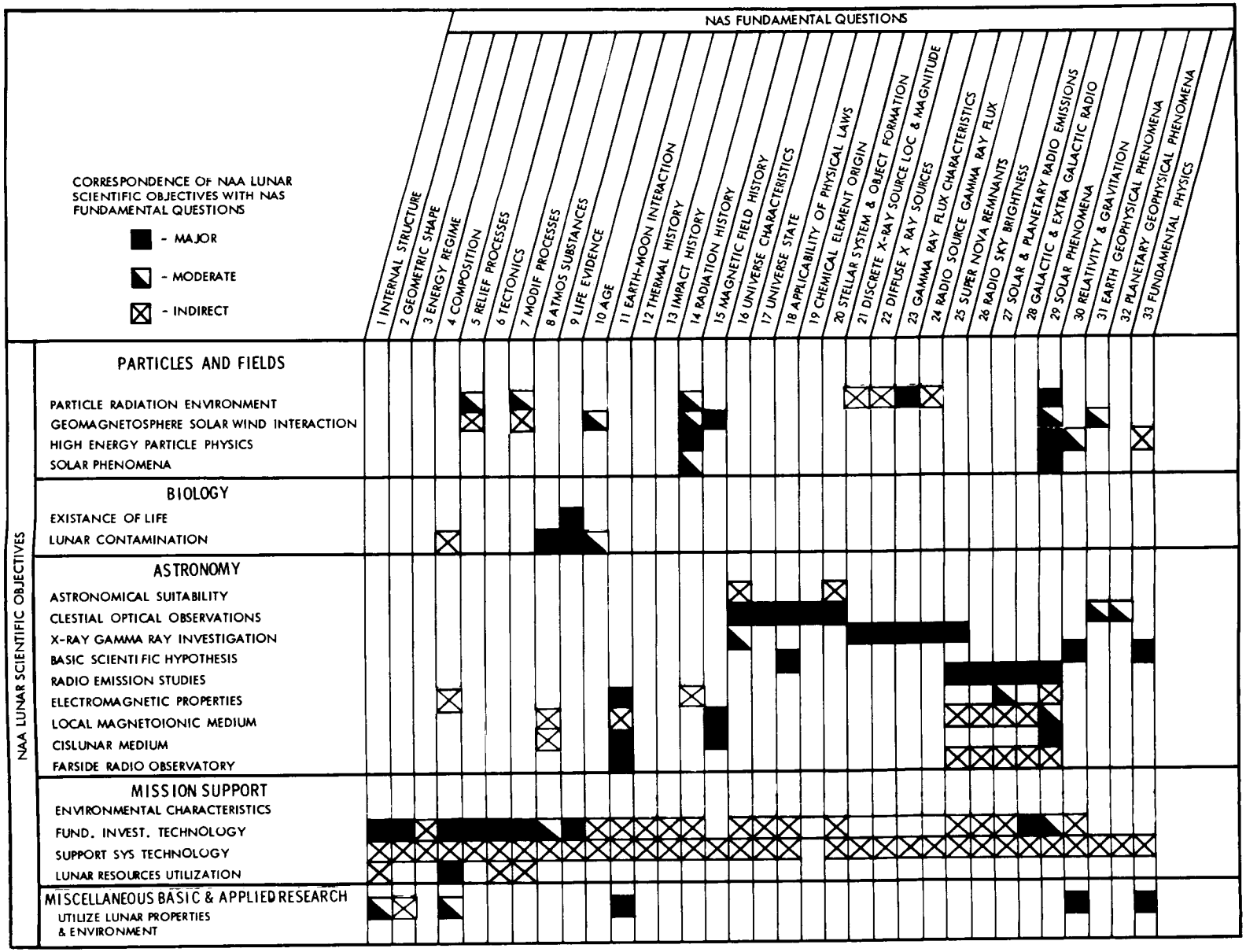


Figure 4b. Correlation of Scientific Objectives With Fundamental Questions Raised by Space Science Board National Academy of Sciences

2.5 SPECIALTIES

Specialties associated with each discipline area were identified. These specialties may be defined in several ways but primarily are related to a special characteristic, phenomena, method of measurement or an instrument, depending upon the commonly accepted specialties within the academic scientific community. The specialty designation is helpful in determining the training requirements of the personnel conducting the experiment. Specialties for each discipline area are given in Table 2. The specialties are not necessarily related to the scientific objectives for all disciplines.

Table 2. Specialties

LUNAR ATMOSPHERES
Mass Spectrometry
Analytical Chemistry
Atmospheric Physics
GEODESY
Cartography
Geodetic Surveying
Topography
GEOLOGY
Surface Geology
Subsurface Geology
Geomorphology
Photogeology
GEOCHEMISTRY
Analytical Chemistry
Petrology-Mineralogy
Isotopic Analysis
GEOPHYSICS
Active Seismology
Passive Seismology
Gravity

Table 2. Specialties (Cont)

GEOPHYSICS (Cont)
Magnetic Fields
Magnetic Properties
Electrical Surveying
Geothermal
Meteoritics
Soil Mechanics
Atmospheric Physics (Lunar)
Nuclear Physics
Gamma-Ray Spectroscopy
Nuclear Geophysics
Earth Atmospheric Physics
Planetary Atmospheric Physics
Radiometry
Photogrammetry
PARTICLES AND FIELDS
Solar Wind Particles
Solar Energetic Particles
Galactic Particles
Geomagnetically Trapped Particles
Interplanetary Magnetic Fields
Geomagnetic Field

Table 2. Specialties (Cont)

PARTICLES AND FIELDS (Cont)
Electric Fields
Particle Physics
Neutrinos
Solar Magnetic Field
Solar Velocity Fields
Solar Chemical Composition
BIOLOGY
Plant Biology
Animal Biology
Microbiology
Biochemistry
ASTRONOMY
Optical, UV, and IR Radiation
X-Ray Radiation
Gamma-Ray Radiation
Long Wavelength Radio Waves
Short Wavelength Radio Waves
Submillimeter Radio Waves
Cislunar Radio Wave Propagation

2.6 SCIENTIFIC INVESTIGATIONS

Investigations were formulated as a means of grouping related experiments. The eight-digit experiment identification number utilizes the fifth and sixth digits to identify an investigation topic under which one or more related experiments can be grouped. A listing of these investigation topics is presented in Table 3. Instructions for encoding the investigations are given in Volume 6 (Appendix C).

Table 3. Investigation Descriptions

LUNAR ATMOSPHERES
Lunar atmosphere experiments for determining total atmospheric pressure
Lunar atmosphere experiments for determining composition and atmospheric dust
Lunar atmosphere experiments to determine electric fields near surface
Lunar atmosphere experiments for determining extent and composition of neutral gases emanating from the lunar surface
GEODESY
Astronomical observations used to determine selenodetic parameters
Selenodetic surface surveying observations to establish ground control for lunar orbital mapping
Lunar surface gravity observations to aid in the determination of an accurate selenodetic coordinate system
Active seismic measurements to determine internal density distributions to supplement surface gravity observations
Earth-Moon distance observations to aid in establishment of accurate selenocentric coordinate systems and facilitate transformation between geocentric and selenocentric coordinate systems

Table 3. Investigation Descriptions (Cont)

GEODESY (Cont)
Selenodetic mapping observations to provide data for detailed topographic maps of the Moon
Gravity observations performed from lunar orbit to supplement surface gravity and seismic data
GEOLOGY
Production of lunar geologic maps from lunar orbit data
Construction of detailed geologic maps of selected lunar areas
Lunar sample collection for geological analysis to determine element composition and minerology of rocks and textural aspects and mineral distribution in the rocks, age dating of lunar rocks and formations
Determination of subsurface structure of the lunar body
GEOCHEMISTRY
Analytical chemical analysis to determine the geochemical, petrological, and mineralogical nature of lunar materials
Gamma-ray spectrometry experiments on surface traverses and from lunar orbit to provide direct information on radio-nuclides present on the lunar surface
Differential thermal analysis investigation in which volatiles from lunar materials are distilled and collected for further analysis of composition
Chemical analyses of lunar gases by use of mass spectrometers
GEOPHYSICS
Seismic studies of lunar materials
Lunar seismic events and tectonic measurements
Surveys of meteorites in the lunar environment
Lunar surface and material hardness

Table 3. Investigation Descriptions (Cont)

GEOPHYSICS (Cont)
Electromagnetic properties of the lunar material
Electric and magnetic field surveys
Studies of lunar materials with nuclear physics techniques
Lunar surface and subsurface temperatures and heat flows, spectral studies of physical properties of lunar surface materials.
Variations in lunar gravity
Studies of Earth atmosphere heat balance from lunar landing site
Studies of Earth reflectivity and albedo from lunar landing site
Studies of Earth auroral and air glow emissions
Studies of ultraviolet scattering in Earth atmosphere
Studies of Earth atmosphere by passive infrared scanning
Studies of Earth upper atmosphere density variations by stellar refraction techniques
Studies of Earth atmosphere during terrestrial eclipse of the sun
Studies of Earth atmosphere by use of radio telescope techniques
Studies of nonterrestrial planetary atmosphere circulations
Studies of temperatures and composition of planetary atmospheres
Determination of planetary albedoes and spectral reflectivities
Studies of Earth ocean heat balance from the lunar base
Studies of Earth cloud cover, sea surface glitter, water color, ice formation, and other gross dynamic patterns by use of sequential multiband photography

Table 3. Investigation Descriptions (Cont)

GEOPHYSICS (Cont)
Studies of feasibility of Earth-sea-surface height measurements from the lunar base by use of laser ranging devices or other techniques
PARTICLES AND FIELDS
Studies of solar-charged particle environment at the lunar surface, 0.01-to-0.5 Mev energy range
Studies of solar-charged particle environment at the lunar surface in the 0.04-to-1000 Mev energy range
Studies of anisotropy versus charge and energy of solar and galactic particles
Studies of solar and galactic radiation environment at lunar surface; also includes solar energetic electrons associated with solar flares
Studies of galactic nuclei environment at the lunar surface, 100 Mev to 100+ Bev energy range
Studies of galactic electron environment at the lunar surface, 100 to 1000 Mev energies
Studies of solar and galactic neutrino sources
Studies of solar wind interactions with Moon and geomagnetosphere, including the magnetohydraodynamics of the solar wind flow past the Earth and Moon
Studies of solar wind particles at the lunar surface and near the Moon
Studies of electrons escaping the Earth auroral zones during geomagnetic storms
Studies of the interplanetary magnetic field and the distant geomagnetic field
Studies of the magnetic field strength and time variations at the lunar surface and near the Moon

Table 3. Investigation Descriptions (Cont)

PARTICLES AND FIELDS (Cont)
Studies of the electrostatic field at and near the lunar surface
Studies of galactic particle scattering and reactions
Studies of the outer solar corona structure
Studies of solar flare UV spectra
Studies of solar granulation structure and granulation velocity field
Studies of sunspot formation and development
Studies of solar prominence fine structure
Studies of solar flare ejection of material
Moderate dispersion UV scans over the solar disk
Studies of UV spectrum of solar flares
BIOLOGY
Studies of prebiotic chemistry and evidence of existing life in lunar materials
Studies of the behavior and rhythms of plants for several generations in the lunar environment
Studies of the behavior and rhythms of animals for several generations in the lunar environment
Genetic effects of lunar conditions and Earth-Moon trips on plants
Genetic effects of lunar conditions and Earth-Moon trips on microorganisms
Establish a lunar soil bank at an early period of lunar exploration for use in later experiments

Table 3. Investigation Descriptions (Cont)

ASTRONOMY
Optical astronomy experiments based on use of a small medium-resolution reflecting telescope; experiments include testing of the lunar environment for development of an astronomical observatory
Optical astronomy experiments based on use of a small medium-resolution reflecting telescope for medium-resolution photos of planets and stars, photoelectric studies, and medium dispersion spectroscopic studies
Optical astronomy experiments based on the use of a small wide-field reflecting telescope with a five-degree field of view; experiments include photographic sky surveys at a variety of wave-lengths, studies of extended surface phenomena such as zodiacal light, gegenschein, lunar libration clouds, and scanning photometer studies
Optical astronomy experiments based on use of a medium-sized reflecting telescope; studies include photographs of faint and bright galaxies, nebulae, etc., at a variety of wavelengths, photoelectric photometry at wavelengths inaccessible from Earth's surface, and spectroscopic studies at low, medium, and high dispersion
Optical astronomy experiments based on the use of a large diffraction-limited telescope, with major operations in the wavelength interval of 1000 to 3000 angstroms; experiments include very high-resolution photography, high-dispersion spectroscopy, systematic studies of outer envelopes of stars, surveys to detect planet-like companions of stars, and systematic studies of high energy phenomena in stars and quasars
Special optical astronomy studies, such as the Lyman-Alpha survey of the sky or Einstein eclipse problem
X-ray astronomic observations of the X-ray radiation from the Sun, stars, galaxies, or other X-ray sources
Gamma-ray astronomic observations
Nondirectional radio astronomy
Directional radio astronomy

Table 3. Investigation Descriptions (Cont)

ASTRONOMY (Cont)
Submillimeter radio astronomy
Studies of radio wave propagation between stations on the lunar surface
Studies of variations of the lunar ambient vector magnetic field
Studies of radio wave propagation between the Earth and Moon, at various frequencies, polarizations, etc
Measurements of radio astronomy interest performed from lunar orbit, such as electric field measurements, magnetic field measurements, and particle flux measurements

The extent to which each of the scientific investigations listed in Table 3 contributes to answering each of the 33 NAS fundamental questions is shown by the matrix of Figure 5. This matrix lists in a condensed form the 33 fundamental questions across the top of the matrix and the fundamental investigations in the left hand column.

For Geodesy, Geology, and Geochemistry, the major impact of the investigations is obviously with the specific lunar questions.

The Geophysics investigations are concentrated on questions 1 to 15 on lunar exploration and Columns 31 and 32, which are questions concerning terrestrial and planetary geophysics.

The Particles and Fields investigations are primarily directed toward questions of radiation and cosmic ray intensity at the Moon, solar phenomena (flares, sunspots, solar wind, etc.), and the interactions of the geomagnetosphere with the solar wind and the solar and glactic particles.

The Lunar Atmospheres, Biology, and Astronomy disciplines provide a widely scattered correlation with the basic questions. The extent of this coverage is, of course, merely a reflection of the extent of science involved in areas as diverse as biology and astronomy, and comparisons of coverage between these five charts is inappropriate.

The purpose of the charts taken as a whole is to indicate that there is coverage of all of the scientific questions. The actual extent of the coverage can, however, be determined only by detailed examination of the actual experiments.

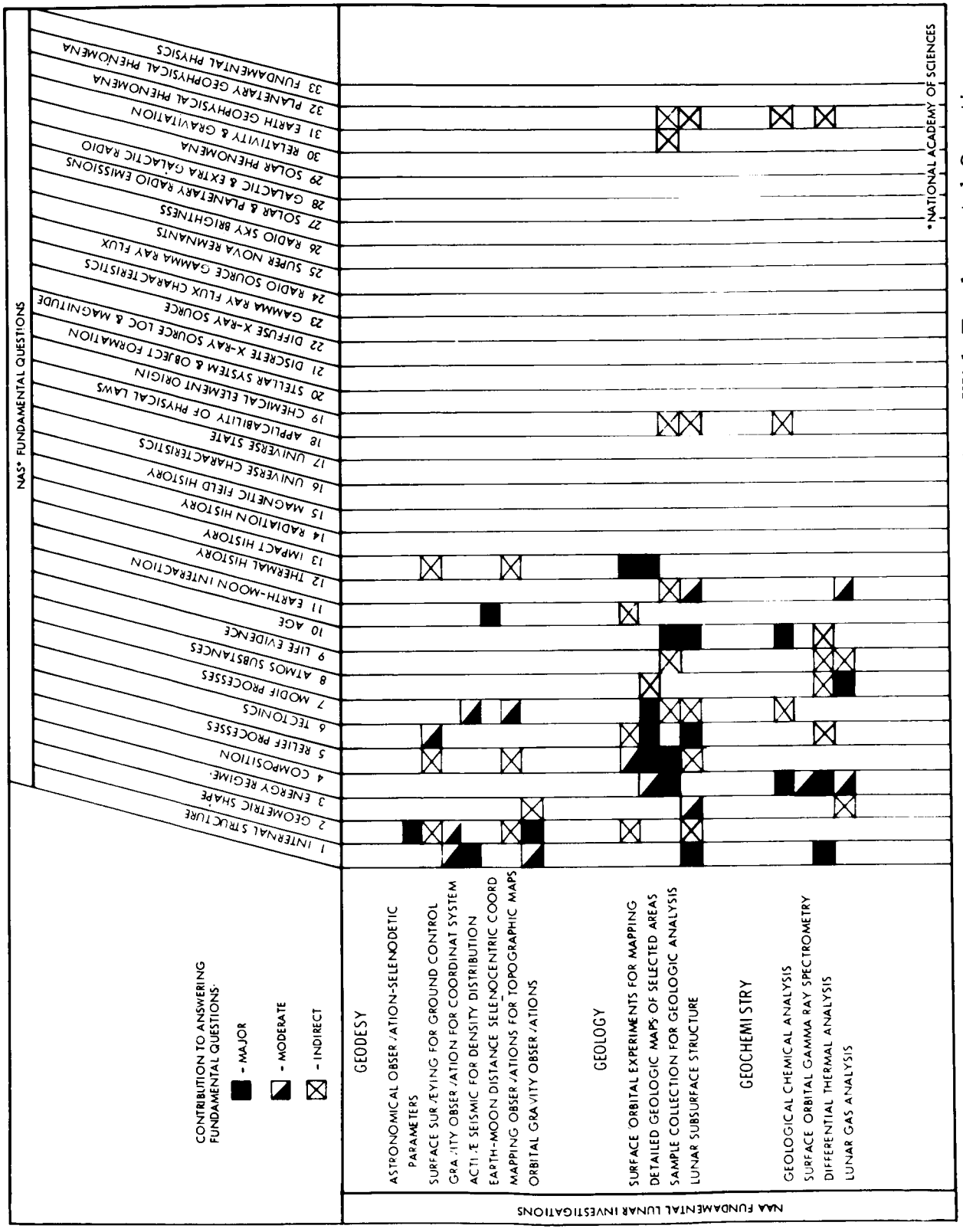


Figure 5a. Correlation of Fundamental Investigations With Fundamental Questions Raised by Space Science Board, National Academy of Sciences

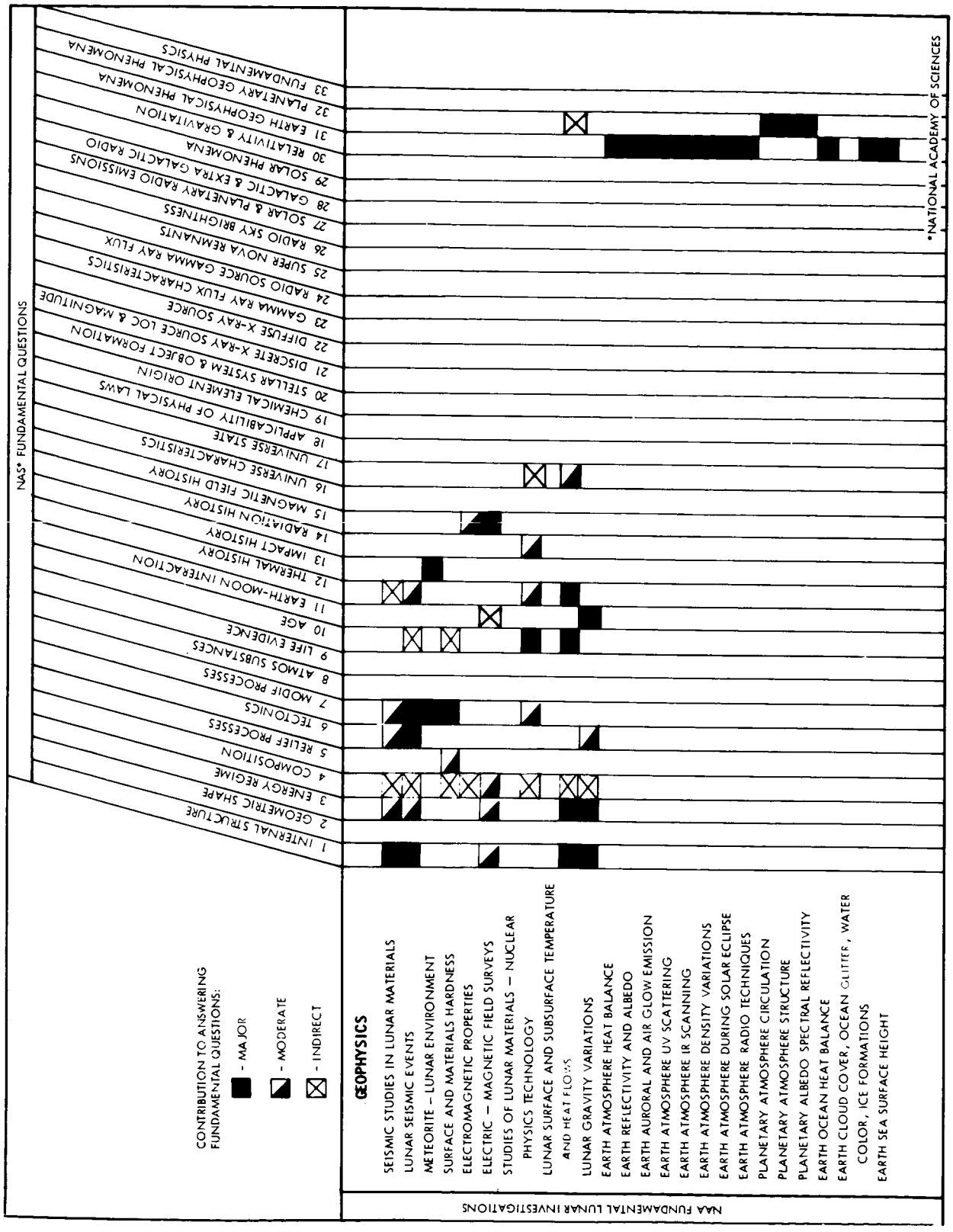


Figure 5b. Correlation of Fundamental Investigations With Fundamental Questions Raised by Space Science Board, National Academy of Sciences

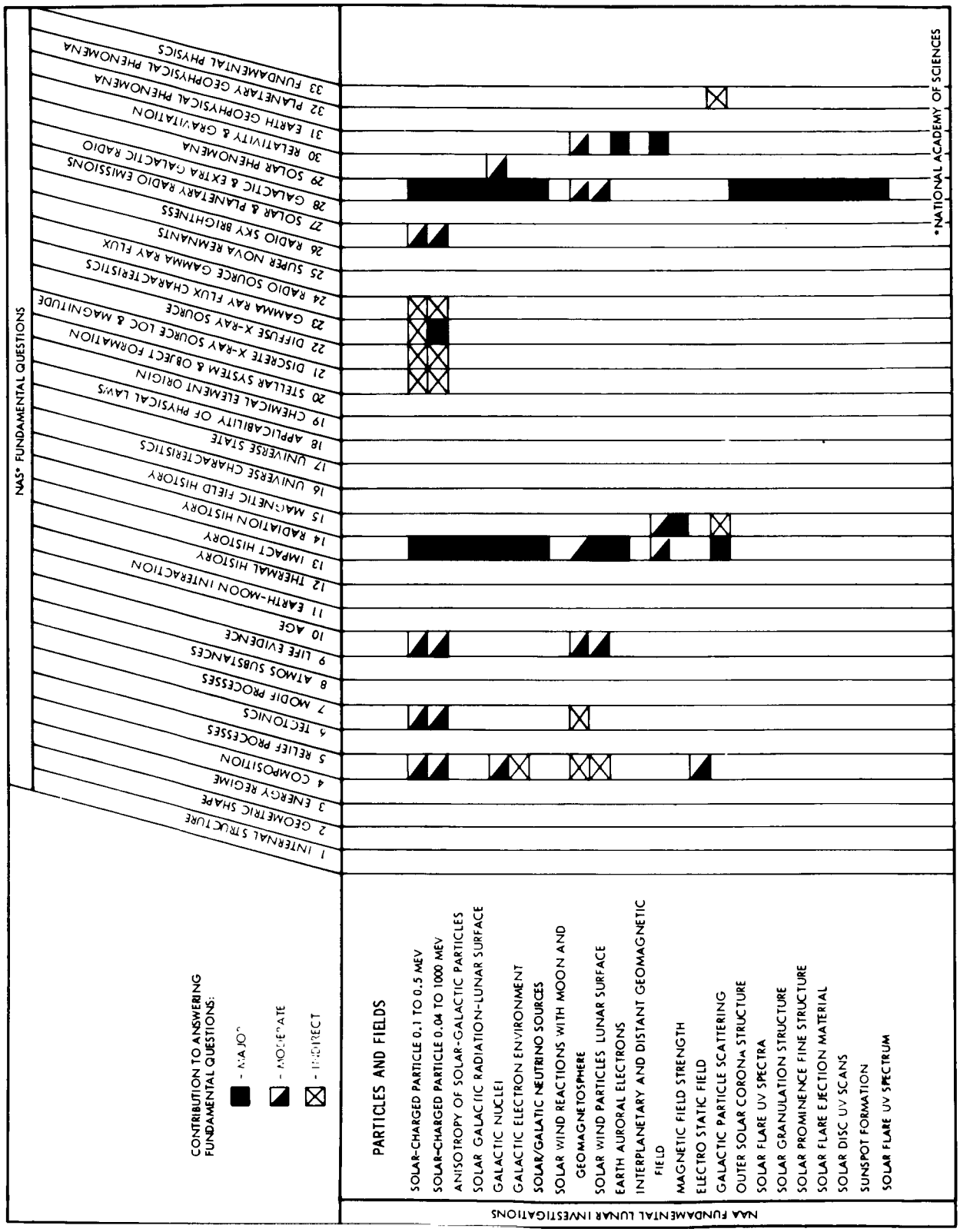


Figure 5c. Correlation of Fundamental Investigations With Fundamental Questions Raised by Space Science Board, National Academy of Sciences

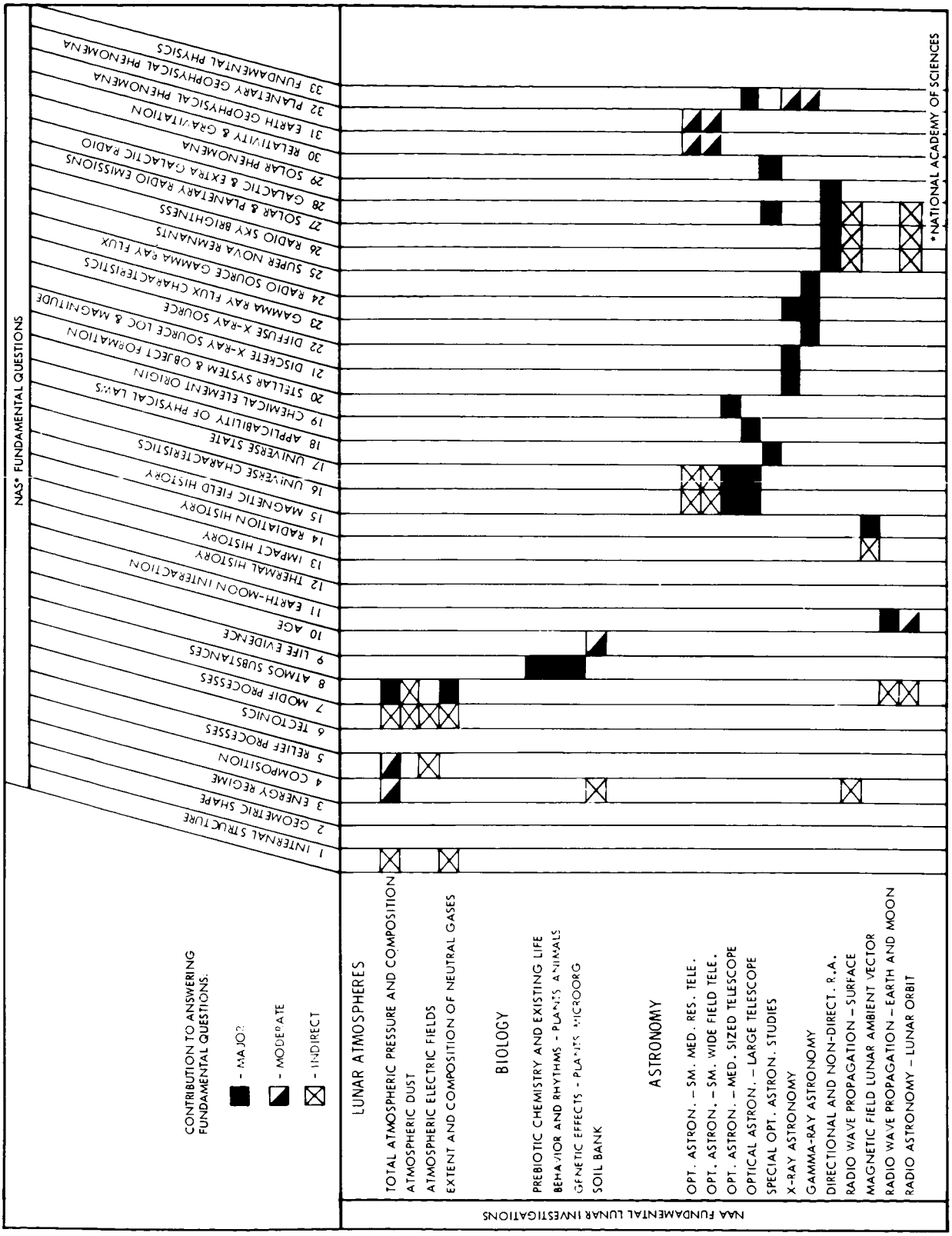


Figure 5d. Correlation of Fundamental Investigations With Fundamental Questions Raised by Space Science Board, National Academy of Sciences

2.7 FUNDAMENTAL INVESTIGATIONS SUMMARY

Table 4 gives the total number of experiments included in the category "Fundamental Investigations" by early and extended exploration phase.

Table 5 summarizes the fundamental experiments for each scientific area of interest by a written descriptive title. A summary of major support parameters is also provided for each experiment. A brief written description of each experiment is provided in Section 2.8. The total description of the experiments is presented in Volume 5 (Appendix B) in the encoded form of the experiment data management system.

Table 4. Fundamental Experiments Summary

Discipline Area	Early Exploration	Extended Exploration	Orbital	Totals
0 Lunar Atmospheres	4	2	0	6
1 Geodesy	5	0	2	7
2 Geology	9	3	2	14
3 Geochemistry	10	9	4	23
4 Geophysics	50	34	10	94
5 Particles and Fields	15	29	3	47
6 Biology	4	3	0	7
7 Astronomy	17	17	3	37
Total	114	97	24	235

There are 235 fundamental experiments compiled in the present data management system. These experiments are organized within 85 investigations with 39 scientific objectives identified. The number of experiments compared to number of investigations may be considered small. However, the investigations were formulated with a future growth in the number of experiments anticipated as lunar exploration progresses. The present number of experiments appears to be satisfactory from the standpoint of adequate scientific coverage, the limited knowledge of the lunar surface, the definition of actual scientific equipment and instrumentation as well as the capability of the supporting systems. As more knowledge is acquired of the

lunar surface and of eventual systems capability, and as the experiments and associated equipment become better defined, the number of experiments may accordingly be altered.

Table 5. Experiment Summary Information (SMS-ELE)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
				LUNAR ATMOSPHERES								
01030159	Lunar atmospheric pressure at landing sites	Site	Walk	Initial landings	1	1.0	8,000 *	0.1	20	$ 1,000,000 100,000	2	0
01030260	Time variations of lunar atmosphere pressure	Site	LSSM	Early exploration	1	1.0	40,000 **	0.1	20	$ 1,000,000 100,000	2	0
02030263	Charged atmospheric dust analyses with a charged dust spectrometer	Site	LSSM	Initial landings	1	8.5	2,000 *	1.0	0.5	$ 3,000,000 300,000	3	0
02030361	Electric field magnitude and direction at and near lunar surface	Site	Walk	Early exploration	1	2.0	0.016	1.0	0.4	$ 1,000,000 50,000	3	0
02030362	Electric field magnitude and direction at different lunar positions	Traverse	Rover	Extended exploration	1	2.0	0.016	0.1	0.4	$ 1,000,000 50,000	3	0
01030464	Gas chromatography for identification of heavy gases	Traverse	Rover	Extended exploration	1	6.3	18,000	20	30	$ 2,000.000 200,000	3	0
				SELENODESY (GEODESY)								
12020606	Selenodetic mapping to establish detailed topographic lunar maps	Orbit	None	Orbital Studies	1	530	5,100	0	1,000	$ 10,000,000 1,000,000	5	100
11010101	Selenodetic astronomy observations for improving map accuracy	Site, traverse	Combinations of vehicles	All phases	1	150	6,800	73	25	$ 1,000,000 100,000	5	60
11010505	Earth-Moon distance observations for determining librations, etc.	Site, traverse	Combinations of vehicles	All phases	1	300	8,000	73	1,000	$ 2,000,000 200,000	5	60
12010202	Selenodetic surveying to establish ground control for satellite mapping	Site, traverse	Combinations of vehicles	All phases	1	140	4,000	55	1,000	$ 2,000,000 200,000	5	60
13030707	Gravity observations from lunar orbit to supplement surface observations	Orbit	None	Orbital studies	1	140	2,200	0	10	$ 10,000,000 1,000,000	5	0
13030303	Gravity measurements at lunar surface to supplement surveying observations	Site, traverse	Combination of vehicles	All phases	1	27	2,100	17	10	$ 1,000,000 100,000	5	0
13040404	Seismic measurements to supplement gravity observations	Site, traverse	Combination of vehicles	All phases	1	64	1,700	14	5	$ 200,000 20,000	3	0
				GEOLOGY								
21040101	Geologic base maps from unmanned lunar orbiters	Orbit	None	Orbital studies	0	160	5,000	0	10,000	$ 10,000,000 1,000,000	4	0
21010203	Detailed mapping of lunar surface geologic fine structure	Site, traverse	Combination of vehicles	All phases	1	38	170	5.0	100	$ 10,000,000 800,000	3	0.
21010204	Geologic mapping, general, including on-site verification of features identified from orbital experiments	Site, traverse	Combination of vehicles	All phases	1	28	160	8.0	25	$ 7,000,000 600,000	3	0.1
21010309	Sample collection from all sites and traverses	Site, traverse	Combination of vehicles	All phases	1	4.1	0	5.0	0.0	$ 500,000 40,000	1	200
21040102	Photogeologic mapping from lunar orbit	Orbit	None	Orbital studies	0	75	380	0	25	$ 3,000,000 500,000	2	80
21020307	Shallow drilling for subsurface structure and sampling	Site, traverse	LSSM	Early Exploration	1	44	2,000	2.4	1,200	$ 5,000,000 100,000	3	42

*Energy supplied by ALSEP RTG Source
**Energy supplied by ESS RTG source

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
GEOLOGY (Cont)												
21040205	Surface photogeology	Site	Walk	Initial ~~Landing~~	1	33 □	960 □	3.0	100	$ 9,000,000 800,000	3	10
24030310	Age dating of lunar rocks and formations	Traverse	Combination of vehicles	All phases	1	28	40	2.0	25	$ 9,000,000 900,000	3	10
21020308	Deep-drilling for subsurface structure and sampling	Site	Walk	Extended exploration	4	7,000	4,200,000	1,200	12,000	$ 50,000,000 5,000,000	1	2,000
21040411	Visual subsurface logging for fine structure	Site	Walk	Early exploration	1	1.7	45	10	100	$ 1,000,000 60,000	2	0
24030413	Paleomagnetism of the Moon	Traverse	LSSM	Early exploration	1	1.0	1.0	0.2	5	$ 400,000 80,000	1	0
22010412	Formation stratigraphic correlation over large distances by coring, etc.	Site, traverse	Rover	Extended exploration	1	110	24,000	14	5,000	$ 20,000,000 1,000,000	3	10
23010320	Sample collection	Traverse	Walk	All phases	1	6.0	0	0.1	0.0	$ 300,000 1,000	2	100
21010330	Subsurface sampling	Traverse	Rover	Extended exploration	1	14	0	0.2	0.0	$ 300,000 5,000	2	200
GEOCHEMISTRY												
34010401	Mass spectrometric analyses from lunar orbit	Orbit	None	Orbital Studies	0	20	150,000	0	30	$ 10,000,000 500,000	3	0
32010111	Chemical analyses using neutron activation at lunar bases	Site	None	All phases	1	16	600	24	25	$ 5,000,000 500,000	3	0
32010101	Chemical analyses using neutron activation	Traverse	Combination of vehicles	All phases	1	16	500	22	25	$ 5,000,000 800,000	3	0
34010403	Mass spectrometry near emission sources	Emplaced points	From orbit and LSSM	Early exploration	0	20	150,000 ●	0	30	$ 5,000,000 200,000	3	0
34010402	Mass spectrometric analysis of gases on lunar surface	Traverse	Combination of vehicles	Early exploration	1	20	7,500	4.5	30	$ 5,000,000 200,000	3	0
31010108	Mineralogical and petrographic studies by use of microscope	Site	None	Early exploration	1	7.3	5,900	100	500	$ 600,000 60,000	3	0
33010102	Gamma-ray spectrometry from lunar orbit	Orbit	None	Orbital studies	0	32	2,000	0	1	$ 10,000,000 1,000,000	3	0
33010101	Gamma-ray spectrometry on traverse	Traverse	Combination of vehicles	Early exploration	1	32	2,000	20	1	$ 5,000,000 200,000	2	0
35010110	Chemical analysis of solids using mass spectrometer	Site	None	Early exploration	1	23	600	40	30	$ 5,000,000 400,000	3	0
32010301	Distillation of solids and differential thermal analysis	Site	None	Early exploration	1	7.0	150	19	100	$ 300,000 20,000	2	5 0
32010102	Chemical analysis using IR spectrometer	Site	None	Early exploration	1	16	130	22	1	$ 5,000,000 500,000	5	0

□ Energy supplied by independent power source (Astronaut Survey Staff).
Mass includes 20 Kg for TV monitors located in the LEM
● Energy supplied by independent power source (emplaced package)
‡ Experiment primarily recommended for early exploration phase, may be desirable for later phases; combination of vehicles identifies requirement for using the most advanced vehicles available in each exploration phase

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
GEOCHEMISTRY (Cont)												
32010112	Chemical analysis using X-ray fluorescence at lunar base	Site	None	Early exploration	1	7.0	100	22	0.5	$ 5,000,000 500,000	2	0
32010104	Chemical analysis using X-ray fluorescence	Traverse	Rover	Extended exploration	1	7.0	100	22	0.5	$ 5,000,000 500,000	2	0
32010117	IR reflectance and emissivity from orbit	Orbit	None	Orbital studies	0	15	150,000	0	1,000	$ 10,000,000 1,000,000	3	0
32010116	UV and visible reflectance spectra from orbit	Orbit	None	Orbital studies	0	15	150,000	0	1,000	$ 20,000,000 2,000,000	3	0
32010118	IR reflectance and emissivity in situ	Traverse	Combination of vehicles ‡	Early exploration	1	15	7,500	7	30	$ 1,000,000 100,000	2	500
32010115	UV and visible reflectance spectra in situ	Traverse	Combination of vehicles	Early exploration	1	15	7,500	7	30	$ 2,000,000 200,000	2	500
32010105	Chemical analysis at base laboratory using chemical reagents, etc.	Site	None	Extended exploration	1	21	3,000	200	100	$ 200,000 10,000	1	0
32010103	Chemical analysis using a nuclear magnetic resonance spectrometer	Site	None	Extended exploration	1	20	4,000	21	25	$ 5,000,000 500,000	4	0
32010114	Mineralogical study with X-ray diffractometer in situ	Traverse	Combination of vehicles	Extended exploration	1	9.0	200	10	60	$ 1,000,000 100,000	2	0
32010107	Mineralogical study using an X-ray diffractometer	Site	None	Extended exploration	1	9.0	250	81	60	$ 1,000,000 100,000	4	0
32010113	Density measurements by gamma scattering in situ	Traverse	Combination of vehicles	Extended exploration	1	2.0	250	10	25	$ 5,000,000 500,000	1	0
32010106	Density measurements by flotation	Site	None	Early exploration	1	0.5	0	20	0.0	$ 100,000 1,000	0	0
GEOPHYSICS												
40010101	Seismic velocity, surface	Site	Walk	Initial landings	1	13	1.7	0.2	20	$ 800,000 100,000	1	0
44070882	Temperature gradient in borehole	Site	Walk	Initial landings	1	4.4	190	0.5	9	$ 200,000 6,000	2	0
44070842	Temperature, shallow probe	Site	Walk	Initial landings	1	0.55	0	0.1	3	$ 400,000 7,000	2	0
40080353	Meteorite measurements	Site	Walk	Initial landings	1	3.3	190	0.3	5	$ 900,000 100,000	0	0
44070847	Thermal diffusivity, surface	Site	Walk	Initial landings	1	6.8	12	0.3	1,000	$ 600,000 30,000	1	0
44070850	Thermal emissivity, surface	Site	Walk	Initial landings	1	0.9	5.0	0.4	5	$ 300,000 10,000	2	0
46040616	Magnetic field, determine existence of permanent lunar magnetic field	Site	Walk	Initial landings	1	6.0	250	0.3	5	$ 800,000 100,000	1	0
46040617	Magnetic field, total	Site	Walk	Initial landings	1	7.5	160	0.5	12	$ 800,000 100,000	1	0
45030913	Gravity absolute (ESS)	Emplaced site	Walk	Early exploration	1	15.0	18,000 **	1.2	15	$ 2,000,000 200,000	2	0

**Energy supplied by ESS RTG source

‡Experiment primarily recommended for early exploration phase, may be desirable for later phases; combination of vehicles identifies requirement for using the most advanced vehicles available in each exploration phase

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
GEOPHYSICS (Cont)												
41020207	Seismic recording, passive	Site	Walk	Initial landings	1	11	190	1.0	11	$ 1,000,000 50,000	2	0
44070845	Temperature profile in deep borehole	Site	Walk	Early exploration	1	0.55	0	0.5	3	$ 200,000 6,000	1	0
40120778	Surface and subsurface gamma ray spectroscopy	Site	Walk	Early exploration	1	6.0	4.5	0.5	1	$ 1,000,000 100,000	1	0
41020208	Seismic recording, passive, (long period, short period)	Site	LSSM	Early exploration	2	14	36	6.0	3	$ 1,000,000 90,000	2	0
40060565	Determination of surface and subsurface structure and formations by use of high resolution radar	Orbit	None	Orbital studies	0	100	2,400	0	10,000	$ 5,000,000 1,000,000	5	0
40120779	Surface and subsurface gamma-ray spectroscopy	Traverse	Rover	Extended exploration	1	6.0	7.0	1.0	1	$ 1,000,000 100,000	1	0
40010102	Seismic velocity, subsurface logging	Site	‡Combination of vehicles	Early exploration	1	11	4.6	0.3	20	$ 800,000 100,000	1	0
44070848	Thermal diffusivity, borehole	Site	Walk	Initial landings	1	2.6	720	1.0	10	$ 400,000 20,000	2	0
40010103	Seismic profiling, shallow reflection	Geological area	Walk	Early exploration	1	11	4.6	0.3	20	$ 800,000 100,000	1	0
46040619	Magnetic field components	Emplaced points	Walk	Early exploration	1	6.0	18,000**	1.0	5	$ 400,000 80,000	1	0
44070843	Temperature, borehole logging	Geological area	LSSM	Early exploration	1	0.55	0	0.2	3	$ 200,000 6,000	1	0
40060630	Electrical survey, surface	Geological area	LSSM	Early exploration	1	4.3	33	1.0	500	$ 1,000,000 40,000	2	0
40060532	Resistivity of lunar surface materials in situ	Geological area	LSSM	Early exploration	1	4.0	0.001	0.2	5	$ 800,000 60,000	1	0
44070866	Passive microwave determination of surface temperature and formations	Orbit	None	Orbital studies	0	50	240	0	10	$ 1,000,000 200,000	5	0
45030968	Gravity gradient from orbit	Orbit	None	Orbital studies	0	50	3,000	0	10	$ 2,000,000 200,000	5	0
43030985	Orbital gravity gradient for moment-of-inertia calculations	Orbit	None	Orbital studies	0	50	3,000	0	10	$ 2,000,000 200,000	5	0
46040667	Magnetic field mapping from orbit	Orbit	None	Orbital studies	0	50	240	0	10	$ 800,000 100,000	1	0
41020211	Seismic recording, large array	Emplaced points	LSSM	Extended exploration	2	20	48	2.0	140	$ 1,000,000 50,000	2	0
41010206	Seismic profiling, deep refraction	Traverse	Rover	Extended exploration	0	110	0.05	0	3	$ 1,000,000 50,000	2	0
41060540	Electrical surveying, deep formations	Traverse	Rover	Extended exploration	0	6.0	0	0	10	$ 1,000,000 100,000	3	0

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Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
GEOPHYSICS (Cont)												
44070844	Temperature and emissivity of borehole walls	Traverse	Rover	Extended exploration	1	0.55	0	0.3	3	$ 200,000 6,000	1	0
44070849	Thermal diffusivity, borehole	Traverse	Rover	Extended exploration	1	11	0.03	0.2	10	$ 500,000 20,000	3	0
40130775	Neutron activation experiment	Site	Walk	Early exploration	1	9.0	1,700	2.0	29	$ 2,000,000 500,000	3	0
40130776	Neutron activation experiment on traverse	Traverse	Rover	Extended exploration	1	6.0	1,700	0	29	$ 2,000,000 500,000	3	0
44070846	Heat flow, thermal blanket	Site	Walk	Initial landings	1	2.5	0	0.2	3	$ 1,000,000 100,000	3	0
46040618	Magnetic field, total, ESS	Emplaced points	Walk	Early exploration	1	6.0	18,000**	1.0	5	$ 800,000 100,000	1	0
41050541	Electrical surveying, subsurface	Geological area	LSSM	Early exploration	0	4.0	0	0	10	$ 1,000,000 100,000	1	0
45030912	Gravity, absolute, and its variations	Site	Walk	Initial landings	1	15	18,000*	0.5	15	$ 2,000,000 200,000	2	0
40050524	Magnetic susceptibility, surface, in situ	Traverse	LSSM	Early exploration	1	2.0	2,300	1.0	15	$ 500,000 $ 50,000	2	0
41050622	Magnetism, remnant	Geologic area	LSSM	Early exploration	1	2.0	0	2.0	0	$ 40,000 800	1	2.0
41050623	Magnetism, remnant, late exploration	Emplaced points	Rover	Extended exploration	1	2.0	0	3.0	0	$ 40,000 800	1	5.0
45030914	Gravity survey on traverses	Traverse	LSSM	Early exploration	1	15	600	2.5	15	$ 2,000,000 200,000	2	0
45100601	Plasma potential variations versus height and time	Surface plus orbit	Walk	Early exploration	1	3.0	4.0	11	2	$ 200,000 100,000	1	0
46040620	Magnetic field, total field surveying	Traverse	LSSM	Early exploration	1	6.0	25	2.5	5	$ 800,000 100,000	1	0
40010104	Seismic profiling, shallow refraction	Geological area	LSSM	Early exploration	1	11	4.5	0.6	20	$ 800,000 100,000	1	0
40060534	Resistivity, subsurface	Geological area	LSSM	Early exploration	1	2.0	0.001	0.2	5	$ 1,000,000 200,000	2	0
42020284	Remote seismic station	Emplaced points from orbit	None	Orbital studies	0	3.0	12	0	1	$ 200,000 10,000	1	0
41010205	Seismic profiling, deep reflection	Geologic area	Rover	Extended exploration	2	12	4.2	2.1	20	$ 800,000 100,000	0	0
40050526	Magnetic susceptibility, subsurface	Site	Walk	Early exploration	1	2.0	300	1.0	15	$ 1,000,000 200,000	2	0
40060628	Self potential, subsurface	Traverse	LSSM	Early exploration	1	2.5	20	2.0	1	$ 1,000,000 20,000	1	0
46040621	Magnetic field survey for determining models of lunar structure	Traverse	Rover	Extended exploration	1	6.0	50	11	5	$ 800,000 100,000	1	0

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Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
GEOPHYSICS (Cont)												
45030915	Gravity survey, regional anomalies	Traverse	Rover	Extended exploration	1	15	750	11	15	$ 2,000,000 200,000	2	0
40050525	Magnetic susceptibility surface	Traverse	Rover	Extended exploration	1	2.0	300	2.0	15	$ 500,000 50,000	2	0
40060631	Electrical surveying, surface	Traverse	Rover	Extended exploration	2	4.3	36	0.5	500	$ 1,000,000 40,000	2	0
40060533	Resistivity of lunar-surface materials on traverses	Traverse	Rover	Extended exploration	1	5.0	0.001	0.1	10	$ 800,000 60,000	1	0
44070851	Temperature, surface profile	Traverse	Rover	Extended exploration	0	1.0	0	0	5	$ 800,000 60,000	2	0
40050527	Magnetic susceptibility, subsurface	Traverse	Rover	Extended exploration	1	2.0	300	2.0	15	$ 1,000,000 100,000	2	0
40060629	Self potential, subsurface	Traverse	Rover	Extended exploration	1	2.5	20	3.0	1	$ 1,000,000 20,000	1	0
44070886	Temperature probes emplaced from lunar orbit	Emplaced points	None	Orbital studies	0	20	120	0	10	$ 1,000,000 100,000	4	0
41040681	Electrical surveying, earth current	Geological area	LSSM	Early exploration	2	4.6	120	3.0	5	$ 1,000,000 30,000	2	0
40080370	Meteorite counter in orbit	Orbit	None	Orbital studies	1	3.7	56	0	0.2	$ 1,000,000 200,000	1	0
40050536	Electrical permittivity, surface	Geological area	LSSM	Early exploration	1	0.6	0	1.0	0.0	$ 100,000 200	1	2
40070883	Measure spectral reflectance of lunar-surface materials	Site	Walk	Early exploration	1	12	250	1.0	5	$ 3,000,000 300,000	2	0
40110777	Neutron flux and energy spectrum	Site	Walk	Early exploration	1	5.5	29,000**	0.2	5.4	$ 1,000,000 100,000	2	0
40130773	Natural radioactivity at different lunar locations	Site	Walk	Early exploration	1	1.8	1,300	1.0	8	$ 800,000 80,000	0	0
40130772	Alpha particle mass spectrometer on traverse	Traverse	Rover	Extended exploration	1	12	2.8	0	0.3	$ 1,000,000 90,000	1	0
40130774	Natural radioactivity on traverse	Traverse	Rover	Extended exploration	1	1.8	2,600	1.0	8	$ 800,000 60,000	0	0
41090487	Subsurface hardness	Traverse	LSSM	Early exploration	1	10	2.0	0.2	20	$ 1,000,000 100,000	4	0
40080352	Meteorite measurements, velocities, and momentums	Site	LSSM	Early exploration	1	3.3	190	0.4	5	$ 1,000,000 100,000	1	0
40070869	Spectrazonal photography to determine lunar-surface temperature and geologic formations	Orbit	None	Orbital studies	1	1.0	0	0	0.0	$ 2,000,000 200,000	2	5.0
40130771	Alpha particle mass spectrometer	Site	Walk	Early exploration	1	12	1.4	0.1	0.3	$ 1,000,000 90,000	1	0
40050538	Electrical permittivity, subsurface	Geological area	LSSM	Early exploration	1	4.0	0.02	0.1	5	$ 500,000 20,000	1	0

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Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
GEOPHYSICS (Cont)												
40050539	Electrical permittivity, subsurface	Traverse	Rover	Extended exploration	1	4.0	0.02	0.1	10	$ 500,000 20,000	1	0
40050537	Electrical permittivity, surface	Traverse	Rover	Extended exploration	1	4.0	0.02	0.1	5	$ 500,000 60,000	1	0
40060535	Resistivity of near-surface materials in boreholes	Traverse	Rover	Extended exploration	1	2.0	0.001	1.0	10	$ 800,000 60,000	2	0
40080354	Meteorite measurements on traverse	Traverse	Rover	Extended exploration	0	3.5	360	0	10	$ 600,000 50,000	2	0
47011101	Study of Earth atmosphere heat balance from lunar site	Site	Walk	Early exploration	1	78	320	27	15	$ 400,000 90,000	2	2.0
47021202	Study of Earth reflectivity and albedo	Site	Walk	Early exploration	1	78	44	25	2	$ 400,000 100,000	2	2.0
47031303	Study of Earth auroral and airglow emission	Site	Walk	Early exploration	1	74	44	20	2	$ 300,000 80,000	2	2.0
47041404	Ultraviolet scattering in earth atmosphere	Site	Walk	Early exploration	1	78	44	20	1.5	$ 400,000 90,000	2	2.0
47051505	Earth atmosphere sounding by passive infrared scanning	Site	Walk	Early exploration	1	80	44	20	2	$ 400,000 90,000	2	4.0
47061606	Earth atmosphere density measurements by stellar refraction	Site	Walk	Extended exploration	2	3,100	40	120	20	$ 9,000,000 2,000,000	4	4.0
48092109	Study of nonterrestrial planetary atmosphere circulations	Site	Walk	Extended exploration	1	3,000	5.0	33	20	$ 10,000,000 3,000,000	4	9.0
48102210	Measurements of temperature and composition of planetary atmospheres	Site	Walk	Extended exploration	2	22,000	9,700	43	50	$100,000,000 20,000,000	9	10
40090456	Determine hardness of subsurface lunar material	Traverse	Rover	Extended exploration	0	2.0	0	0	5	$ 500,000 50,000	1	0
40120780	Orbital gamma-ray spectroscopy	Orbit	None	Orbital studies	1	28	400	0	2	$ 1,000,000 100,000	1	0
48112311	Determination of planetary albedoes and reflectivities	Site	Walk	Extended exploration	1	3,000	240	180	20	$ 9,000,000 2,000,000	4	6.0
47071707	Study of earth atmosphere during terrestrial eclipse of sun	Site	Walk	Extended exploration	1	3,000	16	2.3	20	$ 9,000,000 2,000,000	4	4.0
47081808	Passive probe of earth atmosphere by microwave scan	Site	Walk	Extended exploration	2	930	2,800	14	50	$ 6,000,000 1,000,000	9	0
47051512	Observations and analyses of earth atmosphere circulation	Site	Walk	Extended exploration	1	3,000	65	52	20	$ 10,000,000 2,000,000	4	6.0
49013101	Earth ocean heat balance study	Site	Walk	Early exploration	1	69	3,200	33	15	$ 7,000,000 700,000	3	0
49023201	Sequential multiband ocean photography	Site	Walk	Early exploration	1	73	3,000	31	15	$ 2,000,000 200,000	1	2.0
49013102	Ocean heat balance study, layer phase	Site	Walk	Extended exploration	1	3,100	8,100	1,000	20	$ 9,000,000 2,000,000	6	0

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
				GEOPHYSICS (Cont)								
49023202	Sequential multiband ocean photography, later phase	Site	Walk	Extended exploration	1	21,000	1,100	820	50	$100,000,000 20,000,000	8	10
49033301	Sea surface height measurements by use of lunar-based sensor	Site	Walk	Extended exploration	1	3,100	13,000	940	50	$ 10,000,000 2,000,000	8	10
				PARTICLES AND FIELDS								
52020401	Solar and galactic radiation environment at lunar surface	Site	Walk	Inital landings	2	4.8	14,000**	39.0	1.5	$ 1,000,000 200,000	0	1.0
52020201	Solar-charged particle environment at surface, 0.04 - 1000 MEV	Site	Walk	Early exploration	1	20	20,000	54	4	$ 1,000,000 300,000	2	4.0
52020101	Solar-charged particle environment at surface, 0.01 - 0.5 MEV	Site	Walk	Early exploration	1	4.6	1,200	100	3	$ 500,000 100,000	1	0
53010201	Solar wind particles at lunar surface	Site	Walk	Initial landings	1	2.3	13,000*	0.2	3	$ 0 200,000	0	0
55230101	Measure UV spectrum over solar disk	Site	Walk	Extended exploration	2	2,500	100	8.0	30	$ 10,000,000 2,000,000	5	0
55220201	Measure UV spectrum of solar flares	Site	Walk	Early exploration	1	130	3,000	7.0	10	$ 1,000,000 200,000	3	0
53050201	Monitor magnetic field strength and direction at lunar surface	Site	Walk	Initial landings	1	2.0	18,000**	2.5	6.5	$ 0 100,000	0	0
53010101	Solar wind interaction with Moon and geomagnetosphere	Geological area	LSSM	Early exploration	2	7.0	1,800	20	4	$ 2,000,000 400,000	1	0
53070101	Steady and slowly varying electrostatic field near lunar surface	Site	Walk	Initial landings	1	3.0	26,000**	3.5	2	$ 800,000 100,000	1	0
52030101	Galactic nuclei environment at surface, 100 MEV - 100+ BEV	Site	Walk	Early exploration	1	110	24,000	55	4	$ 2,000,000 400,000	1	10
55220101	Observe spectrum of outer solar corona	Site	Walk	Early exploration	1	110	30	12	12	$ 5,000,000 1,000,000	3	0
52020402	Solar energetic electrons associated with solar flares	Emplaced points	Rover	Extended exploration	2	18	120,000	91	10	$ 1,000,000 400,000	2	0
52030201	Galactic electron environment at surface, 100 - 1000 MEV	Site	Walk	Early exploration	1	110	24,000	21	4	$ 2,000,000 400,000	1	10
52020202	Solar-charged particle environment at surface, 0.04 - 1000 MEV, later activity	Site	Walk	Extended exploration	1	25	39,000	160	4	$ 1,000,000 300,000	3	6.0
53010102	Solar wind interaction with moon and geomagnetosphere including lunar limb measurements	Traverse	Rover	Extended exploration	3	33	34,000	39	4	$ 2,000,000 400,000	2	0
53050101	Interplanetary magnetic field and distant geomagnetic field	Site	Walk	Early exploration	2	5.0	32,000	21	11	$ 2,000,000 400,000	1	0
55220301	Measure size distribution versus time of solar photospheric granulations	Site	Walk	Extended exploration	2	1,700	400	54	100	$ 9,000,000 2,000,000	5	0

*Energy supplied by ALSEP RTG source
**Energy supplied by ESS RTG source

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PARTICLES AND FIELDS (Cont)												
55220601	Observe motion of solar chromospheric and coronal material in and above solar flares	Site	Walk	Extended exploration	2	1,600	80	17	25	$ 9,000,000 2,000,000	5	10
53050102	Interplanetary magnetic field and distant geomagnetic field, including lunar limb measurements	Traverse	Rover	Extended exploration	2	4.1	48,000	37	7	$ 2,000,000 400,000	2	0
53050202	Magnetic field in solar wind shock front near Moon	Orbit	None	Orbital studies	0	3.0	22,000	0	5	$ 0 100,000	0	0
52020203	Solar-charged particle environment at surface, 0.04- 1000 MEV, later activity	Site	Walk	Extended exploration	1	43	78,000	310	4	$ 1,000,000 400,000	3	10
52030102	Galactic nuclei environment at surface, 100 MEV - 100+ BEV, later solar activity	Site	Walk	Extended exploration	1	110	48,000	210	4	$ 2,000,000 400,000	3	10
52030202	Galactic electron environment at surface, 100 - 1000 MEV, later solar activity	Site	Walk	Extended exploration	1	110	48,000	77	4	$ 2,000,000 400,000	1	10
55230102	Measure UV and visible spectrum from point to point over solar disk; determine chemical composition	Site	Walk	Extended exploration	2	2,500	200	11	30	$ 10,000,000 2,000,000	5	0
55230201	Measure UV spectrum of solar flares, advanced	Site	Walk	Extended exploration	2	2,500	500	21	30	$ 10,000,000 2,000,000	5	0
55220302	Measure velocity of photospheric material in granulations	Site	Walk	Extended exploration	2	2,500	400	31	25	$ 9,000,000 2,000,000	5	0
53010103	Solar wind interaction with Moon and geomagnetosphere, several stations and solar eclipse event	Emplaced points	Rover	Extended exploration	4	33	64,000	61	4	$ 2,000,000 400,000	2	0
53050103	Interplanetary magnetic field and distant geomagnetic field, several stations	Emplaced points	Rover	Extended exploration	2	4.1	96,000	65	7	$ 0 400,000	2	0
54080101	Galactic particle scattering and reactions	Site	Walk	Early exploration	2	6.8	100	59	30	$ 5,000,000 500,000	3	0
53070102	Vertical component of electrostatic field at and above lunar surface	Site and lunar orbit	Walk	Early exploration	2	6.6	360	9.7	1	$ 500,000 70,000	1	0
53010202	Solar wind particles in shock front near moon	Orbit	None	Orbital studies	0	2.3	13,000	0	3	$ 0 200,000	0	0
53010104	Magnetohydrodynamics of solar wind flow past Earth and Moon	Lunar surface and in lunar polar orbit	Rover	Extended exploration	4	34	130,000	140	4	$ 2,000,000 500,000	2	0
53050203	Magnetic field time variation at lunar surface	Site	Walk	Initial landings	1	3.0	22,000*	0.3	5	$ 0 100,000	0	0
53050104	Interplanetary magnetic field and distant geomagnetic field with added measurements from lunar orbiter	Surface and orbit	Rover	Extended exploration	2	7.6	210,000	110	9	$ 2,000,000 800,000	2	0

*Energy supplied by ALSEP RTG source

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PARTICLES AND FIELDS (Cont)												
52020301	Anistropy versus charge and energy of solar and galactic particles	Orbit	None	Orbital studies	1	11	4,300	3.3	6	$ 1,000,000 200,000	1	3.0
52020403	Solar energetic electrons associated with solar flares, lunar limb stations	Emplaced points	Rover	Extended exploration	2	18	120,000	91	10	$ 0 500,000	2	0
55220401	Observe size and magnetic field of sunspots versus time	Site	Walk	Extended exploration	2	1,700	2,200	16	100	$ 9,000,000 2,000,000	5	0
53040101	Electrons escaping Earth auroral zones during geomagnetic storms	Site	Walk	Extended exploration	1	4.5	5,600	220	4	$ 80,000 200,000	1	0
52090101	Solar and galactic neutrino sources	Site	Rover	Extended exploration	3	460	1,600,000	520	110	$ 30,000,000 5,000,000	9	0
54080102	Galactic particle scattering and reactions, advanced	Site	LSSM	Extended exploration	2	70	20,000	97	200	$ 10,000,000 1,000,000	6	2.0
52020103	Solar-charged particle environment at surface, 0.01 - 0.5 MEV, later activity	Site	Walk	Extended exploration	1	4.6	3,600	270	3	$ 500,000 100,000	1	0
52030103	Galactic nuclei environment at surface, 100 MEV - 100+ BEV, later solar activity	Site	Walk	Extended exploration	1	130	96,000	400	4	$ 0 1,000,000	3	20
52030203	Galactic electron environment at lunar surface, 100 - 1000 MEV, later solar activity	Site	Walk	Extended exploration	1	110	96,000	77	4	$ 2,000,000 400,000	3	10
54080103	Galactic particle scattering and reactions, detailed studies	Site	Walk	Extended exploration	2	100	200,000	88	1,500	$100,000,000 20,000,000	9	4.0
55220501	Observe structure and sudden disappearances of quiescent solar prominences	Site	Walk	Extended exploration	2	1,600	1,200	220	25	$ 9,000,000 2,000,000	5	1.0
53040102	Electrons escaping Earth auroral zones during geomagnetic storms, later solar activity	Site	Walk	Extended exploration	1	4.5	11,000	420	4	$ 80,000 200,000	1	0
52020102	Solar-charged particle environment at surface, 0.01 - 0.5 MEV, later phase	Site	Walk	Extended exploration	1	4.6	1,800	150	3	$ 500,000 100,000	1	0
BIOLOGY												
62030401	Soil bank, establish lunar sample depots at various locations on the Moon	Emplaced points	Walk and LSSM	All early phases	2	0	0	0	0.0	0 0	0	0
61040102	Evidence of existing life	Traverse	LSSM	Early exploration	2	57	7,700	270	500	$ 300,000 70,000	2	3.0
61010301	Genetic effects of lunar conditions and Earth-lunar trips on plants	Site	None	Early exploration	1	260	0	170	0.0	$ 200,000 30,000	1	0
61030303	Genetic effects of lunar conditions and Earth-lunar trips on microorganisms	Site	None	Early exploration	1	0	0	20	0.0	$ 0 0	0	0
61040101	Induced prebiotic chemistry	Site	None	Early exploration	1	45	1,500	240	15	$ 300,000 50,000	1	1.0

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watt)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
BIOLOGY (Cont)												
61010201	Behavior and rhythms of plants under the lunar day-night cycle	Site	None	Extended exploration	1	26	30	800	0.1	$ 70,000 10,000	2	2.0
61020202	Behavior and rhythms of animals under the lunar light/dark cycle	Site	None	Extended exploration	1	1.0	0	2,400	0.0	$ 10,000 1,000	1	1.0
ASTRONOMY												
71010101	Test the influence of lunar environment on optical telescope installation	Site	Walk	Early exploration	1	50.0	300	310	20	$ 200,000 50,000	2	1.0
72010102	High-resolution astronomical photos with 12-inch telescope	Site	Walk	Early exploration	1	52	320	320	20	$ 200,000 50,000	2	21.0
72010103	Photoelectric observations with the 12-inch telescope	Site	Walk	Early exploration	1	60	30,000	250	100	$ 200,000 50,000	2	1.0
72010104	Medium and low-dispersion spectroscopy of stars, planets, galaxies, etc.	Site	Walk	Early exploration	1	52	1,800	310	20	$ 300,000 70,000	2	2.0
73020622	Investigation of the X-ray radiation from Sun, stars, galaxies and X-ray sources	Site	Walk	Early exploration	1	10	10,000	980	200	$ 500,000 100,000	2	0
73020623	High resolution study of X-ray sources	Site	Walk	Early exploration	1	25	1,000	590	200	$ 500,000 100,000	2	0
73020624	Interstellar medium distribution investigation	Site	Walk	Early exploration	1	25	1,000	390	200	$ 500,000 100,000	2	0
73030725	Detection of high-energy gamma rays	Site	Walk	Early exploration	1	25	100,000	610	200	$ 500,000 100,000	2	0
72010205	Photo survey of sky, 1000 - 3000 angstroms, with 12-inch wide field telescope	Site	Walk	Early exploration	1	51	1,600	920	20	$ 200,000 60,000	2	5.0
72010308	Photographic studies of faint and bright objects at high resolution, 40-inch telescope	Site	Walk	Extended exploration	2	3,000	300	540	20	$ 9,000,000 2,000,000	4	50
72010309	Wide-band photographic photometry at very faint limits	Site	Walk	Extended exploration	2	3,000	300	240	20	$ 9,000,000 2,000,000	4	50
72010310	Photoelectric photometry of selected objects	Site	Walk	Extended exploration	2	3,000	30,000	480	200	$ 9,000,000 2,000,000	4	50
72010311	Medium- and low-dispersion spectroscopy of faint stars	Site	Walk	Extended exploration	2	3,000	7,800	910	20	$ 9,000,000 2,000,000	4	55
72010312	High-dispersion spectroscopy of bright stars, nebulae, etc.	Site	Walk	Extended exploration	2	3,200	15,000	940	20	$ 10,000,000 2,000,000	4	100
72010313	Spectral scans of various objects	Site	Walk	Extended exploration	2	3,000	45,000	910	200	$ 9,000,000 2,000,000	4	50
72010414	High-resolution photographic studies with diffraction-limited 100-inch telescope	Site	Walk	Extended exploration	2	22,000	18,000	1,100	50	$100,000,000 20,000,000	6	50

Table 5. Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-Hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
ASTRONOMY (Cont)												
72010415	High-dispersion spectroscopy of stars, planets, nebulae, comets, etc.	Site	Walk	Extended exploration	2	20,000	60,000	1,100	50	$100,000,000 20,000,000	6	100
72010416	Systematic observations of high-energy stellar phenomena	Site	Walk	Extended exploration	2	18,000	20,000	690	50	$100,000,000 20,000,000	6	50
72010417	Determination of nature and extent of stellar outer envelope	Site	Walk	Extended exploration	2	18,000	20,000	730	50	$100,000,000 20,000,000	6	50
72010418	Photo survey for planet-like companions of stars	Site	Walk	Extended exploration	2	18,000	20,000	430	50	$100,000,000 20,000,000	6	50
72010419	Photoelectric magnitude and color index measurements of stars	Site	Walk	Extended exploration	2	18,000	40,000	1,000	200	$100,000,000 20,000,000	6	50
72010521	Lyman-alpha survey of the sky	Site	Walk	Early exploration	1	25	10,000	610	20	$ 100,000 50,000	2	0
74010520	Einstein eclipse problem	Site	Walk	Early exploration	1	20	40	62	20	$ 200,000 30,000	1	20
72010206	Investigation of variable brightness extended surface phenomena	Site	Walk	Early exploration	1	50	1,600	500	20	$ 300,000 60,000	2	5.0
72010207	Photoelectric scanning data on extended objects	Site	Walk	Early exploration	1	52	32,000	280	20	$ 400,000 70,000	2	5.0
75050102	Directional radio astronomy using interferometer	Geological area	Rover	Extended exploration	2	510	30,000	23	3	$ 500,000 100,000	1	0
75040101	Nondirectional radio astronomy	Site	Walk	Early exploration	1	7.0	15,000	6.0	3	$ 500,000 90,000	2	0
78070101	Cislunar wave propagation, study of medium	Site	Walk	Early exploration	1	20	1,500	8.0	5	$ 300,000 50,000	1	0
77070101	Lunar ambient vector magnetic field measurements	Site	Walk	Early exploration	1	5.5	5,000	57	5	$ 100,000 20,000	1	0
76070102	Lunar wave propagation experiment	Geological area	LSSM	Early exploration	2	20	51,000	19	40	$ 400,000 80,000	1	0
78070102	Cislunar wave propagation advanced central station	Lunar site and earth	Walk	Extended exploration	1	20	7,500	8.0	5	$ 400,000 70,000	1	0
78070103	Cislunar wave propagation, advanced outlying Station A	Emplaced points	Flying vehicle or rover	Extended exploration	1	50	7,500	8.0	5	$ 400,000 70,000	1	0
78070104	Cislunar wave propagation advanced outlying Station B	Emplaced points	Flying vehicle or rover	Extended exploration	1	50	7,500	8.0	5	$ 400,000 70,000	1	0
79070101	Electric field measurement from lunar orbit	Orbit	None	Orbital studies	1	2.0	2.0	0	0.4	$ 100,000 20,000	1	0
79070102	Magnetic field measurement from lunar orbit	Orbit	None	Orbital studies	1	3.3	700	0	7	$ 100,000 20,000	1	0
79070103	Particle flux measurements from lunar orbit	Orbit	None	Orbital studies	1	2.3	21,000	0	2	$ 200,000 60,000	1	0
75060101	Submillimeter radio astronomy experiments	Lunar limb, emplaced points	Rover	Extended exploration	3	5,000	20,000,000	1,000	1,000	$100,000,000 20,000,000	5	200

2.8 EXPERIMENT DESCRIPTIONS

This section presents the fundamental experiments with a brief written description of each experiment. These written descriptions were reproduced from the type O computer cards, provided in the experiment-data management system (see Section 4.5), for each experiment. They are presented here for convenience. Complete experiment descriptions are provided in Volume 5 (Appendix B).

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA SPEC INVS EXPT	LUNAR ATMOSPHERES
01 03 01 59	ATMOSPHERIC PRESSURE, ALSEP THE PURPOSE OF THIS EXPERIMENT IS TO MEASURE THE TOTAL ATMOSPHERIC PRESSURE AT THE ALSEP SITE. THE GAUGE WILL CONSIST OF A MODIFIED RED-HEAD OR KRIESSMAN GAUGE CONNECTED WITH SIMPLE DIRECT CURRENT ELECTRONICS. THE SYSTEM WILL BE PART OF THE ALSEP EMPLACED BY THE ASTRONAUT. IT MAY BE NECESSARY TO MEASURE THE PRESSURE SOME TIME AFTER THE ASTRONAUTS LEAVE SINCE OUTGASSING AND LEAKAGE OF THE PRESSURIZED SUITS AND SPACECRAFT MAY RAISE THE PRESSURE IN THE VICINITY BY AN ORDER OF MAGNITUDE OR MORE. THE VARIATIONS OF PRESSURE WITH TIME WILL BE RECORDED, ESPECIALLY THROUGH A LUNAR DAY AND NIGHT. CONTINUAL READOUT IS NOT NECESSARY BUT ONLY PERIODIC SAMPLING WILL BE REQUIRED.
C 1 03 C2 60	ATMOSPHERIC PRESSURE, ESS THE OBJECT OF THIS EXPERIMENT IS TO MEASURE THE TOTAL LUNAR ATMOSPHERIC PRESSURE AT THE ESS. A MODIFIED RED HEAD GAUGE OR A KIIESMAN GAUGE WILL BE USED. THE OUTPUT WILL CONSIST OF A DC VOLTAGE. THE INFORMATION AS TO TOTAL PRESSURE WILL ALSO BE INFERRED FROM THE MEASUREMENTS MADE BY THE LUNAR ATMOSPHERIC ANALYZER OUTGASSING OF PRESSURIZED CRAFT AND SPACESUITS MAY CAUSE PRESSURES IN THE VICINITY OF THE ESS TO INCREASE SUBSTANTIALLY SO THAT USEFUL MEASUREMENTS CAN BE MADE ONLY AFTER DEPARTURE OF THE ASTRONAUTS. THE OUTPUT OF THE PRESSURE MEASURING DEVICE WILL BE SAMPLED ONLY INTERMITTENLY TO OBTAIN THE TIME VARIATION OF PRESSURE.
1 03 C4 64	GAS CHROMATOGRAPHY THIS EXPERIMENT WILL BE USED TO IDENTIFY HEAVY GASES SUCH AS THOSE FROM VOLCANIC FUMAROLES ON THE LUNAR SURFACE. A CARRIER GAS, SUCH AS HELIUM PUSHES THE UNKNOWN GASES THROUGH A PACKED COLUMN WHERE THE UNKNOWN GASES SEPARATE ACCORDING TO THEIR AFFINITY FROM COLUMN PACKING AND FLOW OUT OF THE COLUMN AT DIFFERENT TIMES. THEY ARE SENSED AND MEASURED BY A DETECTOR AT THE EFFICIENT END OF THE COLUMN. THE DETECTOR CAN BE A THERMAL CONDUCTIVITY CELL WITH A SENSITIVITY LIMIT OF 10E-09 TO 10E-10 GRAM MOLE, AN IONIZATION GAUGE WITH SENSITIVITY LIMIT OF 10E-12 GRAM MOLE, OR OTHER. ANALYSIS TIME IS 2 MINUTES TO 2 HOURS.
0 2 03 02 63	CHARGED ATMOSPHERIC DUST, ALSEP IN THIS EXPERIMENT A CHARGED DUST SPECTROMETER WILL BE USED TO DETECT AND ANALYZE FOR MASS, CHARGE, SPEED, AND FLUX FINELY DIVIDED ELECTRICALLY CHARGED MOVING PARTICLES IN THE LUNAR ATMOSPHERE. THIS CHARGED LUNAR DUST COULD RESULT FROM PHOTOELECTRIC EMISSION BY UNCONSOLIDATED PARTICLES WHICH HAVE BEEN EJECTED FROM THE LUNAR SURFACE BY METEOROID IMPACT. INSTRUMENTATION INCLUDES AN ELECTROSTATIC ENERGY/CHARGE SELECTOR, A PULSE CHAMBER FOR PARTICLE SPEED MEASUREMENT, AND AN IMPACT PLATE WHICH MEASURES PARTICLE CHARGE AND FLUX. THE ENERGY/CHARGE SELECTOR IS A CAPACITOR WHOSE PLATES ARE QUARTER CYLINDERS. ONLY PARTICLES WHOSE ENERGY/CHARGE RATIO IS EQUAL TO THE VOLTAGE BETWEEN THE PLATES DIVIDED BY THE NATURAL LOGARITHRM OF THE RATIO OF THE PLATE RADII WILL PASS THROUGH THE ANGULAR REGION THE PLATES. THE VELOCITY IS DETERMINED FROM THE LENGTH OF THE VOLTAGE PULSE INDUCED IN THE CHAMBER BY THE CHARGED PARTICLE TRAVERSING IT. VOLTAGE PUSLES FROM THE IMPACT PLATE ARE COUNTED FOR FLUX MEASUREMENT AND PULSE HEIGHT ANALYZED FOR CHARGE DETERMINATION. THE VOLTAGE BETWEEN THE PLATES OF THE ENERGY/CHARGE IS VARIED IN TEN STEPS TO COVER A LARGE RANGE OF THIS RATIO. THE VERTICAL ELECTRIC FIELD STRENGTH SHOULD BE MEASURED SIMULTANEOUSLY WITH (OR SHORTLY AFTER) THESE MEASUREMENTS.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVST	EXPT

EXPERIMENT DESCRIPTION

LUNAR ATMOSPHERES

C 2 02 03 61

ELECTRIC FIELD EARLY EXPLORATION

THIS EXPERIMENT WILL MEASURE THE ELECTRIC FIELD MAGNITUDE AND DIRECTION NEAR THE SURFACE OF THE MOON. AN ELECTRON BEAM DEFLECTION METHOD WOULD TAKE ADVANTAGE OF THE EXTREMELY LOW ATMOSPHERIC PRESSURE AND WOULD BE QUITE SENSITIVE AND VARIED TO COVER A LARGE RANGE. ELECTRONS ARE ACCELERATED AND ELECTROSTATICALLY DEFLECTED TO SCAN A RECTANGULAR RASTER ON A METAL PLATE WITH A HOLE LOCATED SO THAT THE ELECTRON BEAM PASSES THROUGH IT WHEN BOTH DEFLECTING VOLTAGES AND EXTERNAL ELECTRIC AND MAGNETIC FIELDS ARE EQUAL TO ZERO. WHEN AN EXTERNAL FIELD IS APPLIED THE BEAM WILL PASS THROUGH THE HOLE AND BE DETECTED WHEN THE DEFLECTION VOLTAGES ARE NON-ZERO, I.E., AT A DIFFERENT TIME IN THE SWEEP CYCLE. A MEASUREMENT OF THIS TIME CONSTITUTES A MEASUREMENT OF THE EXTERNAL FIELD. ELECTRIC AND MAGNETIC FIELDS CAN BE DISTINGUISHED BY VARYING THE ACCELERATING VOLTAGE. TWO ELECTRIC FIELD METERS ARE DESIRABLE AT THE ESS SITE, ONE CLOSE TO THE SURFACE AND THE OTHER 5 TO 10 METERS ABOVE IT. MEASUREMENTS OF THE ELECTRIC FIELD WOULD BE TAKEN WITH THE CHARGED DUST MEASUREMENTS.

C 2 03 03 62

ELECTRIC FIELD EXTENDED EXPLORATION

THIS EXPERIMENT WILL MEASURE THE ELECTRIC FIELD MAGNITUDE AND DIRECTION NEAR THE SURFACE OF THE MOON. AN ELECTRON BEAM DEFLECTION METHOD WOULD TAKE ADVANTAGE OF THE EXTREMELY LOW ATMOSPHERIC PRESSURE AND COULD BE QUITE SENSITIVE AND VARIED TO COVER A LARGE RANGE. ELECTRONS ARE ACCELERATED AND ELECTROSTATICALLY DEFLECTED TO SCAN A RECTANGULAR RASTER ON A METAL PLATE WITH A HOLE LOCATED SO THAT THE ELECTRON BEAM PASSES THROUGH IT WHEN BOTH DEFLECTING VOLTAGES AND EXTERNAL ELECTRIC AND MAGNETIC FIELDS ARE EQUAL TO ZERO. WHEN AN EXTERNAL FIELD IS APPLIED THE BEAM WILL PASS THROUGH THE HOLE AND BE DETECTED WHEN THE DEFLECTION VOLTAGES ARE NON ZERO, I.E., AT A DIFFERENT TIME IN THE SWEEP CYCLE. A MEASUREMENT OF THIS TIME CONSTITUTES A MEASUREMENT OF THE EXTERNAL FIELD. ELECTRIC AND MAGNETIC FIELDS CAN BE DISTINGUISHED BY VARYING THE ACCELERATING VOLTAGE. THE DEVICE COULD BE CARRIED IN THE ROVER AND MEASUREMENTS OF THE ELECTRIC FIELD SHOULD BE TAKEN WITH THE CHARGED DUST MEASUREMENTS.

EXPERIMENT NUMBER (AGE BJAT SCIE VSNX PT)	EXPERIMENT DESCRIPTION
	GEODESY
1 1 01 C1 01	SELENODETIC ASTRONOMY OBSERVATIONS FUNDAMENTAL ANGULAR POSITION AND TIME MEASUREMENTS WILL BE MADE WITH PHOTOGRAPHIC ASTRONOMICAL TRANSIT AND CHRONOGRAPH OF SELECTED STARS, SUN, EARTH, AND LUNAR ARTIFICIAL SATELLITES FOR PURPOSES OF DETERMINING ROTATIONAL PERIOD AND POLE ORIENTATION, SIZE AND SHAPE OF MOON, AND ORBITAL MOTION OF MOON AND LUNAR ARTIFICIAL SATELLITES AND ESTABLISHING ACCURATE SELENOCENTRIC COORDINATE SYSTEMS AND PRELIMINARY EPHEMERIDES (STAR CATALOGUES). THIS EXPERIMENT SHOULD BE PERFORMED AT LEAST ONCE AT ALL LANDING AND TRAVERSE SITES, THROUGHOUT ALL LUNAR EXPLORATION. DATA IS BOTH STORED DIGITAL TELEMETRY AND PHOTOGRAPHIC FILM. SINCE THIS IS A PRECISION EXPERIMENT USING PRECISION INSTRUMENTS, PACKAGING, STORAGE, AND HANDLING REQUIREMENTS ARE OF THE HIGHEST ORDER OF PROTECTION POSSIBLE.
1 1 01 C5 C5	EARTH-MOON DISTANCE OBSERVATIONS ANGULAR POSITION, TIME, AND DISTANCE MEASUREMENTS WILL BE MADE WITH PHOTOGRAPHIC ASTRONOMICAL TRANSIT, CHRONOGRAPH, AND RADAR UNIT SIMULTANEOUSLY OF AND FROM SELECTED TERRESTRIAL SURFACE STATIONS FOR PURPOSES OF DETERMINING EARTH-MOON DISTANCE, LUNAR AND TERRESTRIAL RADII, RELATIVE LIBRATIONS, AND TERRESTRIAL ATMOSPHERIC REFRACTION AND SUPPLEMENTING SELENODETIC ASTRONOMY OBSERVATIONS IN ESTABLISHING ACCURATE SELENOCENTRIC COORDINATE SYSTEMS, IN FACILITATING TRANSFORMATIONS BETWEEN SELENOCENTRIC AND GEOCENTRIC COORDINATE SYSTEMS, AND IN DETERMINING ABSOLUTE LUNAR AND TERRESTRIAL LIBRATIONS. THIS EXPERIMENT SHOULD BE PERFORMED AT LEAST ONCE AT ALL LANDING AND TRAVERSE SITES THAT ARE OBSERVABLE FROM AT LEAST THREE WIDELY DISPERSED TERRESTRIAL STATIONS, THROUGHOUT ALL LUNAR EXPLORATION. DATA IS REAL TIME AND STORED DIGITAL TELEMETRY AND PHOTOGRAPHIC FILM. SINCE THIS IS A PRECISION EXPERIMENT USING PRECISION INSTRUMENTS, PACKAGING, STORAGE, AND HANDLING REQUIREMENTS ARE OF THE HIGHEST ORDER OF PROTECTION POSSIBLE.
1 2 01 C2 C2	SELENODETIC SURVEYING OBSERVATIONS ANGULAR POSITION, TIME, AND DISTANCE MEASUREMENTS WILL BE MADE WITH PHOTOTHEODOLITE, CHRONOGRAPH, RADAR UNIT, AND SURVEYING TAPE OF SELECTED LUNAR SURFACE POINTS FOR PURPOSES OF ESTABLISHING ACCURATE GROUND CONTROL FOR LUNAR ARTIFICIAL SATELLITE MAPPING AND SUPPLEMENTING SELENODETIC ASTRONOMY OBSERVATIONS IN DETERMINING SIZE AND SHAPE OF MOON. THIS EXPERIMENT SHOULD BE PERFORMED AT LEAST TWICE AT ALL LANDING AND TRAVERSE SITES THROUGHOUT ALL LUNAR EXPLORATION. DATA IS BOTH STORED DIGITAL TELEMETRY AND PHOTOGRAPHIC FILM. SINCE THIS IS A PRECISION EXPERIMENT USING PRECISION INSTRUMENTS, PACKAGING, STORAGE, AND HANDLING REQUIREMENTS ARE OF THE HIGHEST ORDER OF PROTECTION POSSIBLE.
1 2 02 06 C6	SELENODETIC MAPPING OBSERVATIONS, ORBIT ANGULAR POSITION, TIME, AND DISTANCE MEASUREMENTS WILL BE MADE WITH ASTRONOMICAL TRANSIT, PHOTOGRAMMETRIC CAMERA, CHRONOGRAPH, AND RADAR UNIT OF SELECTED STARS, OTHER LUNAR MAPPING SATELLITES, SELECTED LUNAR SURFACE AREAS, AND SELECTED SURFACE POINTS WITHIN THE SELECTED AREAS, INCLUDING SURFACE OBSERVATIONAL STATIONS, FOR PURPOSES OF PERFORMING DETAILED TOPOGRAPHIC MAPPING OF MOON, AT SELECTED SCALES, IN CONJUNCTION WITH SELENODETIC SURVEYING OBSERVATIONS AND SUPPLEMENTING SELENODETIC ASTRONOMY AND SURVEYING OBSERVATIONS IN DETERMINING SIZE AND SHAPE OF MOON AND IN ESTABLISHING ACCURATE SELENOCENTRIC COORDINATE SYSTEMS. THIS EXPERIMENT SHOULD BE PERFORMED ACCORDING TO PATTERNS THAT WILL GIVE COMPLETE STEREOPHOTOGRAPHIC COVERAGE OF THE LUNAR SURFACE UNDER FAVORABLE LIGHTING CONDITIONS FOR ALL SELECTED SCALES. DATA IS BOTH STORED DIGITAL TELEMETRY AND PHOTOGRAPHIC FILM. SINCE THIS IS A PRECISION EXPERIMENT USING PRECISION INSTRUMENTS, PACKAGING, STORAGE, AND HANDLING REQUIREMENTS ARE OF THE HIGHEST ORDER OF PROTECTION POSSIBLE.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	GEODESY
1 3 03 03 03	**SURFACE GRAVITY OBSERVATIONS** GRAVIMETRIC MEASUREMENTS WILL BE MADE WITH PRECISION PENDULUM, OR OTHER GRAVIMETRIC INSTRUMENT, AND CHRONOGRAPH OF SURFACE GRAVITATIONAL ACCELERATION FOR PURPOSES OF DETERMINING THE LUNAR GRAVITATIONAL FIELD AND SUPPLEMENTING SELENODETIC ASTRONOMY AND SURVEYING OBSERVATIONS IN DETERMINING ACCURATE SELENOCENTRIC COORDINATE SYSTEMS AND ACCURATE GROUND CONTROL, RESPECTIVELY. THIS EXPERIMENT SHOULD BE PERFORMED AT LEAST TWICE AT ALL LANDING AND TRAVERSE SITES, THROUGHOUT ALL LUNAR EXPLORATION. DATA IS STORED DIGITAL TELEMETRY. SINCE THIS IS A PRECISION EXPERIMENT USING PRECISION INSTRUMENTS, PACKAGING, STORAGE, AND HANDLING REQUIREMENTS ARE OF THE HIGHEST ORDER OF PROTECTION POSSIBLE.
1 3 03 07 07	**ORBITING GRAVITY OBSERVATIONS** GRAVIMETRIC MEASUREMENTS WILL BE MADE WITH PRECISION PENDULUM, OR OTHER GRAVIMETRIC INSTRUMENT, CHRONOGRAPH, AND ASTRONOMICAL TRANSIT OF MEAN GRAVITATIONAL ACCELERATION AT ORBITAL HEIGHTS FOR THE PURPOSE OF SUPPLEMENTING SURFACE GRAVITY AND SEISMIC OBSERVATIONS IN DETERMINING THE LUNAR GRAVITATIONAL FIELD. THIS EXPERIMENT SHOULD BE PERFORMED ACCORDING TO PATTERNS THAT WILL GIVE COMPLETE COVERAGE OF THE LUNAR GRAVITATIONAL FIELD AT ORBITAL HEIGHTS FOR EACH OF SEVERAL ORBITAL MISSIONS THROUGHOUT ALL LUNAR EXPLORATION. DATA IS STORED DIGITAL TELEMETRY. SINCE THIS IS A PRECISION EXPERIMENT USING PRECISION INSTRUMENTS, PACKAGING, STORAGE, AND HANDLING REQUIREMENTS ARE OF THE HIGHEST ORDER OF PROTECTION POSSIBLE.
1 3 04 04 04	**SEISMIC OBSERVATIONS** SEISMIC MEASUREMENTS WILL BE MADE WITH EXPLOSIVE CHARGES, RECORDING LONGITUDINAL AND TRANSVERSE WAVE DETECTOR, AND CHRONOGRAPH OF THE PROPAGATION VELOCITY WITHIN THE LUNAR INTERIOR FOR PURPOSES OF DETERMINING INTERNAL DENSITY DISTRIBUTION IN ORDER TO SUPPLEMENT SURFACE AND ARTIFICIAL SATELLITE GRAVITY OBSERVATIONS IN DETERMINING THE LUNAR GRAVITATIONAL FIELD. THIS EXPERIMENT SHOULD BE PERFORMED AT LEAST ONCE AT ALL LANDING AND TRAVERSE SITES, THROUGHOUT ALL LUNAR EXPLORATION. DATA IS STORED DIGITAL TELEMETRY. THE CHRONOGRAPH IS A PRECISION INSTRUMENT AND REQUIRES THE HIGHEST ORDER OF PROTECTION POSSIBLE IN PACKAGING, STORAGE, AND HANDLING. THE SEISMIC DETECTOR REQUIREMENTS FOR PACKAGING, STORAGE, AND HANDLING ARE REASONABLE. THE EXPLOSIVE CHARGES REQUIRE THE HIGHEST SAFETY MEASURES IN PACKAGING, STORAGE, AND HANDLING.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

GEOLOGY

2 1 G1 C2 03 **DETAILED LUNAR SURFACE MAPPING FOR FINE STRUCTURE**

THE DETAILED FINE STRUCTURE OF THE LUNAR SURFACE WILL BE DETERMINED. INFORMATION WILL INCLUDE, BUT NOT BE LIMITED TO THE LITHOLOGIC COMPOSITION, STRUCTURE, NATURE OF EMPLACEMENT, GEOLOGIC ENVIRONMENT AND OTHER PHYSICAL PARAMETERS. THE INFORMATION WILL PROVIDE GROUND TRUTH DATA FOR THE REMOTE SENSING EXPERIMENTS AS WELL AS GIVING DETAILED STRUCTURE OF THE LUNAR SURFACE. DETAILED FINE STRUCTURE MAPS SHOULD BE PREPARED IN SOME AREA AT EACH LANDING SITE AND IN THE LATER EXPLORATION PHASES AT POINTS OF INTEREST ALONG MAJOR TRAVERSES. THE ASTRONAUT PERFORMING THIS MAPPING SHOULD BE A HIGHLY TRAINED FIELD GEOLOGIST. DATA WILL CONSIST OF MAPS, TV IMAGES AND SAMPLES. A BANDWITH OF C.5 MEGACYCLE IS REQUIRED FOR TV SUBSYSTEM, AND 1.4 KILOCYCLE FOR THE STAFF TRACKING AND ORIENTATION SUBSYSTEM, AND 100 KILOCYCLE FOR THE GEOPHYSICAL MEASUREMENTS SUBSYSTEM. DETAILED PHOTOS WILL BE TAKEN OF EACH SITE TO AID IN COMPLETING THE DETAILED MAP UPON EARTH RETURN. EQUIPMENT WILL CONSIST PRIMARILY OF A MAPPING KIT, GEOLOGIC TOOL KIT PLUS A SURVEYING STAFF CONTAINING PHOTOGRAPHIC, AUTOMATIC TRACKING AND GEOPHYSICAL PROBES. IN ADDITION A COMMUNICATION LINK FOR RECORDING VERBAL DESCRIPTIONS OF THE TERRAIN WILL BE PART OF THE NECESSSRY SUPPORT EQUIPMENT. INCLUDED DURING THE LATER MISSIONS WILL BE THIN SECTIONING EQUIPMENT AND A PETROGRAPHIC MICROSCOPE WITH A TV ADAPTER FOR TRANSMITTING THIN SECTION AND POLISHED SECTION PICTURES TO EARTH. THE LEM SURVELLANCE TV SYSTEM MAY BE USED FOR THIS FUNCTION BY THE USE OF AN ADAPTER. BY THE USE OF FILTERS, COLOR IMAGES OR MULTI-SPECTRAL IMAGES MAY BE TRANSMITTED.

2 1 C1 C2 04 **GEOLOGIC SURFACE MAPPING- GENERAL**

GENERAL GEOLOGIC MAPS WILL BE PREPARED AT ALL LANDING SITES AND ON ALL TRAVERSES. WHEN POSSIBLE, THE GEOLOGIST/ ASTRONAUT WILL BE PROVIDED BEFOREHAND WITH BASE MAPS MADE BY REMOTE SENSORS. IDENTIFICATION OF GEOLOGIC FORMATIONS MAPPED BY REMOTE SENSORS IS ESSENTIAL DURING THIS EXPERIMENT, AS THIS INFORMATION, ALONG WITH SAMPLE STUDIES AND OTHER PHYSICAL MEASUREMENTS WILL PROVIDE THE NECESSARY INFORMATION TO EXTEND THE MAPPING BY REMOTE SENSORS OVER THE ENTIRE LUNAR SURFACE. MORE DETAILED MAPS OF FEATURES OF SPECIAL INTEREST SUCH AS CRATERS AND AREAS WHERE MAXIMUM GEOPHYSICAL DATA IS AVAILABLE WILL BE MADE (EXP 21C1C2C3). AN AUTOMATIC LASER SURVEYING SYSTEM WOULD BE OF GREAT VALUE IN PRODUCING BASE TOPOGRAPHIC MAPS OF LANDING AREAS AND SAVE MUCH VALUABLE ASTRONAUT TIME. ADDITIONAL INFORMATION TO BE ADDED TO SUCH MAPS WILL BE OBTAINED FROM SURFACE PHOTOGRAPHS AND SAMPLES COLLECTED IN THE MAPPED AREAS. DATA WILL CONSIST OF MAPS, FILM, TV AND VERBAL DESCRIPTION OF THE AREA. THE SAMPLES COLLECTED ARE CONSIDERED IN EXPERIMENT 21C10309. THE EQUIPMENT USED WILL CONSIST OF A MAPPING KIT, A GEOLOGIC TOOL KIT, THE ASTRONAUT STAFF AND AN AUTOMATIC ASTRONAUT TRACKING DEVICE. THE TRACKING EQUIPMENT AT THE LEM IS NOT CONSIDERED AS PART OF THE SCIENTIFIC EQUIPMENT. THE MOBILITY MODE WILL DEPEND UPON THE TIME FRAME OF THE EXPERIMENT. THE STAFF TV SUBSYSTEM HAS A C.5 MEGACYCLE BANDWIDTH WITH AN ADDITIONAL 1.4C KILOCYCLE BANDWIDTH REQUIRED FOR STAFF TRACKING AND ORIENTATION. THE GEOPHYSICAL EXPERIMENTS SUBSYSTEM HAS A 10C KILOCYCLE BANDWITH WITH INTERMITTENT OPERATION.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AGSIE RBPNX EJEVP ATCST	GEOLOGY
2 1 01 03 09	SAMPLE COLLECTION - ALL SITES AND TRAVERSES SAMPLES WILL BE COLLECTED AT ALL SITES AND ON ALL TRAVERSES AND WILL PROVIDE THE MAXIMUM INFORMATION AS TO THE COMPOSITION OF THE LUNAR SURFACE MATERIALS. MAXIMUM EFFORT IN EARLY LUNAR EXPLORATION SHOULD BE PLACED ON SAMPLE COLLECTION. UNDISTURBED AND ORIENTED SAMPLES WILL BE SELECTED. SAMPLES WILL BE COLLECTED AND PACKAGED SO AS TO RETAIN INHERENT CHARACTERISTICS DURING THE RETURN TO EARTH LABORATORIES. DEPENDING UPON THE LABORATORY TEST TO BE CONDUCTED, SAMPLES MAY HAVE TO BE PROTECTED FROM EXCESSIVE HEAT, SHOCK, RADIATION AND MAGNETIC FIELDS. HANDLING OF BIOLOGICAL AND GEOCHEMICAL SAMPLES MAY BE REQUIRED. OF SPECIAL INTEREST WILL BE ORIENTED SAMPLES OBTAINED FROM MAJOR COLLECTION. SAMPLES SHOULD BE PRESELECTED BY THE ASTRONAUT/GEOLOGIST FORMATIONS. SUCH SAMPLES SHOULD BE PHOTOGRAPHED IN PLACE BEFORE ON THE LUNAR SURFACE AS MUCH AS POSSIBLE TO PROVIDE A REPRESENTATIVE COLLECTION. SAMPLES WILL BE COLLECTED ON ALL MANNED MISSIONS AND FROM EACH SIGNIFICANTLY DIFFERENT LITHOGRAPHIC TYPE ENCOUNTERED. SAMPLE CONTAINERS MUST BE DESIGNED SO THAT THEY ARE EASILY FILLED AND SEALED. SPECIAL SAMPLING TOOLS MUST BE PROVIDED FOR SAMPLING, ESPECIALLY FOR OBTAINING STERILE SAMPLES. DATA WILL CONSIST OF SAMPLES AND PHOTOS OF SAMPLES IN SITU PLUS A VERBAL DESCRIPTION OF THE SAMPLES. THE VERBAL DESCRIPTION OF THE SAMPLES WILL INCLUDE, BUT NOT BE LIMITED TO INFORMATION RELATING THE SAMPLE TO THE SURROUNDING ROCK FORMATION, THE GRAIN SIZE AND TEXTURE, AND THE MINERALS PRESENT TO THE EXTENT THAT THEY CAN BE DETERMINED. DURING LATER MISSIONS THIN SECTIONS WILL BE MADE OF SOME SAMPLES AND ANALYZED UNDER A PETROGRAPHIC MICROSCOPE. OTHER EXPERIMENTS TO BE PERFORMED ON THE SAMPLES ARE DISCUSSED IN THE GEOCHEMISTRY EXPERIMENTS.
2 3 01 03 20	SAMPLE COLLECTION SELECTED SAMPLES WILL BE COLLECTED BY THE ASTRONAUT TO BE RETURNED TO EARTH FOR ANALYSIS. CARE MUST BE TAKEN TO MAINTAIN SAMPLE PROTECTION FOR CERTAIN TYPES OF ANALYSIS. FOR REMNANT MAGNETISM THE SAMPLES CANNOT BE EXPOSED TO MAGNETIC FIELDS WHICH WILL REQUIRE A SHIELD CONTAINER, NOR CAN THEY BE EXPOSED TO EXTREME TEMPERATURE OR SHOCK. FOR THERMOLUMINESCENCE THE SAMPLES CANNOT BE SUBJECTED TO SHOCK OR HIGH TEMPERATURE. OF PRIME IMPORTANCE IS THE ASTRONAUT TRAINING SO THAT REPRESENTATIVE SAMPLES CAN BE COLLECTED. THE SAMPLING EXPERIMENT WILL CONTINUE THROUGHOUT THE LUNAR EXPLORATION PROGRAM. FOR THE EARLIER MISSIONS ORIENTED SAMPLES WILL NOT BE TAKEN WHILE ON LATER MISSIONS ORIENTED SAMPLES WILL BECOME MORE IMPORTANT. IT IS ALSO IMPORTANT THAT STERILE SAMPLES BE OBTAINED EARLY IN THE PROGRAM SINCE BY THE LATER MISSIONS PARTS OF THE LUNAR SURFACE MAY BE CONTAMINATED.
2 1 01 03 30	SAMPLE COLLECTION DURING THIS EXPERIMENT SAMPLES, INCLUDING ORIENTED SAMPLES AND CORES, WILL BE COLLECTED TO BE ANALYZED IN THE ROVER OR A PERMANENT LUNAR GEOLOGIC LAB. ANALYSIS EXPERIMENTS THAT CAN BEST BE PERFORMED ON THE LUNAR SURFACE OR IN A LUNAR ENVIRONMENT WILL BE PERFORMED THERE WITH ONLY CAREFULLY SELECTED SAMPLES RETURNED TO EARTH FOR ANALYSIS. A HIGH DEGREE OF TRAINING IS NECESSARY FOR THE ASTRONAUT SELECTING THE SAMPLES. LOCATION AND ORIENTATION WILL BE RECORDED BY THE ASTRONAUT OR ON VOICE TAPE.

EXPERIMENT NUMBER (AREA / OBJECT / SPEC / INVS / EXPT)	EXPERIMENT DESCRIPTION
	GEOLOGY
2 2 01 C4 12	30 METER DRILLING AND SUBSURFACE MAPPING FORMATION STRATIGRAPHIC CORRELATION OVER LARGE DISTANCES BY CORING AND/OR TRENCHING - THIS EXPERIMENT WILL DETERMINE THE EXTENT AND THE UNIFORMITY OF NEAR SURFACE FORMATIONS. DRILLING OR TRENCHING COULD BE USED BUT A TRENCHING MACHINE WOULD REQUIRE A MUCH HIGHER POWER AND DRILLING APPEARS MORE FEASIBLE. USING A BOREHOLE TECHNICLE, THE HOLE WILL BE LOGGED WITH A TV PROBE AND ALSO WITH THE GEOPHYSICAL SUBSURFACE PROBES. CORE SAMPLES WILL BE COLLECTED FROM EACH HOLE. TIMES AND DATA ARE BASED ON LOGGING A 10 METER HOLE. SEISMIC PROFILING RESULTS MAY PROVE USEFUL IN SELECTING DRILLING SITES. CORRELATION WILL BE MADE IN ALL BOREHOLES DRILLED ON THE LUNAR SURFACE. THE DRILL WILL HAVE THE CAPABILITY OF DRILLING TO 30 M DEPTHS IN ABOUT 20 HOURS.
2 1 02 03 07	SHALLOW DRILLING FOR SUBSURFACE STRUCTURE AND SAMPLING THIS EXPERIMENT WILL GIVE INFORMATION AS TO NEAR SURFACE FINE STRUCTURE AND PROVIDE SUBSURFACE SAMPLES AND CORES. SHALLOW CORE DRILLING WILL BE CARRIED OUT THROUGHOUT THE EARLY EXPLORATION PHASE. ORIENTED CORES WILL BE COLLECTED FROM AREAS DEEMED REPRESENTATIVE OF THE LUNAR SURFACE. THE SAME HOLES WILL BE LOGGED USING THE GEOPHYSICAL SUBSURFACE SONDE. A CORE APPROXIMATELY ONE HALF TO ONE INCH IN DIAMETER WILL BE DRILLED. THE HOLE WILL BE LOGGED VISUALY BY USING A PERISCOPE. A DRILL CAPABLE OF DRILLING UP TO TEN METERS WHEN TRANSPORTED ON THE LSSM VEHICLE MUST BE DEVELOPED. THE MOBILITY MODE WILL DEPEND UPON THE MISSION AND VEHICLES AVAILABLE. DATA WILL CONSIST OF CORES RETURNED TO EARTH FOR ANALYSIS. THE CORE AND SUBSURFACE SAMPLES OBTAINED WILL ASLO BE SUBJECTED TO PRELIMINARY ANALYSIS ON THE MOON. OF INTEREST WILL BE THE MINERALOGIC AND PHYSICAL PROPERTIES OF THE SAMPLE. THE MINERALS PRESENT, THE SURFACE TEXTURE AND THE HARDNESS OF THE SAMPLE WILL BE MEASURED AND RECORDED. ALSO, AN AUXILIARY HAND-CARRIED DRILL, CAPABLE OF DRILLING HOLES ONE AND 1/8 INCHES IN DIAMETER TO DEPTHS OF 1 TO 3 METERS WILL BE USED FOR VARIOUS PURPOSES SUCH AS SAMPLING NEAR SURFACE MATERIALS, HEAT FLOW EXPERIMENTS OR OBTAINING STERILE SAMPLES FOR BIOSCIENCE EXPERIMENTS. TIMES ARE BASED ON 3 METER HOLE IN BASALT OR 10 METER HOLE IN PUMICE. TIMES FOR DRILLING WITH THE 1 METER DRILL ARE NOT INCLUDED BUT ARE ESTIMATED AT 0.3 HOURS FOR A 1 METER HOLE.
2 1 02 03 08	DEEP DRILLING FOR SUBSURFACE STRUCTURE AND SAMPLING EXPERIMENT WILL GIVE INFORMATION ABOUT THE DEEPER SURFACE LAYERS. A 300 METER HOLE MAY REACH BENEATH THE IMPACT SHATTERED BLANKET THAT EXISTS. THE BORE HOLE WILL BE 2 INCHES IN DIAMETER. LUNAR COMPOSITION WITH DEPTH WILL VARY AND AMOUNT OF FOREIGN MATERIAL WILL BE INDICATIVE OF THE AMOUNT OF METEOR DEPOSITS. UNDISTURBED CORES WILL BE COLLECTED. IT IS ESTIMATED THAT A 300 METER HOLE COULD BE DRILLED IN A 1 MONTH PERIOD. THE HOLE WILL BE LOGGED WITH THE SUBSURFACE GEOPHYSICAL SONDE. THE HOLE WILL ALSO BE INSPECTED VISUALY BY A TV PROBE (EX 21C4C411). DATA WILL CONSIST OF CORES, SELECTED PORTIONS OF WHICH WILL BE RETURNED TO EARTH FOR COMPLETE ANALYSIS. PORTIONS OF THE SAMPLES WILL BE ANALYZED IN A LUNAR LABORATORY AT THE BASE WHERE THE 300 METER HOLE IS DRILLED. ANALYSIS ON THE MOON WILL CONSIST OF, BUT NOT LIMITED TO, ELEMENTAL AND MINERAL COMPOSITION, TEXTURE, HARDNESS, MAGNETIC AND ELECTRICAL PROPERTIES, AND THIN SECTION ANALYSIS UNDER A PETROGRAPHIC MICROSCOPE. IT SEEMS FEASIBLE TO TRANSMIT COLOR TV IMAGES OF THIN SECTIONS TO EARTH FOR STUDY.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	GEOLOGY

AREA	OBJECT	SPECIES	INVEST	EXPT
2	1	04	C1	01

GEOLOGIC BASE MAPS FROM UNMANNED ORBITERS

MAPS RANGING FROM LARGE (1 TO 2500000) AND SMALL SCALE (1 TO 25000) MAPS WILL BE PREPARED OF THE LUNAR SURFACE. THE LARGE SCALE MAPS WILL BE PREPARED OF THE ENTIRE MOON EARLY IN THE EXPLORATION PROGRAM. IN ADDITION SMALL SCALE MAPS OF AREAS OF INTEREST AND IN PARTICULAR, OF POTENTIAL LANDING SITES, WILL BE PREPARED AS SOON AS POSSIBLE. INITIAL WORK WILL BEGIN ON THIS EXPERIMENT ON THE FIRST APOLLO FLIGHT AND CONTINUE THROUGHOUT THE ENTIRE LUNAR EXPLORATION PROGRAM WITH THE ULTIMATE OBJECTIVE BEING A COMPLETE MAP OF THE LUNAR SURFACE. IMAGERY WILL BE OBTAINED FROM VIDICONS, IR SCANNERS, MICROWAVE RADIOMETERS, ELECTROMAGNETIC PULSE PROBES, GAMMA RAY RADIATION AND HIGH RESOLUTION MAPPING RADAR. MAPS DERIVED FROM THE EARLY DATA WILL BE USED TO CHOOSE LANDING SITES. GROUND TRUTH DATA OF FORMATION TYPES AND SURFACE STRUCTURE WILL BE OBTAINED FROM THE MANNED MISSIONS. THE SAME DATA WILL BE USED BY THE CARTOGRAPHIC GROUP TO MAKE TOPOGRAPHIC MAPS OF THE LUNAR SURFACE. THIS SURVEY MAY ALSO PROVE USEFUL IN LOCATING POTENTIAL RESOURCES THAT COULD BE USED IN THE ESTABLISHMENT OF A PERMANENT LUNAR BASE. THE DATA WILL BE CLOSELY CORRELATED WITH THE PHOTOGRAPHS OBTAINED FROM ORBIT (EX. 21C4C1C2). DATA IS BASED ON A 24 HOUR PERIOD OF OPERATION. THE TOTAL DATA WILL DEPEND UPON THE MISSION DURATION. A BANDWIDTH OF ABOUT 0.5 MHZ WILL BE REQUIRED FOR EACH EXPERIMENT EXCEPT THE GAMMA RAY SPECTROSCOPY WHICH HAS A VERY LOW DATA RATE. THE MAJOR PIECES OF EQUIPMENT USED IN THE EXPERIMENT WILL BE A TV SYSTEM, AN IR SCANNER, A MICROWAVE RADIOMETER AND MAPPING RADAR.

AREA	OBJECT	SPECIES	INVEST	EXPT
2	1	04	C1	02

PHOTOGEOLOGIC MAPPING FROM LUNAR ORBITERS

LARGE SCALE PHOTOGEOLOGIC BASE MAPS WILL BE PREPARED OF THE ENTIRE LUNAR SURFACE AS WELL AS HIGH RESOLUTION MAPS OF SPECIFIC AREAS. GROUND TRUTH INFORMATION WILL BE OBTAINED FROM THE SURFACE SURVEY. THE PHOTOGEOLOGIC MAPS WILL BE CLOSELY CORRELATED WITH REMOTE SENSING IMAGERY FROM UNMANNED ORBITERS (EX. 21C40101). THE DATA WILL ALSO BE USED BY THE CARTOGRAPHY EXPERIMENTS TO ESTABLISH TOPOGRAPHIC MAPS. DATA WILL CONSIST OF FILMS RETURNED TO EARTH FOR PROCESSING. A SYSTEM OF SIX CAMERAS WILL BE USED OF VARYING RESOLUTION. TWO 9 INCH STERO MOUNTED CAMERAS, TWO 70MM STERO CAMERAS, A LONG FOCAL LENGTH 70 MM CAMERA, AND A SHORT FOCAL LENGTH, 9 OR 4.5 INCH CAMERA FOR SYNOPTIC COVERAGE WILL COMPLETE THE SET FOR THE TOTAL COVERAGE NEEDED. IT MAY NOT BE POSSIBLE TO FLY ALL CAMERAS ON ALL MISSIONS BUT PHOTOGRAPHIC EXPERIMENTS RANK HIGH ON THE PRIORITY LIST. A RESOLUTION OF LESS THAN 1 METER WILL BE OBTAINED FROM AN ORBITAL HEIGHT OF 80 KM. FILM WILL BE RETURNED WITH THE SPACECRAFT ON MANNED FLIGHTS AND IF AN UNMANNED PHOTOGRAPHIC SATELLITE SHOULD BE USED TO PROVIDE STERO-PAIRS WITH ONE CAMERA ON THE MANNED VEHICLE WHILE A SURFACE MISSION IS IN PROGRESS, THE FILM COULD BE EJECTED TO THE LUNAR SURFACE FOR RECOVERY. A TWO SATELLITE CONCEPT FOR STERO-PAIRS SEEMS FEASIBLE. ALSO IF A CRAFT IS IN A POLAR ORBIT STERO-PAIRS MAY ALSO BY CONSTRUCTED FROM PHOTOS TAKEN ON DIFFERENT ORBITS. SOME ASTRONAUT TIME MAY BE NEEDED TO MAINTAIN CAMERAS WHILE IN A LUNAR ORBIT.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
A O S I E R B P N X E J E V P A T C S T	GEOLOGY
2 1 04 02 05	SURFACE PHOTOGEOLOGY -AREAS TRAVERSED AND MAPPED BY THE ASTRONAUT WILL BE PHOTOGRAPHED WITH CONVENTIONAL AND STEROMETRIC PHOTOGRAPHY. THIS WILL PROVIDE MAXIMUM DETAILS OF GENERAL AND SPECIFIC AREAS OF INTEREST AND ASSIST THE ASTRONAUT IN DESCRIBING DETAILS UPON RETURN TO EARTH. THE DATA WILL BE FROM A PAIR OF VIDICON TUBES IN THE ASTRONAUT STAFF PLUS TV IMAGING FROM THE LEM OR MOBILE VEHICLE. ALL AREAS TRAVERSED BY THE ASTRONAUT WILL BE PHOTOGRAPHED EVERY 5 SECONDS. THE MOBILITY MODE WILL DEPEND UPON THE TIME PHASE OF THE EXPERIMENT. TIME INVOLVED MAYBE TWO HOURS OUT OF AN 8 HOUR DAY. THE REST OF THE TIME WILL BE SPENT PERFORMING OTHER RELATED EXPERIMENTS. THE STAFF CAMERA AND THE LEM CAMERA EACH REQUIRE A 500 KILOCYCLE BANDWITH.
2 1 04 04 11	VISUAL SUBSURFACE LOGGING FOR FINE STRUCTURE THIS EXPERIMENT WILL ENABLE THE ASTRONAUT TO OBSERVE BORE HOLE WALLS BY USING A PERISCOPE AND/OR TV CAMERA. IF BOREHOLES ARE DRILLED IN UNCONSOLIDATED MATERIALS WHERE COMPETANT CORES CANNOT BE OBTAINED, VISUAL OBSERVATIONS OF THE BOREHOLE WALLS WILL PROVE VERY VALUABLE. FINE STRUCTURE GEOLOGIC PROFILES CAN BE OBTAINED IN THIS MANNER. THIS INSTRUMENT COULD ALSO BE USED TO EXAMINE CREVASSES AND SUBSURFACE VOIDS IF FOUND ON THE LUNAR SURFACE. SHALLOW HOLES ON EARLY MISSION WILL BE LOGGED WITH A PERISCOPE AND LATER DEEP BOREHOLES WILL REQUIRE A TV SYSTEM.
2 4 03 03 10	AGE DATING OF LUNAR ROCKS AND FORMATIONS SAMPLING AND AGE DATING OF LUNAR ROCKS AND FORMATIONS WILL SERVE TO DETERMINE THE AGE OF THE VARIOUS LUNAR MATERIALS AND FORMATIONS AND THE HISTORY OF EVENTS SHAPING THE LUNAR SURFACE. THE STRATIGRAPHIC RELATIONSHIP OF LUNAR FORMATIONS WILL BE MAPPED. THE GENESIS OF STRATIGRAPHIC COMPONENTS AND PRINCIPAL PROCESSES OF EROSION,TRANSPORTATION AND DEPOSITION WILL BE DETERMINED BY THIS MAPPING. SAMPLES COLLECTED DURING THE SAMPLING EXPERIMENTS WILL BE USED TO DETERMINE ABSOLUTE AGE BY ISOTOPIC AGE DATING. AGE DATING EXPERIMENTS WILL CONTINUE THROUGHOUT THE LUNAR EXPLORATION PROGRAM WITH DETAILED STUDIES IN LOCAL AREAS UNDERTAKEN DURING THE LATER PROGRAM PHASES. STUDIES MUST BE PERFORMED OF A REPRESENTATIVE NUMBER OF LUNAR TYPES DURING THE PROGRAM AND AT DIFFERENT GEOGRAPHIC LOCATIONS. AT LEAST ONE AREA SHOULD BE MAPPED IN DETAIL ON EACH MISSION. TIMES ARE BASED ON STUDYING A SMALL EXPOSED GEOLOGIC COLUMN SUCH AS A CRATER WALL, WHICH IS ESSENTIALLY ONE EXPERIMENT. DATA WILL CONSIST OF HAND SKETCHED MAPS, SURFACE REPLICA PADS, FILM AND SAMPLES FOR EARTH RETURN. NO SPECIAL SAMPLING IS REQUIRED FOR THE SAMPLES FOR RADIOISOTOPE AGE DATING, BUT OTHER EXPERIMENTS TO BE PERFORMED ON THE SAMPLES MAY REQUIRE SPECIAL HANDLING. THE VEHICLE INVOLVED DURING THE PARTICULAR EXPERIMENT WILL DEPEND ON THE MISSION IN WHICH IT IS PERFORMED. THE EQUIPMENT USED WILL BE A MAPPING SET, STEROMETRIC CAMERA, SAMPLING TOOL AND SAMPLE CONTAINERS AS USED IN THE SURFACE SAMPLING EXPERIMENTS. A 500 KHZ BANDWITH IS REQUIRED BY THE ASTRONAUTS STAFF.

EXPERIMENT NUMBER				
AREA	OBJECT	SPEC	INVS	EXPT
2 4	02	C4	13	

EXPERIMENT DESCRIPTION

GEOLOGY

PALEOMAGNETISM OF THE MOON

THIS EXPERIMENT WILL ESTABLISH THE EXISTENCE OF A PAST MAGNETIC FIELD ON THE MOON AND THE DIRECTION OF THE FIELD. THE DIRECTION OF THE LUNAR MAGNETIC FIELD WILL BE MEASURED IN BOREHOLES WITH A THREE COMPONENT FLUXGATE MAGNETOMETER. FROM THE DIRECTION OF THE FIELD ABOVE AND BELOW THE SURFACE INFERENCE CAN BE MADE AS TO AN ORIGINAL MAGNETIC FIELD AND ITS DIRECTION. ADDITIONAL INFORMATION IS ALSO OBTAINED ON THE PROBLEM FROM THE REMANENT MAGNETISM EXPERIMENTS IN THE GEOPHYSICS AREA. DATA AND DATA RATES ARE BASED ON TEN MEASUREMENTS IN THE 10 M DRILL HOLE. THE EQUIPMENT WILL CONSIST OF A THREE-COMPONENT FLUX GATE MAGNETOMETER. ALL HOLES IN MAJOR FORMATIONS SHOULD BE LOGGED.

EXPERIMENT NUMBER AREA OBJT SPEC INVS EXPT	EXPERIMENT DESCRIPTION GEOCHEMISTRY
3 2 01 01 01	CHEMICAL ANALYSIS USING NEUTRON ACTIVATION CHEMICAL ANALYSIS USING NEUTRON ACTIVATION ANALYSIS ON ALL MOBILE VEHICLES AS A MEANS OF SCREENING SAMPLES AND INVESTIGATING THE COMPOSITION OF THE SURFACE THE PRINCIPAL PARAMETER OF THE EXPERIMENT WILL BE THE IDENTIFICATION OF THE PRESENCE OF SPECIFIC CHEMICAL ELEMENTS IN THE COMPOUND BEING EXAMINED. UN-NORMALIZED QUANTITIES RELATIVE TO THE MOST ABUNDANT ELEMENT WILL BE ESTIMATED. NORMALIZATION OF THESE VALUES WILL REQUIRE CALIBRATION.
3 2 01 01 02	CHEMICAL ANALYSIS USING AN INFRARED SPECTROMETER CHEMICAL ANALYSIS USING AN INFRA RED SPECTROMETER INCLUDING ATR ATTACHMENTS AT A LARGE LUNAR BASE THE SCIENTIST WILL PROVIDE VERBAL INTERPRETATION OF THE TEST EQUIP OUTPUT TO PROVIDE TESTING OF THE IR TECHNIQUES OF ESTIMATING THE COMPOSITION OF LUNAR COMPOUNDS AT THE LUNAR BASE LOCATION.
3 2 01 01 03	CHEMICAL ANALYSIS USING A NUCLEAR MAGNETIC RESONANCE SPECTROMETER CHEMICAL ANALYSIS USING AN NMR SPECTROMETER AT A LARGE PERMANENT BASE DEVICE TO BE DEVELOPED FOR LATE MISSIONS THE SCIENTIST WILL PROVIDE VERBAL INTERPRETATION OF THE SPECTROMETER READINGS TO AID IN LATER CALIBRATION OF TEST RESULTS.
3 2 01 01 04	CHEMICAL ANALYSIS OF LUNAR MATERIALS USING X-RAY FLUORESCENCE. CHEMICAL ANALYSIS OF LUNAR MATERIALS USING X RAY FLUORESCENCE ON ALL TRAVERSES BY ROVING VEHICLES THE EXPERIMENT WILL PROVIDE SAMPLE DIFFERENTIATION BY USING A GAMMA SOURCE IN COMBINATION WITH AN XRAY FLUORESCENCE SPECTROMETER TO COUNT THE XRAYS. THE COUNTER PULSES WILL BE SORTED IN AN ANALYZER TO PRODUCE A SPECTRUM FOR COMPARISON WITH LIBRARY SPECTRA FOR PATTERN ANALYSIS. THE RESULTING ELEMENTAL IDENTIFICATION CAN BE TELEMETERED BACK TO THE ASTRONAUT BY VERBAL INTERPRETATION.
3 2 01 01 05	CHEMICAL ANALYSIS, BASE LABORATORY CHEMICAL ANALYSIS WITH CHEMICAL REAGENTS AND CHEMICAL LABORATORY AT LUNAR BASE EACH MISSION WHICH INCLUDES A LUNAR BASE SHOULD TRANSPORT EQUIPMENT TO START UP A CHEMICAL LABORATORY OR TO AUGMENT A LABORATORY AT AN ESTABLISHED BASE.EQUIPMENT MASS AND VOLUME ARE FOR EACH MISSION SAMPLES OF LUNAR MATERIALS WILL BE SUBJECTED TO WET CHEMICAL ANALYSIS TO DETERMINE COMPOSITION AND CONCENTRATION. STANDARD REAGENTS AND CHEMICAL SOLUTIONS WILL BE USED WITH LAB EQUIPMENT TO CLASSIFY SAMPLES. THE SCIENTIST WILL PROVIDE VERBAL REPORTS ON THE RESULTS.
3 2 01 01 06	DENSITY MEASUREMENTS BY FLOTATION DENSITY MEASUREMENTS OF ROCKS AND SEPARATED MINERALS BY FLOTATION AT LUNAR BASE THE EXPERIMENT WILL BE USED TO CLASSIFY LUNAR MATERIALS BY DENSITY IN GRAMS PER CC. EQUIPMENT WILL CONSIST OF A SET OF CALIBRATED FLOTATION LIQUIDS COVERING THE RANGE OF INTEREST.
3 2 01 01 07	MINERALOGICAL STUDY USING AN X-RAY DIFFRACTOMETER MINERALOGICAL STUDY WITH AN X RAY DIFFRACTOMETER AT LUNAR BASE THIS EXPERIMENTAL TECHNIQUE WILL BE USED FOR EXAMINATION OF LUNAR SAMPLES FROM VARIOUS SITES TO DETERMINE SIMILARITIES WITH OTHER KNOWN MATERIALS. AN XRAY DIFFRACTOMETER SIMILAR TO THAT USED ON THE SURVEYOR PROGRAM WILL BE USED FOR SAMPLE SELECTION AND DISTINCTION OF VARIOUS CHEMICAL PHASES, TO BE RECORDED BY VERBAL DESCRIPTION.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	GEOCHEMISTRY
3 1 C1 C1 C8	MINERALOGICAL AND PETROGRAPHIC STUDY MINERALOGICAL AND PETROLOGICAL STUDY WITH A MICROSCOPE THE EQUIPMENT PACKAGE SHOULD CONTAIN ACCESSORY EQUIPMENT AS INDEX OF REFRACTION FLUIDS,LIGHT FILTERS,SPECIAL LIGHT SOURCES THIS DIAGNOSTIC EQUIPMENT WILL BE USED TO ASSIST IN SAMPLE SELECTION AT THE LUNAR BASE. A POLARIZING BINOCULAR MICROSCOPE SHOULD BE USED FOR VIEWING OPAQUE SAMPLES. IMMERSION LIQUIDS MUST BE USED TO PREVENT CONTAMINATION OF THE SHELTER ATMOSPHERE AND GIVE GROSS REFRACTIVE INDEX SEPARATION. OBSERVATIONS TO BE RECORDED BY VERBAL DESCRIPTION. THIN AND POLISHED SECTION PETROGRAPHIC ANALYSIS WILL BE PERFORMED TO DETERMINE ROCK TEXTURE AND STRAIN VECTOR IN PETROFABRIC.
3 5 01 C1 10	CHEMICAL ANALYSIS OF SOLIDS USING A MASS SPECTROMETER CHEMICAL ANALYSIS OF SOLIDS WITH A MASS SPECTROMETER AT LUNAR BASE THESE MEASUREMENTS WILL BE MADE TO SELECT SAMPLES OF LUNAR MATERIALS WITH SPECAIL CHARACTERISTICS SUCH AS ORGANIC BEARING MATERIALS, LEAD ISOTOPES, POTASSIUM, AND ARGON MINERALS MASS SPECTROMETER, OBSERVATIONS TO BE RECORDED BY VERBAL DESCRIPTION.
3 2 01 C1 11	CHEMICAL ANALYSIS USING NEUTRON ACTIVATION (BASE) CHEMICAL ANALYSIS USING NEUTRON ACTIVATION ANALYSIS AT LUNAR BASES AS A MEANS OF SCREENING AND INVESTIGATING SAMPLES THESE MEASUREMENTS CAN BE MADE WITH A PULSED NEUTRON SOURCE TO STUDY VARIOUS GAMMA-RAY SPECTRA AND THE TIME SIGNATURE OF NEUTRON CAPTURE. THE METHOD WILL ALLOW PARTIAL ELEMENTAL ANALYSIS OF BULK SAMPLES TO DETECT THE PRESENCE OF HYDROGEN. DATA WILL BE RECORDED BY VERBAL DESCRIPTION.
3 2 01 C1 12	CHEMICAL ANALYSIS USING X-RAY FLUORESCENCE (BASE) CHEMICAL ANALYSIS OF LUNAR MATERIALS USING X RAY FLUORESCENCE AT LUNAR BASE THESE STUDIES ARE SIMILAR TO THE SAMPLE SELECTION MEASUREMENTS TO BE MADE ON TRAVERSE IN AN EARLIER PHASE OF EXPLORATION. THE SAME TYPE OF EQUIPMENT WILL BE USED FOR X-RAY FLUORESCENCE STUDIES, WITH THE POSSIBLE ADDITION OF A PATTERN ANALYSIS COMPUTER TO IDENTIFY SPECTRA. DATA WILL BE RECORDED BY VERBAL AND WRITTEN DESCRIPTION.
3 2 01 01 13	DENSITY MEASUREMENTS BY GAMMA SCATTERING IN SITU DENSITY MEASUREMENTS IN SITU BY MEASUREMENT OF GAMMA SCATTERING.THE DETECTOR IS PART OF THE EQUIPMENT FOR THE GAMMA RAY SPECTROMETER A GAMMA RAY SOURCE IS REQUIRED THE GAMMA BACKSCATTERING DENSITY INDICATOR WILL BE USED ON TRAVERSE TO SELECT SITES FOR DETAILED EXPLORATION. DENSITY MEASUREMENTS ARE MADE BY EXPOSING THE SAMPLES TO A LOW ENERGY SOURCE (0.1-1.5 MEV) AND RECORDING THE TOTAL NUMBER OF SCATTERED GAMMA COUNTS. THE RESULTS CAN BE TELEMETERED BACK TO THE INSTRUMENT IN THE FORM OF A DENSITY NUMBER
3 2 01 01 14	MINERALOGICAL STUDY WITH X-RAY DIFFRACTOMETER IN SITU IN SITU MINERALOGICAL STUDY WITH AN X RAY DIFFRACTOMETER TO DETECT PHASES WHOSE STABILITY DEPENDS ON THE LUNAR ENVIRONMENT THIS EXPERIMENTAL TECHNIQUE WILLBE USED FOR SCREENING OF LUNAR SURFACE FORMATIONS WHILE ON TRAVERSE. THE X-RAY DIFFRACTOMETER WILL BE SIMILAR TO THAT USED ON THE SURVEYOR PROGRAM FOR DISTINCTION OF DIFFERENT CHEMICAL PHASES, AND DATA WILL BE RECORDED BY VERBAL DESCRIPTION.
3 2 01 01 15	UV AND VISIBLE REFLECTANCE SPECTRA IN SITU ULTRA VIOLET AND VISIBLE REFLECTANCE SPECTRA IN SITU TO OBTAIN DATA FOR CORRELATION WITH ORBITAL MEASUREMENTS.SAMPLES OF THE MEASURED MATERIAL TO BE RETURNED TO THE BASE AND TO EARTH FOR DETAILED GEOCHEMICAL STUDY THE EXPERIMENT WILL BE PERFORMED ON TRAVERSE WITH A UV-VISIBLE RECORD-ING SPECTROPHOTOMETER. SPECTRAL SIGNATURE WILL BE CORRELATED WITH CHEMICAL ANALYSES PERFORMED ON THE SAMPLES.

EXPERIMENT NUMBER (AGSIE / RBPNX / EJEVP / ATCST)	EXPERIMENT DESCRIPTION
	GEOCHEMISTRY
3 2 01 C1 16	UV AND VISIBLE REFLECTANCE SPECTRA FROM ORBIT ULTRA VIOLET AND VISIBLE REFLECTANCE SPECTRA FROM ORBIT.THE INTERPRETATION DEPENDS ON DATA OBTAINED FROM KNOWN SAMPLES MEASURED IN SITU USEFUL GEOCHEMICAL INFORMATION DEPENDS ON THIS GROUND TRUTH DATA.IF DATA CANNOT YIELD USEFUL INFORMATION ON GEOCHEMISTRY IT SHOULD STILL BE USEFUL FOR DISTINGUISHING BETWEEN DIFFERENT GEOLOGIC REGIONS THE MEASUREMENTS WILL BE MADE WITH A UV-VISIBLE RANGE RECORDING SPECTROPHOTOMETER SENSING IN THE RANGE 1800-8000 ANGSTROMS.
3 2 01 C1 17	IR REFLECTANCE AND EMISSIVITY FROM ORBIT INFRA RED REFLECTANCE AND EMISSIVITY MEASUREMENTS FROM ORBIT.THE SPECTRA OBTAINED CAN YIELD USEFUL GEOCHEMICAL INFORMATION ONLY IF ONE IS ABLE TO DETERMINE THE RELATION BETWEEN THE SPECTRA AND THE CHEMICAL AND MINERALOGICAL COMPOSITION OF LUNAR SURFACE MATERIALS.IF THESE DATA CAN NOT BE OBTAINED THEN THE INFRA RED SPECTRAL DATA WOULD STILL BE USEFUL FOR DISTINGUISHING BETWEEN DIFFERENT GEOLOGIC REGIONS THE MEASUREMENTS WILL BE MADE WITH A RECORDING IR SPECTROMETER SENSING IN THE RANGE OF 8-20 MICRONS.
3 2 01 C1 18	IR REFLECTANCE AND EMISSIVITY IN SITU INFRA RED REFLECTANCE AND EMISSIVITY MEASUREMENTS IN SITU TO OBTAIN DATA FOR CORRELATION WITH ORBITAL MEASUREMENTS.SAMPLES OF MEASURED MATERIALS TO BE RETURNED TO THE BASE AND TO EARTH FOR DETAILED GEOCHEMICAL STUDY THE MEASUREMENTS WILL BE MADE ON TRAVERSE WITH A RECORDING IR SPECTROMETER SENSING IN THE RANGE OF 8-20 MICRONS.
3 2 01 C3 01	DIFFERENTIAL THERMAL ANALYSIS-DISTILLATION OF VOLATILES FROM SOLIDS DTA ANALYSIS AND THE DISTILLATION AND COLLECTION OF VOLATILES FROM SOLIDS A THERMOBALANCE TO BE USED TO COMPUTE RELATIVE WEIGHT CHANGES THIS TECHNIQUE WILL PROVIDE QUALITATIVE DATA ON THE SAMPLES IN TERMS OF THE WEIGHT PERCENT OF TRAPPED VOLATILES. THE COLLECTED VOLATILES WILL BE SUBJECTED TO ADDITIONAL ANALYSIS FOR COMPOSITION.
3 3 01 C1 01	GAMMA-RAY SPECTROMETRY ON TRAVERSES GAMMA-RAY SPECTROMETRY OF LUNAR MATERIALS ON ALL TRAVERSES THIS EQUIPMENT PROVIDES (GAMMA-RAY) SPECTRA OF SURFACE REGIONS TO A DEPTH OF ABOUT ONE FOOT. A PULSED NEUTRON SOURCE COULD GIVE A MEASURE OF VARIOUS GAMMA-RAY SPECTRA TO PROVIDE A PARTIAL ELEMENTAL ANALYSIS IN SITU. DATA TO BE RECORDED BY VERBAL DESCRIPTION OF SPECTRAL PATTERNS FOR CORRELATION WITH ORBITAL DATA.
3 3 01 C1 02	GAMMA-RAY SPECTROMETRY FROM LUNAR ORBIT GAMMA-RAY SPECTROMETRY FROM ORBITING SATELLITES TO OBTAIN GLOBAL COVERAGE. THESE MEASUREMENTS CAN GIVE DIRECT INFORMATION ON CHEMICAL COMPOSITION WHEN CORRELATED WITH SURFACE DATA. SENSING WILL BE IN THE RANGE OF 100KEV-10MEV.
3 4 01 C4 01	MASS SPECTROMETRIC ANALYSES FROM LUNAR ORBIT MASS SPECTROMETRIC ANALYSIS OF GASES FROM A LOW FLYING SATELLITE TO DETECT FLUCTUATIONS IN GAS DENSITY RELATED TO GAS EMANATING FROM THE SURFACE. DEVICE TO BE EQUIPPED WITH A PRESSURE INTENSIFIER, AS FOR EXAMPLE A SNORKEL AIMED IN THE DIRECTION OF TRAVEL THE MEASUREMENTS WILL BE MADE WITH A QUADRUPOLE MASS SPECTROMETER WITH THE DATA RECORDED FOR TELEMETERING BACK TO EARTH.

EXPERIMENT NUMBER
A C S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

GEOCHEMISTRY

3 4 C1 C4 02

MASS SPECTROMETRIC ANALYSES - SURFACE

MASS SPECTROMETRIC ANALYSIS OF GASES ON THE LUNAR SURFACE A PUMP AND A DIRECTIONAL INTAKE ARE NEEDED TO LOCATE SOURCES OF GAS.MERCURY PUMP S ARE SPECIFICALLY EXCLUDED BECAUSE OF DANGER OF STRESS CORROSION OF METALS.NON MECHANICAL PUMPS ARE PREFERRED. DEVICE ON ALL TRAVERSES. THE EQUIPMENT CAN BE MOUNTED ON THE OUTSIDE OF ROVING VEHICLES FOR LOCATION OF GAS EMISSION REGIONS ON TRAVERSE. IF THE DENSITY IS NEAR THE ESTIMATED 10**5 MOLECULES PER CU CM, THE SYSTEM SHOULD OPERATE WITH A TIME CONSTANT OF ABOUT ONE SECOND.

3 4 01 C4 03

MASS SPECTROMETRY NEAR EMISSION SOURCES

MASS SPECTROMETRIC ANALYSIS OF GASES ON THE SURFACE FOR MEASURING FLU CTUATIONS OF GAS PRESSURE NEAR SUSPECTED SITES OF GAS EMISSION TO BE EMPLACED FROM ORBIT AND FROM MANNED SURFACE MISSIONS
THE EQUIPMENT CONSISTS OF A QUADRUPOLE MASS SPECTROMETER AND GAS COMPRESSOR. THE DATA WILL BE RECORDED AND TELEMETERED BACK TO THE BASE OR MANNED ORBITER FOR PROCESSING AND INTERPRETATION.

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 C C1 C1 01

SEISMIC VELOCITY-SURFACE

THIS EXPERIMENT WILL MEASURE THE SEISMIC VELOCITY OF THE P WAVE OVER A DISTANCE OF 1 TO 5 M. THE EXPERIMENT SHOULD BE PERFORMED ON ONE OF THE EARLY MISSIONS TO ESTABLISH FIRM PARAMETERS FOR LATER SEISMIC EXPERIMENTS AND TO OBTAIN INFORMATION AS TO THE ELASTIC PROPERTIES OF THE LUNAR SURFACE MATERIAL. A TWO GEOPHONE ARRAY WILL BE USED WITH A SMALL EXPLOSIVE SQUIB EMPLACED BY THE ASTRONAUT USED AS A SOURCE. PRECISE DISTANCES FROM THE SOURCE TO THE GEOPHONES MUST BE RECORDED. A PRECISE TIMING SIGNAL, SUCH AS A ONE KHZ OSCILLATOR, MUST BE PROVIDED TO OBTAIN RELATIVE TIME BETWEEN DETONATION AND GEOPHONE ARRIVAL TIMES. A TIMING CHANNEL AND TWO DATA CHANNELS MUST BE PROVIDED FOR WITH A RECORDING TIME OF APPROXIMATELY 10 SEC. ALL ACTIVITIES WHICH MAY INDUCE SEISMIC NOISE INTO THE LUNAR SURFACE MUST CEASE DURING THE EXPERIMENT. IT IS EXPECTED THAT THE RANGE OF VELOCITIES TO BE ENCOUNTERED ON THE LUNAR SURFACE WILL RANGE FROM 20 TO 25,000 FT/SEC. THIS EXPERIMENT SHOULD BE CONDUCTED IN SEVERAL DIFFERENT LUNAR ROCK TYPES ON DIFFERENT EARLY MISSIONS AT THE LEM LANDING SITES. THE PARTICULAR GENERAL LOCATION IS NOT OF SPECIAL IMPORTANCE BUT THE INFORMATION SHOULD BE GATHERED IN MATERIALS THAT APPEAR REPRESENTATIVE OF REGIONAL LUNAR STRUCTURE IN DIFFERENT LUNAR GEOGRAPHIC AREAS. FREQUENCY AND AMPLITUDE PARAMETERS ARE OBTAINED FROM THE SAME DATA.

REAL TIME DATA TRANSMISSION SHOULD BE CONSIDERED SINCE THIS WOULD ELIMINATE STORAGE AND THE TIMING INFORMATION COULD BE OBTAINED FROM EARTH BASED EQUIPMENT.

4 0 C1 C1 02

SEISMIC VELOCITY-SUBSURFACE LOGGING

THIS EXPERIMENT IS DESIGNED TO OBTAIN A VERTICAL SEISMIC VELOCITY PROFILE FOR THE P WAVE. THE RESULTS OF THIS EXPERIMENT WILL PROVIDE INFORMATION NECESSARY TO CORRECT FOR SURFACE EFFECTS FOR PERMANENT SEISMIC RECORDING SITES AND ALSO PROVIDE INFORMATION AS TO THE ELASTIC PROPERTIES OF THE NEAR SURFACE MATERIALS. THE EXPERIMENT WILL BE PERFORMED BY LOWERING A PROBE CONTAINING AN ACCELEROMETER, AS WELL AS SENSORS FOR OTHER EXPERIMENTS, DOWN A BOREHOLE. AT INTERVALS THE ACCELEROMETER WILL BE HELD FIRMLY AGAINST THE SIDE OF THE BOREHOLE AND A SMALL EXPLOSIVE CHARGE DETONATED ON THE SURFACE. (A THUMPER MAY BE USED IN PLACE OF AN EXPLOSIVE CHARGE IF FEASIBLE.) THE TIME FROM DETONATION TO FIRST ARRIVAL MUST BE RECORDED BY USING A PRECISION ONE KHZ OSCILLATOR OR EQUIVALENT TIMING SYSTEM. THE DISTANCE FROM THE SOURCE TO THE GEOPHONE MUST BE KNOWN ACCURATELY. ONE TIMING AND ONE DATA CHANNEL MUST BE PROVIDED FOR APPROXIMATELY 10 SECONDS DURING EACH DETONATION. VELOCITIES FROM 300 TO 25,000 FT/SEC MUST BE COVERED. EXACT WAVE-FORMS MUST BE REPRODUCIBLE FROM THE RECORDED DATA. ALL ACTIVITY THAT MAY INTRODUCE SEISMIC NOISE INTO THE GROUND MUST CEASE DURING THE MEASURE. THE EXPERIMENT SHOULD BE CONDUCTED ON SEVERAL DIFFERENT MISSIONS IN DIFFERENT ROCK TYPES AND IN DEEP HOLES IN MORE ADVANCED MISSIONS. AMPLITUDE AND FREQUENCY PARAMETERS ARE OBTAINED FROM THE SAME DATA. A 10 MINUTE PLAYBACK TIME IS ASSUMED FOR THE DATA. EQUIPMENT OPERATING TIMES AND DATA RATES ARE BASED ON LOGGING ONE BOREHOLE USING THE GEOPHONE AT FIVE POINTS IN THE BOREHOLE AND FIVE SHOTS. DATA IS TAKEN TO 500 HZ, 3 SAMPLES/HZ AND A 5 BIT ACCURACY. REAL TIME DATA TRANSMISSION SHOULD BE CONSIDERED SINCE THIS WOULD ELIMINATE STORAGE AND THE TIMING INFORMATION COULD BE OBTAINED FROM EARTH BASED EQUIPMENT. FREQUENCY AND AMPLITUDE INFORMATION IS

EXPERIMENT NUMBER

ARE JAT OBSERVEXPECT

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 0 01 01 03

SEISMIC PROFILING-SHALLOW REFLECTION

THIS EXPERIMENT IS DESIGNED TO ASCERTAIN THE ELASTIC PROPERTIES OF THE LUNAR SURFACE DOWN TO A DEPTH OF SEVERAL HUNDRED FEET. INFORMATION USEFUL IN INTERPRETING LUNAR SURFACE FEATURES AND NEAR SURFACE STRATIGRAPHY WILL BE OBTAINED FROM THE EXPERIMENT. AN ARRAY OF TWO BURIED GEOPHONES SEPARATED 100 FT WILL BE USED WITH 5 EXPLOSIVE CHARGES DETONATED IN A SEQUENCE AT RANGES UP TO 2,000 FT FROM THE ARRAY. IF FEASIBLE THE CHARGES SHOULD BE EMPLOYED IN SHALLOW BOREHOLES BY THE ASTRONAUT TO ENSURE GOOD COUPLING WITH THE LUNAR SURFACE. IF TIME DOES NOT PERMIT EMPLACEMENT OF THE CHARGES THEY MAY BE EMPLACED AUTOMATICALLY USING MORTARS WITH METERED LINES TO LOCATE THE DETONATION POINTS. THE EXACT LOCATION OF THE DETONATION POINTS AND THE GEOPHONES MUST BE KNOWN. EXPECTED SEISMIC VELOCITIES MAY RANGE UP TO 25,000 FT/SEC. SHOTS AT THE LONGER RANGES MAY GIVE REFRACTION DATA IF THERE ARE NEAR SURFACE DISCONTINUITIES. TWO DATA CHANNELS AND A TIMING CHANNEL WILL BE REQUIRED FOR APPROXIMATELY 20 SECONDS. THIS EXPERIMENT SHOULD BE CONDUCTED JUST PRIOR TO THE SHALLOW REFRACTION PROFILING EXPERIMENT (40010104) SINCE THE ELECTRONICS ARE THE SAME AND RESULTS OF THIS EXPERIMENT WILL SERVE TO LOCATE THE OPTIMUM SHOT POINTS FOR THE REFRACTION EXPERIMENT. REFLECTION PROFILING EXPERIMENTS WILL BE PERFORMED ON A NUMBER OF MISSIONS IN DIFFERENT GEOLOGIC ENVIRONMENTS. A PLAYBACK TIME OF 10 MINUTES IS ASSUMED FOR THE RECORDED DATA. INFORMATION OBTAINED FROM THIS EXPERIMENT WILL GIVE INFORMATION USEFUL IN EVALUATING LOCATIONS FOR CONSTRUCTION OF LUNAR BASES. DATA OBTAINED WILL GIVE INFORMATION AS TO SHALLOW STRUCTURE, DENSITY AND UNIFORMITY OF SHALLOW SUBSURFACE STRUCTURE. THE EXPERIMENT SHOULD BE PERFORMED AT SITES WHERE STRUCTURES ARE TO BE BUILT. EQUIPMENT OPERATING TIMES AND DATA RATES ARE BASED ON USING FIVE EXPLOSIVE

4 0 01 01 04

SEISMIC PROFILING-SHALLOW REFRACTION

THIS EXPERIMENT IS DESIGNED TO DETERMINE THE LOCATION AND ELASTIC PROPERTIES OF SUBSURFACE LAYERS. THE EXPERIMENT SHOULD FOLLOW THE SHALLOW REFLECTION PROFILING EXPERIMENT (40010104) WITH INFORMATION FROM THAT EXPERIMENT USED TO LOCATE OPTIMUM SHOT POINTS FOR THIS EXPERIMENT. THE EXPERIMENT WILL USE A TWO BURIED GEOPHONE ARRAY WITH 5 SHOT POINTS OUT TO SEVERAL THOUSAND FEET. SEISMIC VELOCITIES UP TO 25,000 FT/SEC MAY BE ENCOUNTERED. EXACT LOCATIONS OF GEOPHONES AND SHOT POINTS MUST BE RECORDED. TWO DATA CHANNELS AND A TIMING CHANNEL MUST BE PROVIDED FOR APPROXIMATELY 20 SECONDS. REFRACTION PROFILING WILL BE PERFORMED ON MISSIONS THROUGHOUT THE EARLY EXPLORATION PHASE. A PLAYBACK TIME OF 10 MINUTES IS ASSUMED. REAL TIME DATA TRANSMISSIO SHOULD BE CONSIDERED FOR THE EQUIPMENT SINCE THIS WOULD ELIMINATE STORAGE AND THE TIMING INFORMATION COULD BE OBTAINED FROM EARTH BASED STATIONS. FREQUENCY AND AMPLITUDE INFORMATION IS OBTAINED FROM THE SAME DATA.

4 0 05 05 24

MAGNETIC SUSCEPTIBILITY-SURFACE

THIS EXPERIMENT IS DESIGNED TO MEASURE THE MAGNETIC SUSCEPTIBILITY OF THE LUNAR SURFACE MATERIAL IN SITU BY USING AN AIR CORE TRANSFORMER IN WHICH THE OUTPUT HAS BEEN REDUCED TO ZERO BY REVERSE WINDING OF THE PRIMARY. SUSCEPTIBILITY MEASUREMENTS ARE MADE BY COMPARING THE OUTPUT VOLTAGE AND INPUT CURRENT VECTORS IN A KNOWN MEDIA WITH MEASUREMENTS MADE ON THE LUNAR SURFACE. THE DIFFERENCE IN THESE OUTPUTS WITH IDENTICAL INPUTS IS PROPORTIONAL TO THE MAGNETIC SUSCEPTIBILITY. THE LOCATION OF THE MEASUREMENT AND THE TEMPERATURE OF THE COILS MUST BE RECORDED. EARLY EXPLORATION.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJECT SPEC INVS EXPT	GEOPHYSICS
4 0 05 05 25	MAGNETIC SUSCEPTIBILITY-SURFACE THIS EXPERIMENT IS DESIGNED TO MEASURE THE MAGNETIC SUSCEPTIBILITY OF LUNAR SURFACE MATERIALS IN SITU DURING THE ROVER TRAVERSES. THE MEASUREMENT IS MADE USING A BALANCED AIR CORE TRANSFORMER IN WHICH THE OUTPUT HAS BEEN REDUCED TO ZERO BY REVERSE WINDING OF THE PRIMARY. SUSCEPTIBILITY MEASUREMENTS ARE MADE BY COMPARING THE INPUT VOLTAGE AND OUTPUT CURRENT VECTORS IN A KNOWN MEDIA WITH MEASUREMENTS MADE ON THE LUNAR SURFACE. THE DIFFERENCE IN THESE OUTPUTS WITH IDENTICAL INPUTS IN PROPORTIONAL TO THE MAGNETIC SUSCEPTIBILITY. THE LOCATION OF THE MEASUREMENT AND THE COIL TEMPERATURE MUST BE RECORDED. THE COILS MAY BE BOOM MOUNTED ON THE ROVER TO MINIMIZE ASTRONAUT TIME DURING THE MEASUREMENTS. MEASUREMENTS SHOULD BE MADE FREQUENTLY ALONG THE ROVER TRAVERSE. IT MAY BE FEASIBLE TO USE THE SUSCEPTIBILITY COILS IN THE ELECTROMAGNETI PROFILING EXPERIMENT (41060540).
4 0 05 05 26	MAGNETIC SUSCEPTIBILITY-SUBSURFACE THIS EXPERIMENT IS DESIGNED TO MEASURE THE MAGNETIC SUSCEPTIBILITY OF THE LUNAR MATERIAL IN A BOREHOLE. THE SYSTEM CONSISTS OF AN AIR CORE TRANSFORMER IN A SONDE WHICH IS LOWERED IN A BOREHOLE. MEASUREMENT OF THE INPUT CURRENT AND SUSCEPTIBILITY AND CONDUCTIVITY VECTORS ARE MADE IN A KNOWN MEDIA AND IN A BOREHOLE AND THE DIFFERENCES USED TO COMPUTE THE SUSCEPTIBILITY. THE TEMPERATURE OF THE COILS MUST BE RECORDED SINCE THE EXPERIMENT IS TEMPERATURE SENSITIVE. AT THE PRESENT STATE OF THE ART THE SENSITIVITY OF SUCH A COIL SYSTEM USED IN A BOREHOLE IS MARGINAL DUE TO THE SMALL COIL SIZE. THE SUSCEPTIBILITY PROBE IS CONTAINED IN A SONDE WHICH ALSO MAY CONTAIN OTHER SUBSURFACE LOGGING EXPERIMENTS. THE ELECTRONICS USED IN THE SURFACE PROBE (40050524) MAY BE IDENTICAL TO THE SUBSURFACE PROBE.
4 0 05 05 27	MAGNETIC SUSCEPTIBILITY-SUBSURFACE THIS EXPERIMENT IS DESIGNED TO MEASURE THE SUBSURFACE MAGNETIC SUSCEPTIBILITY DURING THE ROVER TRAVERSES. THE SENSOR WILL BE ESSENTIALLY A LOOSELY COUPLED AIR CORE TRANSFORMER MOUNTED IN THE SUBSURFACE LOGGING SONDE. MEASUREMENTS ARE MADE BY MEASURING THE INPUT CURRENT AND THE OUTPUT CONDUCTIVITY AND SUSCEPTIBILITY VECTORS AND COMPARING THE RESULTS WITH MEASUREMENT MADE IN A MEDIA OF KNOWN SUSCEPTIBILITY. THESE MEASUREMENTS SHOULD BE MADE IN ALL BOREHOLES DRILLED BY THE ROVER DRILL. LOCATION OF THE MEASUREMENTS AND COIL TEMPERATURE AT THE TIME OF THE MEASUREMENTS MUST BE RECORDED. THE ELECTRONICS FOR THE SUBSURFACE PROBE WILL BE ESSENTIALLY THE SAME AS FOR THE SURFACE SUSCEPTIBILITY PACKAGE. EXPERIMENTAL MONITORING OF SUB-SURFACE DISCONTINUITIES YIELDS INFORMATION ON PHYSICAL PROPERTIES AND EXTENDS THE DEPTH OF GEOLOGIC OBSERVATIONS.
4 0 05 05 36	PERMITTIVITY-SURFACE ELECTRICAL THE ELECTRICAL PERMITTIVITY OF THE SURFACE MATERIALS WILL BE MEASURED BY RETURNING SAMPLES TO EARTH DURING EARLY EXPLORATION. PERMITTIVITY IS MEASURED BY USING THE MATERIAL AS A DIELECTRIC IN A PARALLEL PLATE CAPACITOR IN AN EARTH LAB. THE SAMPLES SHOULD BE CHOSEN TO BE REPRESENTATIVE OF THE DIFFERENT LUNAR TERRAIN AND FORMATIONS. LOCATIONS OF WHERE THE SAMPLES WERE OBTAINED WILL BE RECORDED. NO TELEMETRY WILL BE REQUIRED. THE ELECTRICAL PERMITTIVITY OF MOST LUNAR SAMPLES SHOULD BE MEASURED IN THE EARLIER PHASE OF EXPLORATION

EXPERIMENT NUMBER

A G S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 0 05 05 37 **PERMITTIVITY-SURFACE ELECTRICAL**

THIS EXPERIMENT IS DESIGNED TO MEASURE THE DIELECTRIC CONSTANT OR ELECTRICAL PERMITTIVITY OF LUNAR SURFACE MATERIALS DURING THE ROVER TRAVERSES. TWO APPROACHES ARE POSSIBLE. ONE IS THE DEVELOPMENT OF A SENSOR TO MEASURE THE DIELECTRIC CONSTANT IN SITU AND THE SECOND METHOD TO MEASURE THE DIELECTRIC CONSTANT OF SAMPLES COLLECTED ON THE LUNAR SURFACE. THE FIRST OF THESE IS NOT STATE OF THE ART BUT MUST BE DEVELOPED. THE SECOND SCHEME CONSISTS OF USING THE SAMPLE AS THE DIELECTRIC IN A PARALLEL PLATE CAPACITOR AND DETERMINING THE CHANGE IN CAPACITY WITH AND WITHOUT THE MATERIAL PRESENT. THIS EXPERIMENT WILL BE PERFORMED WITHIN THE ROVER. THE MATERIAL CAN BE USED IN A SLAB OR A PULVERIZED FORM. THE FIRST SCHEME WILL BE CONSIDERED HERE.

4 0 05 05 38 **PERMITTIVITY-SUBSURFACE ELECTRICAL**

THIS EXPERIMENT IS DESIGNED TO MEASURE THE DIELECTRIC CONSTANT OF THE MATERIAL SURROUNDING THE BOREHOLE DRILLED DURING THE AES EXPLORATION PROGRAM. THE EXPERIMENT WILL CONSIST OF A CYLINDRICAL CAPACITOR BUILT INTO THE SUBSURFACE LOGGING PROBE. THIS DEVICE IS NOT STATE OF THE ART AND WILL REQUIRE ADDITIONAL DEVELOPMENT TO OBTAIN THE REQUIRED ACCURACY. THE EXPERIMENT WILL USE A HF OSCILLATOR IN A BRIDGE TO DETERMINE THE CHANGE IN CAPACITY IN THE BOREHOLE AS OPPOSED TO FREE SPACE.
ALL BOREHOLES DRILLED SHOULD BE LOGGED.
SEVERAL MEASUREMENTS ARE NEEDED PER HOLE DEPENDING UPON THE DEPTH.
THIS EXPERIMENT WILL NOT DETERMINE THE DRILLING SITE. DRILLING TIMES ARE NOT CONSIDERED PART OF THE EXPERIMENT. EARLY EXPLORATION.

4 0 05 05 39 **PERMITTIVITY-SUBSURFACE ELECTRICAL**

THIS EXPERIMENT WILL MEASURE THE PERMITIVITY OF THE SUBSURFACE LUNAR MATERIAL IN THE BOREHOLES DRILLED DURING THE ROVER SURVEYS. THE DEVICE WILL BE PART OF THE SUBSURFACE GEOPHYSICAL LOGGING TOOL. DEVELOPMENT IS REQUIRED ON THIS TECHNIQUE TO OBTAIN THE DESIRED SENSITIVITY. THE SYSTEM WILL USE A HF OSCILLATOR IN A BRIDGE TO DETERMINE THE DIFFERENCE IN CAPACITY IN THE BOREHOLE AND FREE SPACE. TOTAL DATA PER EXPERIMENT WILL BE SMALL AND LESS THAN 100 BITS. DATA RATES AND OPERATING TIMES ARE ON A PER MEASUREMENT BASIS. ALL HOLES WILL BE LOGGED AND SEVERAL MEASUREMENTS PER HOLE REQUIRED. THIS EXPERIMENT WILL NOT DETERMINE THE DRILLING LOCATION. DRILLING TIME IS NOT CONSIDERED IN THE EXPERIMENT.

4 0 06 05 32 **RESISTIVITY-SURFACE**

THIS EXPERIMENT IS DESIGNED TO MEASURE THE RESISTIVITY OF THE LUNAR SURFACE MATERIALS IN SITU BY MEASURING THE CHANGE IN THE Q OF A COIL PLACED ABOVE THE SURFACE OF THE MOON. IN THE EXPERIMENT A VLF OSCILLATOR WILL BE USED TO DRIVE A COIL. THE Q WILL BE MEASURED WITH THE COIL WELL ABOVE THE LUNAR SURFACE, THE COIL LOWERED TO THE SURFACE AND THE Q RECORDED AGAIN. THE VARIATION IN THE Q WILL BE A MEASURE OF THE CONDUCTIVITY OF THE LUNAR SURFACE MATERIAL. SELECTED SITES WILL BE SURVEYED DURING THE AES MISSIONS BY THIS METHOD. THIS INFORMATION IS ALSO OBTAINED IN THE ELECTRICAL SURVEYING USING A WENNER ARRAY TO MEASURE RESISTIVITY (40060630) BUT MAY PROVE MORE FEASIBLE.
PARTICULAR LOCATIONS FOR THE EXPERIMENT ARE NOT IMPORTANT BUT MEASUREMENTS SHOULD BE MADE AT POINTS REPRESENTATIVE OF THE AREA IN WHICH THE MEASUREMENTS ARE MADE. THE TEMPERATURE OF THE COIL MAY HAVE TO BE KNOWN TO CORRECT THE DATA.

MEASUREMENTS WILL BE MADE AT MANY POINTS ON THE TRAVERSE. OPERATING TIMES ARE PER MEASUREMENT. EARLY EXPLORATION.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 0 C6 C5 33 **RESISTIVITY-SURFACE**

THIS EXPERIMENT IS DESIGNED TO ASCERTAIN THE RESISTIVITY OF THE LUNAR SURFACE MATERIALS ON THE ROVER TRAVERSES. IT WILL DETERMINE THE RESISTIVITY BY MEASURING THE CHANGE IN Q OF A COIL ON THE LUNAR SURFACE AS OPPOSED TO THE Q IN FREE SPACE. THE SYSTEM WILL USE AN OSCILLATOR TO DRIVE THE COIL AT A FEW KHZ AND RECORD THE Q WELL ABOVE THE SURFACE AND ON THE LUNAR SURFACE. THE COIL MAY BE MOUNTED ON AN EXTERNAL BOOM TO MINIMIZE ASTRONAUT PARTICIPATION IN THE EXPERIMENT. COIL TEMPERATURE INFORMATION MAY BE NEEDED TO CORRECT THE DATA.
THE EXPERIMENT CAN BE PERFORMED FROM WITHIN THE ROVER.
THE Q OF THE COIL ABOVE THE SURFACE AND ON THE SURFACE AND THE GENERAL LOCATION WILL BE NEEDED.

4 0 C6 C5 34 **RESISTIVITY-SUBSURFACE**

THIS EXPERIMENT IS DESIGNED TO MEASURE THE RESISTIVITY OF THE LUNAR MATERIALS BY MEASURING THE CHANGE IN Q OF A COIL IMMERSED IN A CONDUCTING MEDIA. THE COIL IS PART OF THE SUBSURFACE GEOPHYSICAL LOGGING PROBE. THE Q OF THE COIL IS KNOWN OR MEASURED IN FREE SPACE AND THE CHANGE IN Q WHILE IN THE BOREHOLE RECORDED. THE SENSITIVITY OF SUCH A DEVICE IS QUESTIONABLE IN ROCKS OF HIGH SENSITIVITY SINCE THE COILS WILL BE QUITE SMALL. THE DEPTH OF THE PROBE MUST BE RECORDED AND THE COIL TEMPERATURE MAY ALSO NEED TO BE KNOWN FOR LATER DATA CORRECTIONS.
SEVERAL MEASUREMENTS WILL BE MADE IN EACH HOLE, THE NUMBER DEPENDING ON THE DEPTH OF THE HOLE. OTHER EXPERIMENTS WILL DETERMINE THE LOCATION OF THE HOLE. A RESISTIVITY LOG WILL BE RUN ON ALL HOLES DRILLED. OPERATING TIMES ARE PER MEASUREMENT. DRILLING TIMES ARE NOT INCLUDED IN THE EXPERIMENT.

4 0 C6 C5 35 **RESISTIVITY-SUBSURFACE**

THIS EXPERIMENT WILL MEASURE THE RESISTIVITY OF THE NEAR SURFACE MATERIALS IN THE BOREHOLES DRILLED DURING THE ROVER EXPLORATION PROGRAM. THIS PARAMETER WILL BE DETERMINED BY MEASURING THE DIFFERENCE IN THE Q OF A COIL IN THE BOREHOLE AND IN FREE SPACE. THE COIL WILL BE PART OF THE GEOPHYSICAL BOREHOLE LOGGING TOOL AND WILL BE USED IN ALL HOLES. THE SENSITIVITY OF THIS EXPERIMENT IN HIGH RESISTIVITY ROCKS SUCH AS IS EXPECTED ON THE LUNAR SURFACE IS QUESTIONABLE. DEPTH AND LOCATION OF THE SONDE AT THE TIME OF THE MEASUREMENT MUST BE RECORDED. THE ELECTRONICS FOR THIS EXPERIMENT SHOULD BE SIMILAR TO THOSE USED FOR THE SURFACE RESISTIVITY SURVEYS.
THE TEMPERATURE OF THE COIL MAY HAVE TO BE RECORDED FOR DATA CORRECTION.
OTHER EXPERIMENTS WILL DETERMINE THE LOCATION OF THE BOREHOLE. ALL HOLES DRILLED WILL BE LOGGED. OPERATING TIMES ARE FOR EACH MEASUREMENT. DRILLING TIMES ARE NOT INCLUDED IN THE EXPERIMENT.

4 0 C6 C5 65 **HIGH RESOLUTION RADAR**

THIS EXPERIMENT WILL BE USED TO DETERMINE SURFACE AND SUBSURFACE STRUCTURE AND FORMATIONS. IN MATERIALS OF VERY HIGH RESISTIVITY, PENETRATION OF SEVERAL KILOMETERS MAY BE EXPECTED AT CERTAIN FREQUENCIES. THE RADAR WILL OPERATE FROM ORBITAL ALTITUDES AND WILL ENABLE LARGE AREAS OF THE LUNAR SURFACE TO BE COVERED. DATA RATES ARE EXTREMELY HIGH, MEGA BPS. CONTINUOUS OPERATION IS PROBABLY NOT POSSIBLE WITH EXPECTED TRANSMISSION RATES.

EXPERIMENT NUMBER

A C S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 C 06 C6 28

SELF POTENTIAL-SUBSURFACE

THE EXPERIMENT IS DESIGNED TO MEASURE ANY SUBSURFACE SELF POTENTIALS THAT MAY OCCUR IN A BOREHOLE DUE TO MINERAL DEPOSITS OR OTHER CAUSES. THE SENSORS WILL BE PART OF A BOREHOLE GEOPHYSICAL LOGGING SONDE. CONTACT ELECTRODES WILL BE HELD AGAINST THE BOREHOLE WALL DURING THE MEASUREMENTS. BEHAVIOR OF DRY CONTACTS WITH MATERIALS OF VERY HIGH RESISTIVITIES SHOULD BE STUDIED IN SOME DETAIL FOR THIS EXPERIMENT. THE ELECTRONICS FOR THIS EXPERIMENT WILL BE THE SAME AS FOR THE RESISTIVITY MEASUREMENTS USING CONTACT ELECTRODES WITH POSSIBLY A DIFFERENT INPUT STAGE. THE DEPTH IN THE BOREHOLE AND LOCATION OF THE BOREHOLE MUST BE RECORDED. MONITORING OF SUB-SURFACE DISCONTINUITIES YIELDS INFORMATION ON PHYSICAL PROPERTIES AND EXTENDS THE DEPTH OF GEOLOGIC OBSERVATIONS.

4 0 06 C6 29

SELF POTENTIAL-SUBSURFACE

THIS EXPERIMENT IS DESIGNED TO MEASURE THE SELF POTENTIALS IN BOREHOLES DRILLED BY THE ROVER DRILL. THE MEASUREMENT IS MADE USING CONTACT ELECTRODES HELD AGAINST THE BOREHOLE WALL DURING THE EXPERIMENT. THE ELECTRONICS FOR THE EXPERIMENT ARE ESSENTIALLY THE SAME AS THOSE USED FOR THE RESISTIVITY MEASUREMENTS AND THE EARTH CURRENT MEASUREMENTS. THE TECHNIQUE OF USING DRY CONTACT ELECTRODES IN A LUNAR ENVIRONMENT NEEDS TO BE STUDIED SINCE SEVERAL EXPERIMENTS REQUIRE THE USE OF SUCH TECHNIQUES EXPERIMENTAL MONITORING OF SUB-SURFACE DISCONTINUITIES WILL YIELD INFORMATION ON PHYSICAL PROPERTIES AND EXTENDS THE DEPTH OF GEOLOGIC OBSERVATIONS.

4 C C6 C6 30

ELECTRICAL SURVEY, SURFACE

THIS EXPERIMENT WILL MEASURE THE ELECTRICAL PROPERTIES OF THE LUNAR SURFACE FORMATIONS INCLUDING INCLUDING SELF POTENTIAL, INDUCED POLARIZATION AND ELECTRICAL RESISTIVITY. THESE PARAMETERS ARE INCLUDED AS THE ELECTRONICS AND ELECTRODES ARE THE SAME FOR EACH PARAMETER WITH ONLY A SLIGHTLY DIFFERENT MODE OF OPERATION TO DETERMINE EACH PARAMETER. A FOUR ELECTRODE WENNER ARRAY WILL BE USED. FOR THE SELF POTENTIAL THE DC POTENTIAL BETWEEN THE CENTER ELECTRODES WILL BE MEASURED. FOR THE INDUCED POLARIZATION MEASUREMENT A DC CURRENT IS PASSED THROUGH THE OUTER TWO ELECTRODES AND THE DECAY RATE OF CURRENT MEASURED AT THE INNER ELECTRODES WHEN THE CURRENT IS SHUT OFF. THIS DETERMINES POLARIZABILITY OF THE LUNAR ROCKS. THE RESISTIVITY IS MEASURED BY DRIVING AN AC CURRENT THROUGH THE OUTER ELECTRODES AND MEASURING THE VOLTAGE BETWEEN THE INNER ELECTRODES. THIS EXPERIMENT WILL BE PERFORMED ON A NUMBER OF MISSIONS AT SELECTED GEOLOGIC SITES. THE LOCATION OF THE EXPERIMENT WILL BE RECORDED. INVESTIGATIONS NEED TO BE PERFORMED ON CONTACT ELECTRODES OPERATING IN THE LUNAR ENVIRONMENT.

MULTIPLE MEASUREMENTS WILL BE MADE ON A SURVEY. OPERATING TIMES ARE PER MEASUREMENT. EARLY EXPLORATION.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
A O S I E R B P N X E J E V P A T C S T	GEOPHYSICS
4 0 06 06 31	ELECTRICAL SURVEY, SURFACE THIS EXPERIMENT IS AN INTEGRATED SELF POTENTIAL, INDUCED POLARIZATION AND RESISTIVITY EXPERIMENT USING COMMON ELECTRONICS TO MEASURE THE THREE PARAMETERS. THE SYSTEM WILL USE A FOUR ELECTRODE WENNER ARRAY. FOR THE SELF POTENTIAL THE DC VOLTAGE BETWEEN THE CENTER ELECTRODES WILL BE MEASURED. FOR THE INDUCED POLARIZATION A DC CURRENT WILL BE PASSED THROUGH THE OUTER ELECTRODES AND THE DECAY OF THE CURRENT MEASURED AT THE INNER ELECTRODES WHEN THE CURRENT IS SHUT OFF. THE RESISTIVITY MEASUREMENT IS MADE BY PASSING AN AC SIGNAL THROUGH THE OUTER ELECTRODES AND DETECTING THE VOLTAGE ON THE INNER ELECTRODES. THIS EXPERIMENT WILL BE PERFORMED ROUTINELY ON THE ROVER TRAVERSES. IT IS SUGGESTED THAT ELECTRODES MAY BE INCORPORATED IN THE BASE OF THE GEOPHONES USED IN SEISMIC EXPERIMENTS. LOCATION OF THE SURVEY SITES MUST BE RECORDED. MANY SUCH MEASUREMENTS WILL BE MADE ON A SURVEY. OPERATING TIMES ARE PER MEASUREMENT.
4 0 07 08 69	SPECTRASONAL PHOTOGRAPHY THIS EXPERIMENT, WHICH INCLUDES UV, BLACK AND WHITE, COLOR AND IR IMAGERY FROM ORBIT, WILL SERVE TO PROVIDE INFORMATION REGARDING THE TEMPERATURE OF THE LUNAR SURFACE AND THE GEOLOGIC FORMATIONS EXPOSED ON THE LUNAR SURFACE AS WELL AS DATA NEEDED TO CONSTRUCT TOPOGRAPHIC MAPS OF THE MOON. THE TEMPERATURE INFORMATION WILL BE OBTAINED FROM THE IR SPECTRAL REGION FROM PHOTOGRAPHS OF THE DARK PORTIONS OF THE MOON. ON THE SUNLIT SIDE OF THE MOON, REFLECTED ENERGY FROM THE SUN WILL MASK THE EFFECTS OF HEAT FROM INTERNAL LUNAR STRUCTURE OR ACTIVITY. THE TEMPERATURE OF THE SURFACE WILL PROVIDE DATA THAT WILL BE USEFUL IN THE CONSTRUCTION OF MODELS OF THE INTERIOR OF THE MOON.
4 0 07 08 83	SPECTRAL REFLECTANCE THE EXPERIMENT IS DESIGN TO MEASURE THE SPECTRAL REFLECTANCE OF THE LUNAR SURFACE MATERIALS TO HELP IN IDENTIFICATION OF THE SURFACE MATERIALS AND PROVIDE DATA NECESSARY FOR THE CORRECTION OF REMOTE SENSING DEVICES. THE EXPERIMENT WILL BE PERFORMED BY ILLUMINATING THE SURFACE WITH A KNOWN ENERGY SOURCE AND MEASURING THE REFLECTED ENERGY WITH A CALIBRATED REMOTE SENSOR. THE EXPERIMENT WILL BE PERFORMED IN A NUMBER OF LOCATIONS AND IN DIFFERENT ROCK TYPES.
4 0 08 03 52	METEORITE COUNTER, ESS THE EXPERIMENT IS DESIGNED TO ASCERTAIN THE NUMBER OF METEORITES IMPINGING ON A GIVEN AREA AND TO DETERMINE THEIR VELOCITIES AND MOMENTUMS. MATERIALS EJECTED FROM THE LUNAR SURFACE WILL ALSO BE DETECTED AND RECORDED BY THE EXPERIMENT. A LARGE MATRIX WILL BE EMPLACED AT THE ESS LOCATION BY THE ASTRONAUT. THE IMPACT RATE, DIRECTION AND VELOCITIES WILL BE DETERMINED BY RECORDING THE ELEMENT OF THE UPPER AND LOWER SURFACE ELEMENTS THAT A METEORITE PASSES THROUGH AND THE MOMENTUM DETERMINED BY THE ENERGY RELEASED ON IMPACT BY THE METEORITES AS THEY STRIKE THE LOWER MATRIX ELEMENT. DATA RATES ARE BASED ON 1000 IMPACTS PER DAY. THIS INFORMATION IS USEFUL IN DETERMINING THE DESIGN REQUIREMENTS FOR PERMANENT LUNAR STRUCTURES. DATA RATES ARE PER DAY BUT THE SYSTEM WILL OPERATE AS LONG AS THE SYSTEM WORKS. READOUT WILL BE ON EARTH COMMAND, PROBABLY ONCE OR TWICE PER DAY. TEN MINUTES OF READ OUT TIME IS ASSUMED. IT MAY ALSO BE POSSIBLE TO USE AN ACOUSTIC TYPE DETECTOR WITH THE OUTPUT GOING TO A PULSE HEIGHT ANALYZER IN PLACE OF THE ELECTROSTATIC PENDULUM. EARLY EXPLORATION.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
ARE AT / OBJ TC / SPE C / INV S / EXP T	GEOPHYSICS
4 0 08 03 53	**METEORITE MEASUREMENT** THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE THE FLUX, VELOCITY, DIRECTION AND MOMENTUM OF METEOROIDS, PRIMARY AND SECONDARY, STRIKING AN ARRAY SET UP BY THE ASTRONAUT AT THE ALSEP SITE. PARTICLE VELOCITIES ARE DETERMINED BY MEASURING THE TIME OF FLIGHT BETWEEN THE UPPER AND LOWER SURFACE OF THE MATRIX ARRAY. THE DIRECTION IS DETERMINED BY RECORDING THE ELEMENT OF THE UPPER AND LOWER SURFACE THAT THE PARTICLE PASSED THROUGH. THE MOMENTUM IS DETERMINED BY LETTING THE METEORITE STRIKING AN ELECTROSTATIC BALLISTIC PENDULUM INCORPORATED IN THE LOWER MATRIX SURFACE. INCREMENTAL REAL TIME DATA IS NECESSARY TO OBTAIN TIME VARYING FLUX RATES. THE EXPERIMENT WILL BE PERFORMED UNTIL THE EQUIPMENT CEASES TO FUNCTION PROPERLY. IMPACTS, MOMENTUMS AND TIME ARE MEASURED DIRECTLY WITH VELOCITY AND DIRECTION CALCULATED. A MAXIMUM OF 1000 PARTICLES PER DAY IS EXPECTED. EARLY MISSIONS.
4 0 08 03 54	**METEORITE COUNTER** THE EXPERIMENT IS TO MEASURE METEORITE IMPACTS AND MOMENTUMS DURING THE ROVER EXPLORATION TIME PERIOD. THE MEASUREMENT WILL BE MADE BY COUNTING THE PARTICLES STRIKING PANELS MOUNTED ON THE ROVER. AN ACOUSTIC SENSOR WILL BE INCORPORATED IN THE PANELS. THE AMPLITUDE OF THE PULSE RECEIVED WILL BE A MEASURE OF THE MOMENTUM OF THE PARTICLES. THIS EXPERIMENT WILL BE PERFORMED CONTINUOUSLY WHILE THE ROVER IS ON THE LUNAR SURFACE IF OTHER CONSTRAINTS, SUCH AS POWER LIMITATIONS DO NOT FORBID. DATA RATES ARE BASED ON 1000 IMPACTS PER DAY. DATA WILL BE READ ONCE PER DAY ON COMMAND FROM EARTH.
4 0 08 03 70	**METEORITE COUNTER, ORBITING SATELLITES** THE EXPERIMENT WILL MEASURE METEORITES INTERCEPTED BY A LUNAR SATELLITE. THIS EXPERIMENT WILL USE AN ACOUSTIC SENSOR TO COUNT IMPACTS ON THE SATELLITE SURFACE. AN ANALYZER MAY ALSO BE INCORPORATED TO DETERMINE THE MOMENTUM, VELOCITY AND DIRECTION OF THE PARTICLES. TOTAL DATA CALCULATED ASSUMING 500 BITS PER HOUR FOR 30 DAYS.
4 0 09 04 56	**HARDNESS-NEAR SURFACE** THE HARDNESS OF THE LUNAR MATERIAL PENETRATED BY THE DRILL WILL BE DETERMINED DURING THE ROVER EXPLORATION BY AUTOMATICALLY RECORDING DRILLING RATES, PRESSURE ON THE DRILL AND DRILL POWER CONSUMPTION. THIS DATA WILL BE RECORDED FOR ALL DRILL HOLES AND DOES NOT REQUIRE ANY ASTRONAUT PARTICIPATION. DATA RATES WILL BE SMALL. TOTAL DATA WILL BE A FUNCTION OF DRILLING TIME. INFORMATION GAINED IN DRILLING WILL BE USEFUL IN CHOOSING LOCATIONS FOR CONSTRUCTION OF PERMANENT STRUCTURES.

EXPERIMENT NUMBER

A O S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 C 11 C7 77

NEUTRON FLUX AND ENERGY SPECTRUM

THIS EXPERIMENT WILL MEASURE THE FLUX AND ENERGY SPECTRA OF INCIDENT AND LUNAR ALBEDO NEUTRONS AT THE ESS. MEASUREMENTS OF INCIDENT NEUTRON FLUXES WILL YEILD INFORMATION ON COSMIC RAY AND SOLAR PHYSICS, AND ON THE ORIGIN OF GEOMAGNETICALLY TRAPPED PROTONS. MEASUREMENTS OF LUNAR ALBEDO NEUTRONS WILL YIELD INFORMATION ON THE LUNAR CRUST. TWO PHOSWICH DETECTORS WILL BE USED. ONE FOR FAST (APPROXIMATELY FISSION) AND ONE FOR SLOW (APPROXIMATELY THERMAL) NEUTRONS. EACH DETECTOR CONSISTS OF FOUR CYLINDRICAL DISCS OF LITHIUM - 6 IODIDE EMBEDDED IN A CYLINDRICAL PLASTIC SCINTILLATOR. A PHOTOMULPLITIPLIER VIEWS BOTH THE PLASTIC AND THE CRYSTAL SCINTILLATOR. THERMAL NEUTRONS PRODUCE 4.8 MEV ALPHA PARTICLES IN THE CRYSTAL BY THE REACTION LITHIUM - 6 (NEUTRON, ALPHA) HYDROGEN - 3. SCINTILLATIONS PRODUCED BY CHARGED PARTICLES IN THE CRYSTAL HAVE MUCH LONGER DECAY TIMES THAN THOSE IN THE PLASTIC SCINTILLATOR SO THAT PULSES FROM THE CRYSTAL ONLY, MADE BY ALPHA PARTICLES FROM THE ABOVE REACTION, CAN BE DISTINGUISHED ELECTRONICALLY FROM PULSES IN BOTH SCINTILLATION, MADE BY INCIDENT CHARGED PARTICLES. THE LENGTH OF THE DETECTORS ARE COVERED BY BORON - 10 SLEEVES INSIDE POTYETHYLENE CYLINDERS TO ABSORB NEUTRONS INCIDENT FROM DIRECTION OUTSIDE THE ACCEPTANCE ZONES OF THE DETECTORS THE FAST NEUTRON DETECTOR WILL HAVE IN ADDITION A MODERATOR IN FRONT OF THE SCINTILLATOR. COUNTING TIMES WILL BE ABOUT FOUR HOURS, WITH THE FLUXES ANTICIPATED. TO SIMULTANEOUSLY MEASURE THE FLUX FROM THE SUN, FROM THE LUNAR SURFACE, AND FROM A DIRECTION PERPENDICULAR TO THE MOON - SUN LINE WILL REQUIRE THREE SETS OF FAST AND SLOW NEUTRON DETECTORS.

4 C 12 C7 78

SURFACE AND SUBSURFACE GAMMA-RAY SPECTROSCOPY

IN THIS EXPERIMENT THE SCINTILLATION DETECTOR AND PULSE HEIGHT ANALYZER OF THE NEUTRON ACTIVATION INSTRUMENT ARE USED TO MEASURE THE DISTRIBUTION IN THE LUNAR CRUST OF GAMMA RAY EMITTING RADIONUCLIDES - PRIMARILY URANIUM, THORIUM, PATASSIUM, AND THEIR DECAY PRODUCTS. PULSE HEIGHT ANALYSIS IS USED TO DETERMINE THE GAMMA RAY FLUX VERSUS ENERGY SPECTRUM OF THE MATERIAL BEING ANALYZED. THE ENERGY SPECTRA ARE THEN COMPARED TO THE KNOWN SPECTRA OF NUCLIDES TO IDENTIFY CONSTITUENTS. THIS EXPERIMENT MUST BE DONE AT EACH LOCATION BEFORE ANY WHICH USE RADIACTIVE SOURCES AND DATA MAY BE TAKEN CONCURRENTLY WITH THE NATURAL RADIOACTIVITY EXPERIMENT. THE INSTRUMENT CAN EASILY BE MOVED FROM PLACE TO PLACE BY AN ASTRONAUT. IF DRILLING FACILITIES ARE AVAILABLE IT CAN BE INSERTED IN A HOLE TO TAKE SUBSURFACE SAMPLES DIRECTLY. THE EXPERIMENT WILL BE CONTINUED AND EXTENDED ON THE ROVER

4 C 12 C7 79

SURFACE AND SUBSURFACE GAMMA-RAY SPECTROSCOPY

IN THIS EXPERIMENT THE SCINTILLATION DETECTOR AND PULSE HEIGHT ANALYZER OF THE NEUTRON ACTIVATION INSTRUMENT ARE USED TO MEASURE THE DISTRIBUTION IN THE LUNAR CRUST OF GAMMA RAY EMITTING RADIONUCLIDES - PRIMARILY URANIUM, THORIUM, POTASSIUM, AND THEIR DECAY PRODUCTS. PULSE HEIGHT ANALYSIS IS USED TO DETERMINE THE GAMMA RAY FLUX VERSUS ENERGY SPECTRUM OF THE MATERIAL BEING ANALYZED. THE ENERGY SPECTRA ARE THEN COMPARED TO THE KNOWN SPECTRA OF NUCLIDES TO IDENTIFY CONSTITUANTS OF THE SAMPLE. THIS EXPERIMENT MUST BE DONE AT EACH LOCATION BEFORE ANY WHICH USE RADIOACTIVE SOURCES AND DATA MAY BE TAKEN CONCURRENTLY WITH THE NATURAL RADIOACTIVITY EXPERIMENT. THE EXPERIMENT IS A CONTINUATION OF THE GAMMA RAY SPECTROSCOPY EXPERIMENT DONE IN THE EARLY PHASE.

EXPERIMENT NUMBER

ARE JAT CBS PEC INS VES EXP T

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 C 12 C7 80

ORBITAL GAMMA-RAY SPECTROSCOPY

IN THIS EXPERIMENT A LARGE SCINTILLATOR WITH PULSE HEIGHT ANALYZED OUTPUT WILL BE USED TO DETECT EXTENDED OR CONCENTRATED DEPOSITS OF GAMMA RAY EMITTING NUCLIDES IN THE LUNAR CRUST FOM A LUNAR ORBITER. THE SENSITIVITY OF THE INSTRUMENT WOULD DEPEND ON THE VOLUME OF THE SCINTILLATOR, MOST PROBABLY A SODIUM IODIDE CRYSTAL. THE REQUIRED SENSITIVITY AS WELL AS THE FEASIBILITY OF THE EXPERIMENT WOULD BEST BE DETERMINED AFTER RESULTS FROM THE ROVER GAMMA RAY SPECTROSCOPY MEASUREMENTS ARE AVAILABLE.

4 C 13 C7 71

ALPHA PARTICLE MASS SPECTROMETER

THIS EXPERIMENT WILL BE USED TO IDENTIFY LIGHT ELEMENTS, EXCEPT HYDROGEN, UP TO MASS NUMBER 40, IN THE LUNAR CRUST. A MONOENERGETIC, COLLIM BEAM OF ALPHA PARTICLES IRRADIATES THE SAMPLE, WHICH IS VIEWED BY A SOLID STATE DETECTOR. THE OUTPUT OF THE DETECTOR FEEDS INTO TWO PULSE-HEIGHT ANALYZERS, ONE FOR ALPHA PARTICLES AND ONE FOR PROTONS. THE DETECTOR THUS RESPONDS TO, AND DETERMINES THE ENERGY OF, ALPHA PARTICLES SCATTERED THROUGH A DEFINITE ANGLE, AND PROTONS FROM ALPHA-PROTON REACTIONS IN THE SAMPLE EMITTED AT THE SAME ANGLE. THE ENERGY OF AN ALPHA PARTICLE SCATTERED THROUGH A GIVEN ANGLE IS A FUNCTION OF THE INCIDENT ENERGY AND THE MASS NUMBER OF THE TARGET NUCLEUS. THUS, IN A TARGET OF FINITE THICKNESS, WHERE MULTIPLE SCATTERINGS AND IONIZATION ENERGY LOSS CAN OCCUR, THE MAXIMUM ENERGY OBSERVED FROM A MONOENERGETIC BEAM AT EACH ANGLE IS RELATED TO THE MASS NUMBER OF THE SCATTERER. ALPHA-PROTON REACTIONS OCCUR IN SOME LIGHT ELEMENTS SUCH AS NITROGEN AND FLUORINE. THE INTENSITY OF SCATTERED ALPHA PARTICLES IS A MINIMUM, AND THE MASS RESOLUTION OF THE INSTRUMENT IS A MAXIMUM, AT 180 DEGREES. NO SAMPLE PREPARATION IS NEEDED FOR THE INSTRUMENT, BUT ONLY THOSE ELEMENTS WITHIN ABOUT 100 MICRONS OF THE SURFACE WILL BE DETECTED. COUNTING TIMES OF ABOUT ONE HOUR PER SAMPLE ARE REQUIRED. THE INSTRUMENT IS SMALL AND COULD EASILY BE MOVED FROM PLACE TO PLACE BY AN ASTRONAUT IN THE EARLY PHASE. A CONTINUATION OF THIS EXPERIMENT WILL BE CARRIED OUT ON THE ROVER.

4 C 13 C7 72

ALPHA PARTICLE MASS SPECTROMETER

THIS EXPERIMENT WILL BE USED TO IDENTIFY LIGHT ELEMENTS, EXCEPT HYDROGEN, UP TO MASS NUMBER 40, IN THE LUNAR CRUST. A MONOENERGETIC, COLLIMATED BEAM OF ALPHA PARTICLES IRRADIATES THE SAMPLE, WHICH IS VIEWED BY A SOLID STATE DETECTOR. THE OUTPUT OF THE DETECTOR FEEDS INTO TWO PULSE-HEIGHT ANALYZERS, ONE FOR ALPHA PARTICLES AND ONE FOR PROTONS. THE DETECTOR THUS RESPONDS TO, AND DETERMINES THE ENERGY OF ALPHA PARTICLES SCATTERED THROUGH A DEFINITE ANGLE, AND PROTONS FROM ALPHA-PROTON REACTIONS IN THE SAMPLE EMITTED AT THE SAME ANGLE. THE ENERGY OF AN ALPHA PARTICLE SCATTERED THROUGH A GIVEN ANGLE IS A FUNCTION OF THE INCIDENT ENERGY AND THE MASS NUMBER OF THE TARGET NUCLEUS. THUS, IN A TARGET OF FINITE THICKNESS, WHERE MULTIPLE SCATTERINGS AN IONIZATION ENERGY LOSS CAN OCCUR, THE MAXIMUM ENERGY OBSERVED FROM A MONOENERGETIC BEAM AT EACH ANGLE IS RELATED TO THE MASS NUMBER OF THE SCATTERER. ALPHA-PROTON REACTIONS OCCUR IN SOME LIGHT ELEMENTS SUCH AS NITROGEN AND FLUORINE. THE INTENSITY OF SCATTERED ALPHAS IS A MINIMUM, AND THE MASS RESOLUTION OF THE INSTRUMENT IS A MAXIMUM, AT 180 DEGREES. NO SAMPLE PREPARATION IS NEEDED, BUT ONLY THOSE ELEMENTS WITHIN APPROXIMATELY 100 MICRONS OF THE SURFACE WILL BE DETECTED. COUNTING TIMES OF ABOUT ONE HOUR PER SAMPLE ARE REQUIRED. THE INSTRUMENT CAN BE MOUNTED BENEATH THE ROVER TO SAMPLE THE LUNAR SURFACE DIRECTLY. THE EXPERIMENT IS A CONTINUATION OF THE ALPHA PARTICLE MASS SPECTROMETER EXPERIMENT IN THE EARLY PHASE.

EXPERIMENT NUMBER

EXPERIMENT DESCRIPTION

A G S I E
R B P N X
E J E V P
A T C S T

GEOPHYSICS

4 0 13 C7 73

NATURAL RADIOACTIVITY

THIS EXPERIMENT WILL MEASURE ALPHA, BETA, AND GAMMA RADIATION INTENSITIES AT DIFFERENT LOCATIONS, SURFACE AND SUBSURFACE, ON THE MOON FOR COMPARISON WITH EACH OTHER AND WITH MEASUREMENTS ON EARTH. THREE DETECTORS ARE USED 1) A SOLID STATE DETECTOR FOR ALPHA PARTICLES UP TO 10 MEV, BIASED TO REJECT ELECTRONS UP TO 0.1 MEV AND PROTONS UP TO 2 MEV, 2) A SOLID STATE DETECTOR FOR BETA PARTICLES UP TO 5 MEV, AND 3) A GEIGER-MULLER COUNTER WHICH REJECTS ALPHA PARTICLES AND DETECTS BETAS AND GAMMAS. THE INSTRUMENT IS PLANNED TO BE CONTAINED IN THE RADIOACTIVITY PROBE WHICH CAN BE USED ON THE SURFACE OR SUBSURFACE WHEN DRILLING FACILITIES ARE AVAILABLE - COUNTING TIMES WILL RANGE UP TO TWO HOURS, DEPENDING ON THE RADIATION LEVELS. THE INSTRUMENT IS EASILY PORTABLE AND ASTRONAUTS COULD MOVE IT ABOUT IN THE EARLY PHASE. THIS EXPERIMENT WOULD HAVE TO BE DONE IN EACH LOCATION BEFORE ANY RADIOACTIVE SOURCES, SUCH AS THE NEUTRON GENERATOR IN THE NEUTRON ACTIVATION EXPERIMENT, OR THE GAMMA RAY SOURCE IN THE GAMMA GAMMA DENSITOMETER, ARE USED. DATA CAN BE TAKEN CONCURRENTLY WITH THE GAMMA RAY SPECTROSCOPY EXPERIMENT. AN EXTENSION OF THIS EXPERIMENT WOULD BE DONE ON THE ROVER.

4 C 13 C7 74

NATURAL RADIOACTIVITY

THIS EXPERIMENT WILL MEASURE ALPHA, BETA, AND GAMMA RACIATION INTENSITIES AT DIFFERENT LOCATIONS, SURFACE AND SUBSURFACE, ON THE MOON FOR COMPARISON WITH EACH OTHER AND WITH MEASUREMENTS ON EARTH. THESE DETECTORS ARE USED 1) A SOLID STATE DETECTOR FOR ALPHA PARTICLES UP TO 10 MEV, BIASED TO REJECT ELECTRONS UP TO 0.1 MEV AND PROTONS UP TO 2 MEV, 2) A SOLID STATE DETECTOR FOR BETA PARTICLES UP TO 5 MEV, AND 3) A GEIGER MULLER COUNTER WHICH REJECTS ALPHA PARTICLES AND DETECTS BETAS AND GAMMAS. THE INSTRUMENT IS PART OF THE RADIOACTIVITY PROBE ON THE MOLAB AND CAN BE USED AT THE SUBSURFACE. COUNTING TIMES WILL RANGE UP TO TWO HOURS, DEPENDING ON THE RADIATION LEVELS. THIS EXPERIMENT WOULD HAVE TO BE DONE AT EACH LOCATION BEFORE ANY RADIOACTIVE SOURCES, SUCH AS THE NEUTRON GENERATOR IN THE NEUTRON ACTIVATION EXPERIMENT, OR THE GAMMA RAY SOURCE IN THE GAMMA GAMMA DESITOMETER, ARE USED. DATA CAN BE TAKEN CONCURRENTLY WITH THE GAMMA RAY SPECTROSCOPY EXPERIMENT. THIS EXPERIMENT IS AN EXTENSION OF THE NATURAL RADIOACTIVITY MEASUREMENTS TAKEN IN THE EARLY PHASE.

EXPERIMENT NUMBER

A O S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 0 13 07 75

NEUTRON ACTIVATION EXPERIMENT

THIS EXPERIMENT IS USED TO DETERMINE THE CHEMICAL COMPOSITION OF LUNAR SURFACE MATERIAL. INSTRUMENTATION INCLUDES A NEUTRON SOURCE AND A SCINTILATOR WITH PULSE HEIGHT ANALYZED OUTPUT. THE SAMPLE IS IRRADIATED WITH NEUTRONS AND THE ACTIVATION GAMMA RAY SPECTRA RECORDED. NEUTRONS ARE GENERATED BY BOMBARDING TRITIUM ATOMS WITH DEUTERONS ACCELERATED ELECTROSTATICALLY TO 8C KEV. 14 MEV NEUTRONS ARE PRODUCED IN THIS REACTION. THE SCINTILLATOR IS A THALLIUM ACTIVATED SODIUM IODIDE CRYSTAL VEIWED BY A PHOTOMULTIPLIER TUBE. THE OUTPUT PULSES OF THE PHOTOMULTIPLIER, WHOSE AMPLITUDES ARE RELATED TO THE ENERGIES OF INDIVIDUAL GAMMA RAYS INCIDENT ON THE CRYSTAL, ARE AMPLIFIED AND SORTED ACCORDING TO AMPLITUDE BY A 100 CHANNEL, PULSE HEIGHT ANALYZER. INTERROGATION OF THE 100 CHANNEL MEMORY UNIT THEN REPRODUCES THE ENERGY SPECTRUM OF GAMMA RAYS INCIDENT ON THE CRYSTAL DURING THE COUNT TIME. THESE SPECTRA, IN PARTICULAR THE PEAKS REPRESENTING SPECIFIC GAMMA RAY ENERGIES, ARE THEN COMPARED WITH THOSE OF KNOWN SAMPLES - IRRADIATION TIME MAY BE AS MUCH AS 200 MINUTES FOR A NEUTRON FLUX OF 1C E + 07 PER SECOND. WITH THE SOURCE OPERATED IN A PULSED MODE OF 5 MICROSECOND PULSE DURATION AND A REPETION RATE OF 1000 TIMES PER SECOND, MELASTIC SCATTERINGS DURING THE PULSE, AND NEUTRON CAPTURE GAMMA RAYS BETWEEN PULSES, CAN BE OBSERVED, ADDING INFORMATION TO AID IN THE IDENTIFICATION OF ELEMENTS. THE INSTRUMENT IN MAN PORTABLE AND COULD BE USED FOR SUBSURFACE ANALYSIS IN HOLES LARGER THAN 7 CM IN DIAMETER. THE MEASUREMENTS SHOULD BE CONTINUED AND EXPANDED ON THE ROVER. EARLY EXPLORATION.

4 0 13 07 76

NEUTRON ACTIVATION EXPERIMENT

THIS EXPERIMENT IS USED TO DETERMINE THE CHEMICAL COMPOSITION OF LUNAR SURFACE MATERIAL. INSTRUMENTATION INCLUDES A NEUTRON SOURCE AND A SCINTILLATOR WITH PULSE HEIGHT ANALYZED OUTPUT. THE SAMPLE IS IRRADIATED WITH NEUTRONS AND THE ACTIVATION GAMMA RAY SPECTRA RECORDED. NEUTRONS ARE GENERATED BY BOMBARDING TRITIUM ATOMS WITH DEUTERONS ACCELERATED ELECTROSTATICALLY TO 80 KEV. 14 KEV NEUTRONS ARE PRODUCED IN THIS REACTION. THE SCINTILLATOR IS A THALLIUM ACTIVATED SODIUM IODIDE CRYSTAL VIEWED BY A PHOTOMULTIPLIER TUBE - THE OUTPUT PULSES OF THE PHOTOMULTIPLIER WHOSE AMPLITUDES ARE RELATED TO THE ENERGIES OF INDIVIDUAL GAMMA RAYS INCIDENT ON THE CRYSTAL, ARE AMPLIFIED AND SORTED ACCORDING TO AMPLITUDE BY A 100 CHANNEL PULSE - HEIGHT ANALYZER, INTERROGATION OF THE 100 CHANNEL MEMORY UNIT THEN REPRODUCES THE ENERGY SPECTRUM OF GAMMA RAYS INCIDENT ON THE CRYSTAL DURING THE COUNT TIME. THESE SPECTRA, IN PARTICULAR THE PEAKS REPRESENTING SPECIFIC GAMMA RAY ENERGIES, ARE THEN COMPARED WITH THOSE OF KNOWN SAMPLES IRRADIATION TIME MAY BE AS MUCH AS 200 MINUTES WITH A NEUTRON FLUX OF 10 E + 07 PER SECOND. WITH THE SOURCE OPERATED IN A PULSED MODE OF 5 MICROSEC MICROSECOND PULSE DURATION AND A REPETITION RATE OF 1000 TIMES PER SECOND, INELASTIC SCATTERINGS DURING THE PULSE, AND NEUTRON CAPTURE GAMMA RAYS BETWEEN PULSES, CAN BE OBSERVED, ADDING INFORMATION TO AID IN THE IDENTIFICATION OF ELEMENTS. THE INSTRUMENT IS PART OF THE RADIOACTIVITY PROBE ON THE ROVER.

EXPERIMENT NUMBER

EXPERIMENT DESCRIPTION

A G S I E
R B P N X
E J E V P
A T C S T

GEOPHYSICS

4 1 C1 C2 05

SEISMIC PROFILING-DEEP REFLECTION

THIS EXPERIMENT IS DESIGNED TO LOCATE DEEP STRATIGRAPHIC HORIZONS AND TO DETERMINE ELASTIC CONSTANTS FOR THE INTERIOR OF THE MOON. AN ARRAY OF 12 GEOPHONES SEPARATED ABOUT 100 FT SHOULD BE USED WITH LARGE EXPLOSIVE CHARGES DETONATED IN BOREHOLES SEVERAL FEET DEEP. THESE HOLES SHOULD BE AVAILABLE FROM THE SUBSURFACE PROBE BOREHOLES DURING THE EXPLORATION PHASE WHEN A ROVER TYPE VEHICLE IS USED. SEISMIC VELOCITIES UP TO 25,000 FT/SEC CAN BE EXPECTED. DEEP REFLECTION EXPERIMENTS WILL CONTINUE THROUGHOUT THE LATER PHASES OF THE LUNAR EXPLORATION PROGRAM. RECORDING TIMES OF APPROXIMATELY 60 SECONDS WILL BE REQUIRED. THESE EXPERIMENTS SHOULD BE RUN IN CONJUNCTION WITH THE DEEP REFRACTION PROFILING EXPERIMENTS (41010206) WITH THE SAME SOURCE USED FOR BOTH EXPERIMENTS. EQUIPMENT OPERATING TIMES AND DATA ARE BASED ON 1 SHOT.

REAL TIME DATA TRANSMISSION SHOULD BE CONSIDERED FOR THE EXPERIMENT.

4 1 01 C2 06

SEISMIC PROFILING, DEEP REFRACTION

THE PURPOSE OF THIS EXPERIMENT IS TO DETERMINE THE EXISTENCE OF MAJOR SUBSURFACE BOUNDARIES AND CHECK FOR ISOSTATIC CONDITIONS IN THE LUNAR CRUST. SEVERAL LARGE EXPLOSIVE CHARGES WILL BE DETONATED SUBSURFACE AT DISTANCES UP TO 100 KILOMETERS FROM THE ESS SITE USING THE ESS SEISMOMETERS AS SENSORS. DUE TO THE SEPARATION OF SOURCE AND DETECTOR, REAL TIME DATA IS REQUIRED TO OBTAIN TRAVEL TIME. THE EXACT LOCATION OF THE SOURCE MUST BE RECORDED. RECORDING TIMES OF UP TO 3 MINUTES WILL BE REQUIRED TO OBTAIN SURFACE WAVE DATA. DEEP REFRACTION EXPERIMENTATION WILL CONTINUE DURING LATER PHASES OF EXPLORATION AND SHOULD BE RUN IN CONJUNCTION WITH EXPERIMENT 41010225 USING THE SAME SOURCE FOR EXPERIMENTS. MANPOWER IS NOT REQUIRED SINCE THE ESS INSTRUMENTATION WILL BE AUTOMATICALLY AND REMOTELY CONTROLLED. THE SHOT INPLACEMENT MANHOURS ARE INCLUDED IN EXPERIMENT 41010225.

4 1 C2 C2 07

SEISMIC RECORDING, PASSIVE - INITIAL LANDING

THIS EXPERIMENT WILL PROVIDE INFORMATION ON THE FOLLOWING, 1) LUNAR SEISMIC ACTIVITY, 2) LUNAR SUBSURFACE BOUNDARIES AND STRUCTURE, 3) LARGE METEORITE IMPACTS, 4) FREE OSCILLATIONS OF THE MOON. THE INSTRUMENTATION RECOMMENDED IS THE LAMONT SEISMOMETER, A COMBINATION VERTICAL SHORT PERIOD SEISMOMETER AND 3 COMPONENT LONG PERIOD SEISMOMETER. THE SHORT PERIOD INSTRUMENT WILL PROVIDE HIGH FREQUENCY, HIGH SENSATIVITY DATA TO SUPPLEMENT THE LONG PERIOD DATA. THE SEISMOMETER WILL BE EMPLACED BY THE ASTRONAUT AT THE ALSEP AND WILL OPERATE CONTINUOUSLY FOR AN EXTENDED PERIOD OF TIME AFTER HIS DEPARTURE. TOTAL DATA EQUIPMENT OPERATING HOURS BASED ON 24 HOUR DAY.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA GBJT SPEC INVS EXPT	GEOPHYSICS
4 1 02 C2 08	SEISMIC RECORDING, PASSIVE - EARLY EXPLORATION THIS EXPERIMENT IS DESIGNED TO PROVIDE INFORMATION AS TO THE EXTENT OF SEISMIC ACTIVITY ON THE MOON, DETERMINE MAJOR SUBSURFACE BOUNDARIES AND STRUCTURES, MEASURE LARGE METEORITE IMPACTS, MEASURE FREE OSCILLATION OF THE MOON, EPICENTER LOCATION AND SEISMIC PHASE VELOCITY. THE RECOMMENDED INSTRUMENTATION IS THE LAMONT SEISMOMETER WHICH IS A COMBINATION VERTICAL COMPONENT SHORT PERIOD SEISMOMETER AND THREE COMPONENT LONG PERIOD SEISMOMETER AND THE RANGER SEISMOMETER AT 3 SATELLITE STATIONS. THE INSTRUMENTATION WILL BE DEPLOYED BY THE ASTRONAUT AND WILL BE OPERATED CONTINUOUSLY DURING THE ESS PHASE. PREPARATION OF THE LUNAR SURFACE TO PROVIDE GOOD COUPLING MUST BE PERFORMED. THE SHORT PERIOD INSTRUMENT WILL PROVIDE HIGH FREQUENCY, HIGH SENSITIVITY DATA TO SUPPLEMENT THE LONG PERIOD DATA. BOTH FREQUENCY AND AMPLITUDE DATA WILL BE OBTAINED.
4 1 02 C2 11	SEISMIC RECORDING, LARGE ARRAY THIS EXPERIMENT IS AN EXTENSION OF EARLIER ESS SEISMIC EXPERIMENTS AND IS ESSENTIAL TO GIVE AN OVERALL PROFILE OF LUNAR SEISMICITY AND INTERNAL STRUCTURE. IT REQUIRES THE OPERATION OF SEVERAL ESS TYPE INSTRUMENTS CONCURRENTLY TO MEASURE SEISMIC WAVES FROM A SOURCE AT WIDELY SEPARATED STATIONS. AN ESS SEISMOMETER (LAMONT) WILL BE LOCATED AT EACH RECORDING SITE. REAL TIME RECORDING AND PRECISE LOCATION OF SITES MUST BE KNOWN TO CORRELATE DATA FROM THE DIFFERENT STATIONS. EQUIPMENT PARAMETERS, DATA RATES, TIMES, ETC. ARE GIVEN FOR AN INDIVIDUAL STATION FOR 24 HOURS. AT LEAST 4 STATIONS SHOULD BE OPERATING IN THE NETWORK CONCURRENTLY FOR AN EXTENDED TIME PERIOD. AMPLITUDE AND FREQUENCY PARAMETERS WILL BE OBTAINED FROM THE DATA. IN CONJUNCTION WITH THE SEISMIC MEASUREMENT SHOULD BE MADE AT ALL STATIONS SINCE THEY WILL HAVE BEEN LOCATED IN REGIONS EVIDENCING TECTONIC PROCESSES. THESE MEASUREMENTS WILL NOT BE MADE WITH CONVENTIONAL QUARTZ STRAIN METERS DUE TO PROHIBITIVE ENVIRONMENTAL AND INSTALLATION FACTORS. A PORTABLE OPTICAL DISTANCE MEASURING DEVICE WILL BE EMPLOYED TO MAKE PERIODIC MEASUREMENTS ACROSS KNOWN FAULTS AND THUS ESTABLISH A NETWORK OF STRAIN MEASUREMENTS TO A FEW CENTIMETER ACCURACY. A SERIES OF BENCH MARKS WILL BE ESTABLISHED TO PERMIT REOCCUPYING MEASUREMENT SITES. AFTER MAJOR SEISMIC EVENTS CONTINUOUS MEASUREMENTS WILL BE MADE IN THE EPICENTRAL REGION TO RELATE SESMIC INTENSITY TO CRUSTAL EFFECTS. THIS EXPERIMENT WILL HAVE CONSIDERABLE APPLICATION TO DEFINITION OF STRUCTRAL CONSTRAINTS IN THESE AREAS.
4 1 04 06 81	ELECTRICAL SURVEYING, EARTH CURRENT THE EXPERIMENT WILL RECORD ELF VARIATIONS OF THE ELECTRIC FIELD IN THE LUNAR CRUST. TWO ORTHOGONAL COMPONENTS OF THE FIELD WILL BE MEASURED. DATA FROM THE EXPERIMENT WILL PROVIDE INFORMATION AS TO THE DEPTH TO MAJOR STRUCTURAL BOUNDARIES IN THE MOON WHEN ANALYZED WITH THE ORTHOGONAL COMPONENTS OF THE MAGNETIC FIELD. THIS REQUIRES THAT THE THREE COMPONENT MANGETIC FIELD RECORDER ALSO BE IN OPERATION AT THE ESS SITE WHERE THE EARTH CURRENT RECORDING IS EMPLACED. DATA WILL BE REAL TIME. DATA WILL BE REAL TIME.

EXPERIMENT NUMBER

AREA	GRAB	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 1 C5 C5 41

ELECTRICAL-ELECTROMAGNETIC PULSE

THIS EXPERIMENT WILL MEASURE THE ELECTRICAL PROPERTIES OF THE DEEPER LUNAR MATERIALS AND ALLOW SUBSURFACE STRUCTURE TO BE CALCULATED. THE SYSTEM WILL USE A TRANSMITTING COIL AND A RECEIVING COIL TO PROBE DEEP INTO THE LUNAR SURFACE BY TRANSMITTING A VLF PULSE AND RECORDING THE REFLECTED EM WAVE. THE SHAPE OF THE REFLECTED WAVE WILL ALLOW SUBSURFACE STRUCTURE TO BE DETERMINED. THIS EXPERIMENT WILL BE CARRIED OUT ON A NUMBER OF EARLY MISSIONS. LOCATION OF THE MEASUREMENT MUST BE RECORDED. DATA RATES FOR THE EXPERIMENT WILL BE HIGH SINCE IN SOME CASES A 10 MEGAHZ PULSE MAY BE USED. THE SYSTEM WILL BE MOUNTED ON A SMALL ROVING VEHICLE AND MEASUREMENTS TAKEN AT DISCRETE POINTS ALONG THE TRAVERSE. WHEN USED IN A HIGH FREQUENCY MODE THE SYSTEM IS ESSENTIALLY A CHIRPING RADAR. STORAGE MAY BE REQUIRED FOR THE EXPERIMENT SINCE DATA RATES MAY EXCEED TRANSMITTING CAPABILITIES.

4 1 C5 C6 22

MAGNETISM-REMNANT

THIS EXPERIMENT IS A SAMPLING EXPERIMENT DURING THE EARLY PHASE OF LUNAR EXPLORATION. IT IS DESIGNED TO YIELD INFORMATION REGARDING THE PAST HISTORY OF THE LUNAR MAGNETIC FIELD. ORIENTED SAMPLES FROM A PRIMORDIAL SURFACE WILL BE COLLECTED IF POSSIBLE AND RETURNED TO EARTH IN MAGNETICALLY SHIELDED CONTAINERS FOR ANALYSIS IN A MAGNETICALLY SHIELDED EARTH LAB. GREAT CARE MUST BE EXERCISED TO PROTECT THE SAMPLES FROM EXTREME ACCELERATIONS, HIGH TEMPERATURE AND STRAY MAGNETIC FIELDS. THE AREA FROM WHICH THE SAMPLES ORIGINATED MUST BE RECORDED. RADIOACTIVE AGE DATING OF THESE SAMPLES MUST BE PERFORMED WHEN POSSIBLE. THE MAGNITUDE, DIRECTION AND AGE OF DECOMPOSITION OF THE SAMPLE SHOULD BE MEASURED.
LUNAR MATERIALS ALLOW COMPARISON WITH PROPERTIES OF EARTH MATERIALS AND PROVIDE DATA WHICH INTERACTS WITH ALL GEOPHYSICAL EXPERIMENTS.

4 1 05 C6 23

MAGNETISM-REMNANT, LATE EXPLORATION PHASE

THIS EXPERIMENT IS DESIGNED TO GIVE INFORMATION REGARDING THE PAST MAGNETIC HISTORY OF THE MOON. ORIENTED SAMPLES WILL BE MEASURED AND ANALYZED IN THE ROVER OR IN A LUNAR GEOLOGIC LAB. IT IS DESIRABLE THAT SOME SAMPLES BE OBTAINED FROM DEEP BOREHOLES. ADDITIONAL SAMPLES WILL BE RETURNED TO EARTH IN MAGNETICALLY SHIELDED CONTAINERS FOR ANALYSIS. CARE MUST BE TAKEN NOT TO EXPOSE THE SAMPLES TO EXTREME HEAT, EXTREME ACCELERATIONS OR STRAY MAGNETIC FIELDS BEFORE ANALYSIS. THE AREA FROM WHICH THE SAMPLES ORIGINATED MUST BE RECORDED. THE MAGNETUDE, DIRECTION AND AGE OF THE SAMPLE MUST BE DETERMINED.
LUNAR MATERIALS ALLOW COMPARISON WITH PROPERTIES OF EARTH MATERIALS AND PROVIDE DATA WHICH INTERACTS WITH ALL GEOPHYSICAL EXPERIMENTS.

4 1 C6 C5 40

ELECTRICAL-ELECTROMAGNETIC PULSE

ELECTRICAL SURVEYING, E-M PULSE - THIS EXPERIMENT IS USED TO DETERMINE THE ELECTRICAL PROPERTIES OF THE DEEP LUNAR FORMATION. THE DEVICE USES TRANSMITTING AND RECEIVING COILS TO PROBE DEEP UNDER THE SURFACE. A VLF PULSE IS TRANSMITTED AND THE REFLECTED EM WAVES RECORDED. THE CHARACTER OF THE REFLECTED WAVE IS INDICATIVE OF THE SUBSURFACE ELECTRICAL PROPERTIES AND THEREFORE OF THE STRUCTURE. THIS EXPERIMENT CAN BE MOUNTED ON THE ROVER AND OPERATED CONTINUOUSLY TO OBTAIN A PROFILE. THE LOCATION OF THE ROVER MUST BE CORRELATED WITH THE DATA.
DATA RATES WILL BE HIGH FOR THIS EXPERIMENT AND AUTOMATIC ANALYSIS ON BOARD THE ROVER SHOULD BE CONSIDERED. WHEN USED IN A HF, SHORT PULSE LENGTH MODE THE SYSTEM IS ESSENTIALLY A CHIRPING RADAR.

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 1 09 04 87 **SUBSURFACE HARDNESS**

THIS EXPERIMENT WILL MEASURE THE HARDNESS OF THE LUNAR SURFACE AND NEAR SURFACE BY MEASURING THE RATE OF PENETRATION AND FORCE NECESSARY TO PUSH A PENETROMETER INTO THE LUNAR SURFACE. THE MEASUREMENT WILL ALSO GIVE INFORMATION ABOUT SHEARING STRENGTH AND COMPACTABILITY OF THE MATERIAL. THIS INFORMATION IS NEEDED FOR THE DESIGN OF LUNAR STRUCTURES AND HEAVY VEHICLES. THE INSTRUMENT WILL CONSIST OF A TUBE WITH A CONICAL PENETROMETER MOUNTED ON THE LOWER END CONTAINING A LOAD CELL. THE PROBE IS DRIVEN BY A SMALL MOTOR AND ITS POSITION AND DRIVING FORCE MONITORED. THE EXPERIMENT PACKAGE WILL BE MOUNTED ON THE LUNAR ROVING VEHICLE. THE EXPERIMENT WILL BE PERFORMED WHENEVER THE VEHICLE STOPS TO PERFORM OTHER MEASUREMENTS. DATA RATES ARE LOW. DATA MAY BE TAKEN CONTINUEOUSLY OR AT INTERVALS OF APPROXIMATELY 0.5 INCHES. PROTOTYPE INSTRUMENTS HAVE BEEN CONSTRUCTED THAT HAVE A CAPABILITY OF MEASURING TWO TO THREE FEET AND CAN BE MODIFIED TO REACH TO DEPTHS OF TEN OR MORE FEET IN LOOSE MATERIAL. TIMES AND DATA RATES ARE BASED ON A ONE SPOT MEASUREMENT. IT MAY BE FEASIBLE TO BUILD A GAMMA-GAMMA DENSITY PROBE INTO THE SYSTEM. DATA IS BASED ON A 1M PENETRATION WITH 14 BITS OF DATA EVERY CM.

4 2 02 02 84 **REMOTE SEISMIC STATION**

REMOTE SEISMIC STATIONS WILL BE EMPLACED FROM A LUNAR ORBITING SATELLITE AT REMOTE STATIONS TO DETECT SEISMIC ACTIVITY AND LOCATE SEISMIC SOURCES DUE TO INTERNAL LUNAR SEISMIC DISTURBANCES. RANGER TYPE SEISMOMITERS WILL BE DEPLOYED FROM LUNAR ORBITING SATELLITES IN AREAS OF INTEREST WHERE LANDINGS ARE NOT ANTICIPATED. THESE STATIONS WILL OPERATE IN CONJUNCTION WITH THE ESS STATIONS. DATA WILL BE TRANSMITTED TO AN ESS SITE, TO AN ORBITING VEHICLE, OR DIRECTLY TO EARTH. DATA IS BASED ON A 24 HOUR PERIOD, ALTHOUGH THE EXPERIMENT DURATION WILL DEPEND ON TOTAL MISSION TIME. IT MAY BE FEASIBLE TO TRANSMIT DATA ONLY WHEN AN EVENT OCCURS BY USING A TRIGGERING CIRCUIT.

4 4 07 08 42 **TEMPERATURE-SHALLOW PROBE**

- THIS EXPERIMENT WILL MEASURE THE TEMPERATURE OF THE MOON JUST BENEATH THE SURFACE. A CONTACT TEMPERATURE PROBE WILL BE EMPLACED BY THE ASTRONAUT IN A VERY SHALLOW BOREHOLE OR, IF A DRILL IS NOT AVAILABLE, INTO THE SURFACE AS FAR AS POSSIBLE IN A SHALLOW HOLE. THE TEMPERATURE MAY BE READ BY THE ASTRONAUT AFTER THERMAL EQUILIBRIUM IS REACHED ON THE FIRST APOLLO MISSION AND LATER TRANSMITTED BY RADIO TO EARTH BY THE LSEP RADIO LINK. THE PROBE SHOULD BE SHADED FROM THE DIRECT SUNLIGHT IF A BOREHOLE IS NOT AVAILABLE. INITIAL ESTIMATES OF THERMAL CONDUCTIVITY AND DIFFUSIVITY MAY BE OBTAINED FROM THE RECOVERED DATA. DEVELOPMENT WORK IS REQUIRED IN THE DEVELOPMENT OF PROBES THAT CAN BE EASILY EMPLACED WITH GOOD THERMAL CONTACT WITH THE LUNAR SURFACE MATERIAL. DATA RATES ARE EXTREMELY LOW FOR THE TEMPERATURE MEASUREMENTS. TEMPERATURE RANGES ARE FROM 120 TO 400 DEGREES K. ABOUT 10 BINARY BITS ARE REQUIRED PER PROBE PER MEASUREMENT WITH READINGS TAKEN ON EARTH COMMAND. SEVERAL PROBES WILL BE EMPLACED AND READ BY A COMMON AMPLIFIER. THIS EXPERIMENT WILL NOT DETERMINE THE LANDING SITE OF THE LEM BUT WILL BE PERFORMED AT WHATEVER SITE IS CHOSEN. THIS EARLY TEMPERATURE SURVEY WILL ALSO PROVIDE INFORMATION NECESSARY FOR PRELIMINARY ENGINEERING DESIGN OF LUNAR STRUCTURE.

EXPERIMENT NUMBER

A B S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 4 07 08 43 **TEMPERATURE-BOREHOLE LOGGING**

THIS EXPERIMENT IS DESIGNED TO MEASURE THE TEMPERATURE PROFILE OF BOREHOLES DRILLED IN THE LUNAR CRUST DURING EARLY MISSIONS. TWO TYPES OF SENSORS MAY BE USED. A CONTACT TYPE SENSOR WHICH SUFFERS FROM THE TIME REQUIRED TO REACH THERMAL EQUILIBRIUM IN THE BOREHOLE AND A REMOTE TYPE SENSOR WHICH SUFFERS FROM THE FACT THAT ONLY THE APPARENT TEMPERATURE OF THE SURFACE IS RECORDED. FOR THE REMOTE SENSORS AN ADDITIONAL PIECE INFORMATION MUST BE KNOWN, AND THAT IS THE EMISSIVITY OF THE SURFACE WHOSE TEMPERATURE IS BEING MEASURED, FOR THE ABSOLUTE TEMPERATURE OF THE SURFACE TO BE DETERMINED. BOTH METHODS WILL REQUIRE IMPROVEMENT BEFORE THEY CAN BE USED EASILY TO MEASURE TEMPERATURES ON THE MOON. TEMPERATURE MEASUREMENTS ARE IMPORTANT AND ALL HOLES DRILLED IN THE SURFACE SHOULD BE LOGGED. A REMOTE SENSOR WILL BE USED IN THE LOGGING TOOL. CONTACT SENSORS WILL BE LEFT IN ALL HOLES DRILLED ON THE LUNAR SURFACE FOR LATER MEASUREMENTS TRIGGERED IN A REMOTE FASHION.
TEMPERATURE MEASUREMENTS WILL NOT GENERALLY DETERMINE THE AREA WHERE THE BOREHOLE WILL BE DRILLED.

4 4 07 08 44 **TEMPERATURE-BOREHOLE LOGGING**

THIS EXPERIMENT WILL MEASURE THE TEMPERATURE PROFILE IN THE BOREHOLES DRILLED BY THE ROVER DRILL BY USING A CONTACT OR REMOTE SENSOR. A REMOTE SENSOR IS PREFERABLE BECAUSE OF THE LONG TIME REQUIRED TO REACH THERMAL EQUILIBRIUM WITH A CONTACT SENSOR. AN IMPROVED METHOD WILL HAVE TO BE DEVELOPED FOR THIS MEASUREMENT INCLUDING A SCHEME TO DETERMINE THE EMMISSIVITY OF THE BOREHOLE WALLS. SINCE TEMPERATURE MEASUREMENTS ARE OF UTMOST IMPORTANCE IT IS NECESSARY TO OBTAIN A TEMPERATURE LOG OF ALL HOLES DRILLED. THE TEMPERATURE SENSING DEVICE WILL BE PART OF GEOPHSYICAL BOREHOLE LOGGING TOOL. PERMANENT CONTACT TEMPERATURE PROBES WILL BE LEFT IN ALL HOLES LOGGED FOR LATER TEMPERATURE MEASUREMENTS IN A REMOTE FASHION. THIS EXPERIMENT WILL NOT, IN GENERAL, DETERMINE THE LOCATION OF THE BOREHOLE.

4 4 07 08 45 **HEAT FLOW**

THIS EXPERIMENT WILL MEASURE THE TEMPERATURE PROFILE IN A BOREHOLE AT THE ESS SITE. SEVERAL CONTACT SENSORS WILL BE EMPLACED IN THE HOLE AND THE TEMPERATURE READ PERIODICALLY. NEAR THE SURFACE THE SENSORS WILL BE SPACED CLOSE TOGETHER WHILE IN THE DEEPER PORTION OF THE HOLE THE SPACING WILL BE INCREASED. IT MAY BE MOST FEASIBLE TO READ THE TEMPERATURE ON COMMAND FROM EARTH SINCE READING WILL NOT BE TAKEN OFTEN. DATA FROM THIS EXPERIMENT MAY BE USED TO DETERMINE THE NET RATE OF HEAT FLOW THROUGH THE LUNAR CRUST IF THE THERMAL CONDUCTIVITY OF THE LUNAR SURFACE MATERIAL IS KNOWN. INCOMING SOLAR RADIATION SHOULD BE RECORDED WHILE THIS EXPERIMENT IS IN PROGRESS.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
A G S I E R B P N X E J E V P A T C S T	GEOPHYSICS

4 4 07 C8 46

HEAT FLOW -THERMAL BLANKET

THIS EXPERIMENT IS DESIGNED TO MEASURE THE TEMPERATURE GRADIENT ACROSS A THERMAL BLANKET EMPLACED ON THE LUNAR SURFACE AT THE LSEP BY THE ASTRONAUT. THE TEMPERATURE GRADIENT ACROSS THE BLANKET WILL BE INDICATIVE OF THE AMOUNT OF HEAT FLOWING FROM THE LUNAR SURFACE THROUGH THE BLANKET AND SERVE TO DETERMINE THE NET LUNAR HEAT BALANCE. THE THERMAL PROPERTIES OF THE BLANKET CAN BE DETERMINED ON EARTH BEFORE TRANSPORTATION TO THE MOON SO THAT THE CONTROL FACTOR IN THE EXPERIMENT IS HIGH COMPARED TO OTHER HEAT FLOW EXPERIMENTS. THE MAGNITUDE OF THE TEMPERATURE GRADIENT ACROSS SUCH A BLANKET WILL BE SUCH THAT VERY PRECISE TEMPERATURE SENSORS WILL BE NEEDED. THE AMOUNT OF INCOMING SOLAR RADIATION DURING THE EXPERIMENT SHOULD BE RECORDED DURING THE EXPERIMENT.

4 4 C7 C8 47

THERMAL DIFFUSIVITY-SURFACE

THE EXPERIMENT IS DESIGNED TO MEASURE THE THERMAL DIFFUSIVITY OF THE LUNAR SURFACE AT ONE POINT. THE INSTRUMENT WILL OPERATE IN A NON-CONTACT FASHION USING A REMOTE SENSOR SUCH AS A TOTAL RADIATION PRYROMETER. THE SURFACE THERMAL DIFFUSIVITY IS TO BE DEDUCED FROM THE CHANGE IN TEMPERATURE EXPERIENCED WITHIN A REGION OF KNOWN GEOMETRY WHEN THE QUANITY OF HEAT ENTERING THE AREA IS ABRUPTLY CHANGED. THE CHANGE IN HEAT ENTERING THE AREA WILL BE PROVIDED BY HEATING THE SURFACE WITH AN INFRARED SOURCE AT NIGHT OR BY SHIELDING THE AREA FROM THE SUN DURING THE DAY WITH A PLATE OF KNOWN EMMISSIVITY. THE TEMPERATURE OF THE AREA SO ALTERED WILL BE RECORDED FOR ABOUT AN HOUR. AN ESTIMATE CAN THEN BE MADE OF THE THERMAL DIFFUSIVITY OF THE LUNAR SURFACE AT THAT POINT. THIS DATA IS VERY IMPORTANT TO THE INTERPRETATION OF DATA FROM ALL REMOTE HEAT SENSORS. THE TEMPERATURE OF THE SHIELD OR HEATER MUST ALSO BE RECORDED. IF POSSIBLE A SAMPLE OF MATERIAL SEEN BY THE SENSOR SHOULD BE RETURNED TO EARTH AND ITS THERMAL PROPERTIES MEASURED. THERMAL DIFFUSIVITY AND EMISSIVITY ARE CALCULATED FROM TEMPERATURE VS TIME CURVES.

4 4 C7 C8 48

THERMAL DIFFUSIVITY-BOREHOLE

THIS EXPERIMENT IS DESIGNED TO MEASURE THE THERMAL DIFFUSIVITY OF THE LUNAR MATERIALS IN A BOREHOLE. TWO TECHNIQUES ARE APPLICABLE HERE WITH THE FIRST BEING MORE PROBABLE IN THE LSEP EXPLORATION PHASE. USING THIS TECHNIQUE A BLACK BODY IS THERMALLY ISOLATED IN THE BOREHOLE AND THE POWER REQUIRED TO MAINTAIN THE BODY AT SOME TEMPERATURE HIGHER THAN THE SURROUNDING ROCK RECORDED. THIS INFORMATION CAN THEN BE USED TO INFER THE THERMAL DIFFUSIVITY OF THE SURROUNDING MATERIAL. THE SECOND SCHEME IS TO FOCUS A SMALL HEAT SOURCE ON THE BOREHOLE WALL AND MEASURE THE TEMPERATURE RISE WITH A REMOTE SENSOR. THIS TECHNIQUE IS MUCH FASTER BUT IT IS DOUBTFUL IF THE STATE OF THE ART WILL ENABLE THE MEASUREMENT TO BE PERFORMED IN THIS MANNER DURING EARLY LUNAR MISSIONS. DATA WILL BE TAKEN FOR ABOUT 10 DAYS. DIFFERENT HOLE MUST BE USED FOR THIS EXPERIMENT THAN FOR THE PERMANENT TEMPERATURE PROBES. DIFFUSIVITY AND EMISSIVITY ARE CALCULATED FROM TEMPERATURE VS TIME CURVES.

EXPERIMENT NUMBER

ABRE JAT CBSP ECIN EVSX PT

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 4 C7 C8 49 **THERMAL DIFFUSIVITY-BOREHOLE**

THIS EXPERIMENT IS DESIGNED TO MEASURE THE THERMAL DIFFUSIVITY OF LUNAR MATERIALS IN BOREHOLES DRILLED BY THE ROVER EXPLORATION PROGRAM. THE MOST PROMISING TECHNIQUE FOR THIS MEASUREMENT IS USING A SMALL FOCUSED INFRARED SOURCE TO HEAT A PORTION OF THE BOREHOLE WALL AND RECORD THE RATE OF TEMPERATURE CHANGE WITH A REMOTE SENSOR. A GREAT DEAL OF DEVELOPMENT IS NECESSARY TO PROVIDE THIS EXPERIMENT BUT IS NECESSARY SINCE OTHER TYPES OF DIFFUSIVITY MEASUREMENTS ARE TOO TIME CONSUMING AND SUCH MEASUREMENTS ARE OF EXTREME IMPORTANCE AND SHOULD BE MADE IN EACH BOREHOLE. THE DIFFUSIVITY PROBE WILL BE CONTAINED IN THE SUBSURFACE LOGGING TOOL. DATA RATES FOR THIS EXPERIMENT ARE SMALL. THE SURFACE REFLECTANCE MAY ALSO BE DETERMINED WHILE THE HEAT SOURCE IS ON. DATA RATES ARE FOR EACH MEASUREMENT. THE THERMAL EMISSIVITY AND DIFFUSIVITY IS CALCULATED FROM TEMPERATURE VS TIME CURVES.

4 4 C7 C8 50 **THERMAL EMISSIVITY-SURFACE**

THE EXPERIMENT WILL MEASURE THE EMISSIVITY OF THE LUNAR SURFACE AT A POINT. THE MEASUREMENT IS MADE BY MEASURING THE TEMPERATURE OF THE LUNAR SURFACE WITH A CONTACT TYPE SENSOR AND COMPANYING THIS TEMPERATURE WITH THE APPARENT BLACK BODY TEMPERATURE OF THE SAME SPOT MEASURED WITH A REMOTE SENSOR. THE RATIO OF THE APPARENT BLACK BODY TEMPERATURE TO THE ACTUAL TEMPERATURE IS THE EMISSIVITY. THIS EXPERIMENT IS CRITICAL AS REDUCTION OF REMOTE SENSOR DATA DEPENDS UPON KNOWING THE EMISSIVITY OF THE DIFFERENT SURFACES OBSERVED. THE EMISSIVITY MUST BE MEASURED MANY DIFFERENT ROCK TYPES AND FORMATIONS AND CONTINUE THROUGHOUT THE LUNAR EXPLORATION PROGRAM. THE SURFACE WILL BE SHIELDED FROM THE SUN DURING THE MEASUREMENT. THIS MEASUREMENT WILL ALSO BE MADE ON SAMPLES RETURNED TO EARTH.

4 4 C7 C8 51 **TEMPERATURE-SURFACE PROFILE**

THIS EXPERIMENT WILL MEASURE THE TEMPERATURE OF THE SURFACE ON THE ROVER TRAVERSES. A REMOTE TYPE SENSOR WILL BE USED TO OBTAIN A CONTINUOUS TEMPERATURE PROFILE OF THE SURFACE IN THE ROVER PATH. ESTIMATES OF SURFACE EMISSIVITY ARE REQUIRED FOR THE MATERIALS ALONG THE PATH. THESE ESTIMATES CAN BE OBTAINED FROM THE EMISSIVITY MEASUREMENTS AND ALSO BY MEASURING THE APPARENT TEMPERATURE IN TWO DIFFERENT SPECTRAL REGIONS AND COMPARING THE RESULTS WITH BLACK BODY RADIATION CURVES. THE RESULTS OF THESE MEASUREMENTS WILL ALSO BE USED ON INTERPRET THE PHOTOGRAPHIC DATA TAKEN ON THE ROVER TRAVERSE.

THIS EXPERIMENT MAY BE USEFUL AS A TERRAIN AVOIDANCE INSTRUMENT IN THE ROVER. AN ALARM COULD BE BUILT INTO THE SYSTEM TO WARN OF SUDDEN CHANGES IN THE TERRAIN AHEAD OF THE VEHICLE.

4 4 C7 C8 66 **PASSIVE MICROWAVE**

THIS EXPERIMENT WILL MEASURE THE PASSIVE RADIATION FROM THE MOON IN THE MICROWAVE REGION FROM AN ORBITAL PLATFORM. USEFUL INFORMATION AS TO THE TEMPERATURE DISTRIBUTION ON THE LUNAR SURFACE WILL BE OBTAINED. ALSO INFORMATION AS TO THE DIFFERENT SURFACE ROCK FORMATIONS WILL BE OBTAINED SINCE THE EMISSIONS DEPEND NOT ONLY ON THE TEMPERATURE OF THE LUNAR SURFACE BUT ALSO ON THE EMISSIVITY OF THE LUNAR SURFACE MATERIALS. THIS EXPERIMENT SHOULD BE CAPABLE OF LOCATING THERMAL REGIONS ON THE LUNAR SURFACE THAT WOULD BE LIKELY SPOTS FOR LATER MANNED SURFACE SURVEYS. DATA RATES FOR ORBITING RADIOMETERS WILL BE HIGH.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	GEOPHYSICS

4 4 C7 C8 82 HEAT FLOW, ALSEP

THIS EXPERIMENT WILL MEASURE THE TEMPERATURE GRADIENT IN A BOREHOLE AT THE ALSEP. SEVERAL CONTACT SENSORS WILL BE EMPLACED IN THE BOREHOLE AND THE TEMPERATURE VARIATIONS WITH TIME MEASURED. THE TEMPERATURE WILL BE RECORDED ONLY PERIODICALLY SINCE ANY VARIATIONS WILL BE EXTREMELY SLOW EXCEPT AT THE NEAR SURFACE. IT IS SUGGESTED THAT THE TEMPERATURE BE READ OUT ON COMMAND FROM EARTH. IF THE THERMAL CONDUCTIVITY OF THE MATERIALS NEAR THE BOREHOLE ARE KNOWN THIS EXPERIMENT WILL ALSO DETERMINE THE RATE OF HEAT FLOW AT ALSEP SITE. DATA RATES ARE ON A PER DAY BASIS BUT THE EXPERIMENT WILL BE CONTINUED AS LONG AS THE EQUIPMENT OPERATES. THE DEPTH OF THE SENSORS MUST BE RECORDED ALONG WITH THE TYPE ROCK IN WHICH THEY ARE PLACED. IF POSSIBLE, SENSORS WILL BE PLACED IN TWO 3-METER HOLES 30 FEET APART, A DISTANCE OF AT LEAST 40 FEET FROM THE RTG. EACH PROBE WILL CONTAIN TEMPERATURE GRADIENT MEASURING DEVICES, TWO CONDUCTIVITY HEATERS, TWO REMOTE CONDUCTIVITY TEMPERATURE SENSORS AND SENSOR THERMOCOUPLES. IF POSSIBLE, SENSORS WILL BE PLACED IN TWO 3-METER HOLES 30 FEET APART, A DISTANCE OF AT LEAST 40 FEET FROM THE RTG. EACH PROBE WILL CONTAIN TEMPERATURE GRADIENT MEASURING DEVICES, TWO CONDUCTIVITY HEATERS, TWO REMOTE CONDUCTIVITY TEMPERATURE SENSORS AND SENSOR THERMOCOUPLES.

4 4 C7 C8 86 TEMPERATURE PROBES EMPLACED FROM LUNAR ORBIT

CONTACT TYPE THERMAL PROBES WILL BE DEPLOYED FROM LUNAR SATELLITES FOR MEASURING SURFACE TEMPERATURE AT MANY REMOTE POINTS NOT VISITED BY SURFACE PARTIES. THESE MEASUREMENTS WILL PROVIDE DATA FOR CALIBRATION OF REMOTE SENSORS AND PROVIDE SURFACE TEMPERATURE DISTRIBUTION NEEDED FOR A MORE COMPLETE UNDERSTANDING OF THE THERMAL STATE OF THE MOON. AREAS THAT SHOW IR ANOMALIES FROM ORBITAL DATA WILL BE OF GREAT INTEREST FOR THIS EXPERIMENT. PROBES SHOULD BE DEVELOPED CONTAINING SEVERAL CONTACT TEMPERATURE DEVICES THAT CAN PENETRATE THE LUNAR SURFACE SO THAT TEMPERATURE GRADIENT INFORMATION CAN ALSO BE OBTAINED. THE PROBES WILL CONTAIN A TELEMETERING PACKAGE THAT CAN BE READ ON COMMAND.
TOTAL DATA AND OPERATING TIMES ARE BASED ON A 24 HOUR PERIOD.

4 5 03 C9 12 GRAVITY-ABSOLUTE (ALSEP)

THIS EXPERIMENT IS DESIGNED TO MEASURE THE ABSOLUTE MAGNITUDE OF THE LUNAR GRAVITATIONAL FIELD AND VARIATIONS IN THIS FIELD DUE TO TIDES, FREE OSCILLATIONS, LIBERATIONS AND SEISMIC ACTIVITY. THE INSTRUMENT WILL BE EMPLACED WITH THE ALSEP PACKAGE BY THE ASTRONAUT AND OPERATE FOR AN EXTENDED PERIOD AFTER HIS DEPARTURE. THE OUTPUT OF THE GRAVIMETER WILL BE SAMPLED APPROXIMATELY EVERY 15 SECONDS. THE INSTRUMENT WILL BE A MODIFIED LA COSTA ROMBERG TYPE DESIGNED TO OPERATE IN A LUNAR GRAVITY FIELD OF 162 MILLIGALS AND HAVE A RESOLUTION OF 0.1 MICROGALS. THE INSTRUMENT MUST BE SELF LEVELING TO WITHIN 6 SECONDS OF ARC AND MUST INCLUDE AN AUTOMATIC ZEROING ADJUSTMENT. INTERNAL TEMPERATURE OF THE GRAVIMETER MUST BE RECORDED. FOR COMPLETE DATA ANALYSIS GRAVITY MEASUREMENTS MUST BE CONTINUE THROUGHOUT THE LUNAR EXPLORATION PROGRAM.

ACCURATE DETERMINATIONS OF THE AMPLITUDES AND PHASES OF TIDAL TILTS, AND VARIATIONS IN GRAVITY CAN BE USED TO DETERMINE THE AVERAGE ELASTIC PROPERTIES OF THE MOON AND THE TIDAL DISSIPATION.

4 5 03 C9 13 GRAVITY-ABSOLUTE (ESS)

THIS EXPERIMENT IS DESIGNED TO MEASURE ABSOLUTE GRAVITY AND VARIATIONS IN GRAVITY DUE TO TIDES AND OTHER EFFECTS. THIS EXPERIMENT IS AN EXTENSION OF (45030912) BUT WITH IMPROVED LA COSTA ROMBERG TYPE INSTRUMENTATION. THE EXPERIMENT WILL GIVE INFORMATION AS TO INTERNAL LUNAR STRUCTURE AND ELASTIC PROPERTIES OF THE MOON. THE EXPERIMENT WILL BE EMPLACED AT THE ESS BY THE ASTRONAUTS AND LEFT TO RECORD FOR EXTENDED PERIODS WITH DATA READINGS TAKEN EVERY 10 SECONDS. AUTOMATIC ZEROING AND LEVELING MUST BE PROVIDED AS WELL AS TEMPERATURE CONTROL OF THE INSTRUMENT. EXACT LOCATIONS OF THE INSTRUMENTATION PACKAGE MUST BE KNOWN. DURING THE EXPERIMENT GRAVITY MEASUREMENTS MUST ALSO BE MADE ON EARTH.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

GEOPHYSICS

4 5 03 C9 14 **GRAVITY-SURVEY**

THIS EXPERIMENT IS DESIGNED TO PROVIDE FOR THE LOCATION OF LOCAL GRAVITY ANOMALIES DURING EARLY EXPLORATION PHASE. IT WILL PROVIDE INFORMATION AS TO GRAVITY ANOMALIES ACROSS SUCH FEATURES AS CRATERS, HILLS AND OTHER GEOLOGIC FEATURES OF INTEREST. THE INFORMATION IS USED IN CONSTRUCTING MODELS OF THE SHALLOW SUBSURFACE LUNAR STRUCTURE BENEATH SUCH FEATURES. THE INSTRUMENT COULD BE SIMILAR TO THE LA COSTA ROMBERG INSTRUMENT USED PRESENTLY FOR OCEANOGRAPHIC GRAVITY SURVEYS. THE TIME OF THE READING AND TEMPERATURE OF THE INSTRUMENT MUST BE RECORDED WHEN MEASUREMENTS ARE MADE AS WELL AS THE EXACT LOCATION INCLUDING ELEVATION OF THE STATION CONTINUOUS RECORDINGS MUST BE MADE AT A PERMANENT LOCATION ON THE LUNAR SURFACE DURING THE TRAVERSE TO CORRECT THE DATA FOR TIDAL VARIATIONS. THIS EXPERIMENT SHOULD BE PERFORMED OVER A NUMBER OF DIFFERENT GEOLOGIC STRUCTURES AND WILL BE A CONTINUING EFFORT DURING THE AES INVESTIGATIONS. GENERAL TOPOGRAPHIC MAPS OF THE SURVEYED AREA MUST BE AVAILABLE FOR TERRAIN CORRECTIONS DURING THE DATA ANALYSIS.

4 5 03 C9 15 **GRAVITY-SURVEY**

THIS EXPERIMENT IS A CONTINUATION OF THE SHORT TRAVERSES RUN DURING THE EARLY PROGRAM BUT WILL GIVE INFORMATION REGARDING REGIONAL GRAVITY ANOMALIES FOR DETERMINATION OF MAJOR LUNAR GEOLOGIC STRUCTURE AS WELL AS LOCAL ANOMALIES. THE INSTRUMENT USED WILL BE AN IMPROVED LA COSTA ROMBERG TYPE INSTRUMENT WHICH CAN BE MOUNTED ON THE ROVER AND LOWERED TO THE SURFACE WHEN THE ROVER STOPS WITH MINIMUM ASTRONAUT PARTICIPATION. GRAVITY READINGS SHOULD BE OBTAINED AT EVERY POINT WHERE THE ROVER STOPS. CONTINUOUS GRAVITY READINGS MUST BE RECORDED AT A PERMANENT STATION TO CORRECT FOR TIDAL EFFECTS. TIME AND INSTRUMENT TEMPERATURE READINGS MUST BE RECORDED WHEN THE INSTRUMENT IS READ AS WELL AS PRECISE STATION LOCATION INCLUDING ELEVATION. THESE EXPERIMENTS WILL CONTINUE THROUGHOUT THE MOLAB EXPLORATORY PHASE. GENERAL TOPOGRAPHIC MAPS MUST BE AVAILABLE FOR TERRAIN CORRECTION DURING THE DATA ANALYSIS.

4 5 03 C9 68 **GRAVITY GRADIENT**

THIS EXPERIMENT IS DESIGNED TO MEASURE AND MAP THE GRAVITATIONAL FIELD OF THE MOON FROM AN ORBITING SATELLITE. INFORMATION OBTAINED FROM THE EXPERIMENT WILL SERVE TO PROVIDE INFORMATION AS TO THE INTERNAL STRUCTURE OF THE MOON, THE ANGULAR MOMENTUM OF THE MOON AND GROSS SURFACE FEATURES ON THE MOON. DATA RATES WILL BE LOW FOR THE EXPERIMENT. DATA RATES ARE FOR ONE MEASUREMENT PER KM WHILE IN ORBIT. DEVELOPMENT STATUS DOES NOT PERMIT ESTIMATES OF VOLUME, MASS AND POWER.

4 3 03 C9 85 **ORBITAL GRAVITY GRADIENT**

THIS EXPERIMENT WILL USE THE GRAVITY FIELD DATA OBTAINED FROM LUNAR ORBIT TO CALCULATE THE OVERALL MOMENT OF INERTIA OF THE MOON. THE TERMS OF THE HARMONIC EXPANSIONS OF THE LUNAR GRAVITY FIELD AND TOPOGRAPHY WILL BE COMPARED TO YIELD INFORMATION ON THE NONSPHERICALLY SYMMETRICAL DENSITY VARIATION WITHIN THE MOON AND POSSIBLY ON THE NATURE AND DEGREE OF ISOSTATIC COMPENSATION OF TOPOGRAPHIC IRREGULARITIES. THE RESULTS OF THIS EXPERIMENT CAN HELP TO DECIDE IF THE MOON IS HOMOGENEOUS OR DIFFERENTIATED AND WILL BEAR ON THE QUESTIONS OF THE ORIGIN OF LUNAR SURFACE FEATURES AND THE ORIGIN OF THE EARTH-MOON SYSTEM. COMPUTER PROGRAMS FOR REDUCTION OF THE DATA PRESENTLY EXIST.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJT SPEC INVS EXPT	GEOPHYSICS
4 5 10 06 01	PLASMA POTENTIAL VARIATIONS VS. HEIGHT AND TIME. MEASURE ELECTROSTATIC POTENTIAL IN AND ABOVE LUNAR ATMOSPHERE WHICH IS CONSIDERED AS A PLASMA. SUGGESTED BY A. H. WEBER. SURFACE + ORBIT. DAWN, NOON, SUNSET, MIDNIGHT. DATA LINKS = ORBIT-EARTH, SURFACE-EARTH
4 6 04 06 16	MAGNETIC FIELD-TOTAL THIS EXPERIMENT IS DESIGNED TO DETERMINE THE EXISTENCE OF A PERMANENT LUNAR MAGNETIC FIELD AND THE MAGNITUDE OF THE FIELD IF IT EXISTS. IT IS KNOWN THAT THE MAXIMUM FIELD IS LESS THAN 30 GAMMAS. THE INSTRUMENTATION WILL BE A PROTON PRECESSION OR RUBIDIUM VAPOR TOTAL FIELD MAGNETOMETER. THIS EXPERIMENT IS CRITICAL AND MUST GO ABOARD ONE OF THE EARLY APOLLO FLIGHTS SINCE LATER MAGNETIC SURVEY EXPERIMENTS PLANNED WILL BE USELESS IF NO PERMANENT MAGNETIC FIELD EXISTS. IF THE MOON HAS NO MAGNETIC FIELDS, ONLY THE INTERPLANETARY FIELD CAN BE MEASURED ON THE LUNAR SURFACE.
4 6 04 06 17	MAGNETIC FIELD-TOTAL - ALSEP THIS EXPERIMENT IS DESIGNED TO MEASURE THE PERMANENT MAGNETIC FIELD OF THE MOON IF IT EXISTS. THE INSTRUMENTATION WILL CONSIST OF A THREE-COMPONENT FLUXGATE MAGNETOMETER TO BE EMPLACED BY THE ASTRONAUT WITH THE ALSEP TO RECORD ON A CONTINUAL BASIS AFTER THE ASTRONAUTS LEAVE. THE MAGNITUDE AND VARIATIONS IN THE IN THE MAGNETIC FIELD WILL PROVIDE INFORMATION AS TO THE STATE OF THE INTERNAL LUNAR MATERIAL AND WHEN USED IN CONJUNCTION WITH EARTH CURRENT INFORMATION WILL GIVE INFORMATION AS TO THE LUNAR SUBSURFACE STRUCTURE. THIS EXPERIMENT SHOULD BE PERFORMED ON TWO OR MORE ALSEP INVESTIGATIONS. SIMILAR MAGNETIC MEASUREMENTS MUST BE MADE ON EARTH AT THE SAME TIME FOR CORRELATION WITH THE LUNAR MEASUREMENTS. ABSOLUTE TIME MUST BE RECORDED. THE LUNAR MAGNETIC FIELD MAY BE RELATED TO AN ANCIENT REMNANT FIELD OF INTERACTION OF THE MOON AND SOLAR WIND. DATA ARE ON A PER-DAY BASIS
4 6 04 06 18	MAGNETIC FIELD-TOTAL THIS EXPERIMENT IS AN EXTENSION OF EARLIER TOTAL FIELD MAGNETIC MEASUREMENTS BUT EXTENTS TO A LARGER SPATIAL AREA AND RECORDS FOR LONGER TIME PERIODS. THE INSTRUMENTATION WILL WILL BE AN UPGRADED PROTON PRECESSION OR RUBIDIUM VAPOR MAGNETOMETER EMPLACED BY THE ASTRONAUTS AT THE ESS SITE AND LEFT TO RECORD FOR AN EXTENDED PERIOD OF TIME. ABSOLUTE TIME MUST BE RECORDED AS WELL AS THE ANALOG DATA. SIMILAR MEASUREMENTS MUST BE MADE ON EARTH AT THE SAME TIME FOR CORRELATION WITH LUNAR MAGNETIC FIELD VARIATIONS.
4 6 04 06 19	MAGNETIC FIELD-COMPONENT, ESS - THIS EXPERIMENT WILL MEASURE THE ORTHOGONAL COMPONENTS OF THE LUNAR MAGNETIC FIELD. THE INSTRUMENTATION WILL CONSIST OF A 3 COMPONENT FLUXGATE TO MEASURE THE TOTAL MAGNETITUDE OF THE FIELD OR WILL USE A 3 COMPONENT VARIOMETER SYSTEM IN CONJUNCTION WITH A TOTAL FIELD INSTRUMENT TO MEASURE ONLY CHANGES IN THE FIELD. THE RESULTS OF THIS EXPERIMENT WILL BE CORRELATED WITH THE EARTH CURRENT MEASUREMENT TO DETERMINE SUBSURFACE STRUCTURE. THE INSTRUMENTATION WILL BE EMPLACED AT THE ESS BY THE ASTRONAUT AND LEFT TO OPERATE FOR EXTENDED PERIODS AFTER HIS DEPARTURE. ABSOLUTE TIME MUST BE RECORDED AS WELL AS THE OUTPUT DATA OF THE SYSTEM. SIMILAR MAGNETIC MEASUREMENTS MUST BE MADE ON EARTH AT THE SAME TIME FOR CORRELATION WITH LUNAR MAGNETIC FIELD VARIATIONS. PERFORMED ON ESS.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
A O S I E R R P N X E J E V P A T C S T	GEOPHYSICS
4 6 04 06 20	MAGNETIC FIELD-TOTAL FIELD SURVEYING THIS EXPERIMENT IS DESIGNED TO OBTAIN MAGNETIC PROFILES ACROSS DESIGNATED GEOLOGIC ANOMALIES TO OBTAIN INFORMATION REGARDING SHALLOW LUNAR STRUCTURE DURING EARLY MISSIONS THE INSTRUMENT USED WILL BE A PROTON PRECESSION MAGNETOMETER SIMILAR TO THOSE PRESENTLY USED IN MAGNETIC EXPLORATION SURVEYS ON EARTH. IT WILL BE NECESSARY TO OPERATE THE TOTAL FIELD MAGNETOMETER AT THE ALSEP SITE WHILE MAGNETIC SURVEYS ARE BEING CONDUCTED. THE LOCATION, INCLUDING ELEVATION, AND TIME OF EACH READING MUST BE RECORDED FOR LATER DATA ANALYSIS.
4 6 04 06 21	MAGNETIC FIELD-SURVEY THIS EXPERIMENT IS DESIGNED TO LOCATE REGIONAL MAGNETIC ANOMALIES AND DETERMINE MODELS FOR DEEP LUNAR STRUCTURE AS WELL AS LOCAL MAGNETIC ANOMALIES. THE INSTRUMENT WILL BE A PROTON PRECESSION MAGNETOMETER AND MAY BE BOOM MOUNTED ON THE ROVER TO ELIMINATE ASTRONAUT PARTICIPATION IN THE EXPERIMENT AS MUCH AS POSSIBLE. A TOTAL FIELD MAGNETOMETER MUST BE OPERATED AT THE ESS TO PROVIDE INFORMATION TO BE USED FOR CORRECTION IN LATER DATA ANALYSIS. THE LOCATION, INCLUDING ELEVATION, AND TIME OF EACH READING MUST BE RECORDED TO BE USED IN DATA REDUCTION. CONTINUOUS MAGNETIC PROFILES SHOULD BE OBTAINED ON ALL TRAVERSES.
4 6 04 06 67	MAGNETIC FIELD THIS EXPERIMENT IS DESIGNED TO MAP THE PERMANENT MAGNETIC FIELD OF THE MOON FROM ORBIT. A PROTON PRECESSION, RUBIDIUM VAPOR OR FLUXGATE MAGNETIC SURVEY WILL BE FLOWN TO COVER MOST OF THE LUNAR SURFACE. INFORMATION AS TO THE MAGNITUDE AND SHAPE OF THE MAGNETIC FIELD WILL BE OBTAINED. THIS WILL ENABLE THE INTERNAL STRUCTURE OF THE MOON TO BE INFERED FROM THE MAGNETIC FIELD STRUCTURE. THIS EXPERIMENT IS OF COURSE DEPENDENT UPON THE EXISTENCE OF A PERMANENT MAGNETIC FIELD THAT CAN BE MEASURED.
4 7 01 11 01	STUDY OF EARTH ATMOSPHERE HEAT BALANCE FROM LANDING SITE STUDY OF EARTH ATMOSPHERE HEAT BALANCE FROM LANDING SITE WILL BE ACCOMPLISHED BY USE OF BOLOMETER AND SPECTROGRAPH IN CONJUNCTION WITH A SIX INCH REFLECTING TELESCOPE. THE EARTH DISK WILL BE SCANNED PERIODICALLY AND RESULTS RECORDED ON PHOTOGRAPHIC FILM AND MAGNETIC TAPE.
4 7 02 12 02	STUDY OF EARTH REFLECTIVITY AND ALBEDO FROM LANDING SITE STUDY OF EARTH REFLECTIVITY AND ALBEDO FROM LANDING SITE WILL BE ACCOMPLISHED BY USE OF THE SIX INCH REFLECTING TELESCOPE WITH ASSOCIATED EQUIPMENT SUCH AS A BOLOMETER AND ASTRONOMICAL SPECTROGRAPH. DATA WILL BE RECORDED ON MAGNETIC TAPE AND PHOTOGRAPHIC FILM FOR LATER ANALYSIS. PERIODIC SCANS WILL BE MADE OF THE EARTH DISK WITH RECORDING OF TIME AND POSITION OF SCAN POINT INCLUDED WITH THE DATA RECORD. BOLOMETER MEASUREMENT RANGE ESTIMATED TO VARY FROM 0.007 TO 1.5 ERGS PER SQUARE CM PER SECOND.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJT SPEC INVS EXPT	GEOPHYSICS
4 7 03 13 03	STUDY OF EARTH AURORAL AND AIR GLOW EMISSION STUDY OF EARTH AURORAL AND AIR GLOW EMISSION FROM LANDING SITE WILL BE MADE TO PROVIDE SYNOPTIC PHOTOGRAPHS OF THESE PHENOMENA AS VISIBLE FROM THE LUNAR DISTANCE. SPECIAL OBSERVATIONS SHOULD BE PROGRAMMED FOR THE PERIODS OF MAJOR SOLAR ACTIVITY. THE PRIMARY RESULTS WILL BE IN THE FORM OF COLOR PHOTOGRAPHS TO BE ANALYZED AFTER RETURN TO EARTH. BOLOMETER AND SPECTROGRAPH DATA WILL BE INCLUDED AS APPROPRIATE. A SIX INCH TELESCOPE CAMERA IS BELIEVED ADEQUATE.
4 7 04 14 04	STUDY OF ULTRAVIOLET SCATTERING IN EARTH ATMOSPHERE STUDY OF ULTRAVIOLET SCATTERING IN EARTHS ATMOSPHERE WILL BE ACCOMPLISHED BY USE OF THE SIX INCH TELESCOPE AND ACCESSORIES AS ALSO USED IN RELATED EXPERIMENTS ON HEAT BALANCE, ALBEDO, AND AIR GLOW. THE COMBINATION OF THESE SEVERAL INVESTIGATIONS WILL PROVIDE SYNOPTIC DATA FOR LONG TERM METEOROLOGICAL PHENOMENA ANALYSIS. THE MAJOR PORTION OF THE DATA WILL BE SPECTROGRAPH DATA IN THE RANGE OF 0.000001 TO 0.02 CM. DATA WILL BE RECORDED ON FILM.
4 7 05 15 05	EARTH ATMOSPHERE SOUNDING BY PASSIVE INFRARED SCANNING EARTH ATMOSPHERE SOUNDING BY PASSIVE INFRARED SCANNING WILL ADD TO SNOPTIC KNOWLEDGE OF THE EARTH ATMOSPHERE AND WILL BE ACCOMPLISHED BY USE OF THE SIX INCH TELESCOPE AND ACCESSORIES. THE BOLOMETER WILL MEASURE RADIATIVE INTENSITY IN THE EXPECTED RANGE OF 0.075 TO 1.5 ERGS PER SQUARE CM PER SECOND.
4 7 05 15 12	OBSERVATIONS AND ANALYSES OF EARTH ATMOSPHERIC CIRCULATION OBSERVATIONS AND ANALYSES OF EARTHS ATMOSPHERIC CIRCULATION AND OTHER LARGE SCALE PHENOMENA IN CONJUNCTION WITH DATA FROM EXPERIMENTS 47011101 THROUGH 47087808 . THE OBJECTIVE OF THESE EXPERIMENTS BEING PERFORMED FROM A LUNAR BASE WOULD BE TO TEST THE EFFECTIVENESS OF THESE LONG RANGE OBSERVATIONS AS COMPARED WITH A LARGER MASS OF SIMILAR DATA FROM EARTH SATELITES IN PREDICTION AND ANALYSIS OF LARGE SCALE METEOROLOGICAL PHENOMENA. THE USE OF A 40 INCH TELESCOPE AND ACCESSORIES IS EXPECTED TO PROVIDE THE REQUIRED RESOLUTION OF MULTISPECTRAL PHOTOGRAPHS IN WAVELENGTHS FROM 0.000001 TO 0.0002 CM.
4 7 06 16 06	EARTH ATMOSPHERE DENSITY ABOVE 30 KM BY STELLAR REFRACTION EARTH ATMOSPHERE DENSITY ABOVE 30 KM BY STELLAR REFRACTION WILL BE MEASURED IN ORDER TO DERTIMINE THE EFFECTIVENESS OF THIS TECHNIQUE FOR ESTIMATING VARIATIONS OF EARTH ATMOSPHERE DENSITY AT ALTITUDE. AN ASTRONOMICAL SPECTROGRAPH MATCHED TO THE FORTY INCH TELESCOPE WILL PROVIDE RADIATIVE INTENSITY MEASUREMENTS IN VARIOUS WAVELENGTHS FROM 0.000001 TO 0.02 CM.
4 7 07 17 07	STUDY OF EARTH ATMOSPHERE DURING TERRESTRIAL ECLIPSE OF SUN STUDY OF EARTH ATMOSPHERE DURING TERRESTRIAL ECLIPSE OF SUN BY MEANS OF PHOTOGRAPHS AND SPECTROGRAPHIC MEASUREMENTS WILL PROVIDE VALUABLE SYNOPTIC DATA NOT AVAILABLE FROM OTHER SENSOR LOCATIONS. RADIATIVE INTENSITY MEASUREMENTS IN THE RANGE OF 0.0075 TO 1.5 ERGS PER SQ CM PER SEC ARE ESTIMATED AS THE RANGE OF MAJOR DATA OUTPUT. THE USE OF A LARGE ASTRONOMICAL TELESCOPE SUCH AS THE 40 INCH UNIT IS RECOMMENDED PROVIDED SCIENTIFIC PRIORITIES WILL MAKE IT AVAILABLE FOR METEOROLOGICAL RESEARCH DURING A UNIQUE ECLIPSE EVENT.

EXPERIMENT NUMBER (AGE SPEC INV SUBT)	EXPERIMENT DESCRIPTION
	GEOPHYSICS
4 7 C8 18 C8	PASSIVE PROBE OF EARTH ATMOSPHERE BY MICROWAVE SCAN PASSIVE PROBE OF EARTHS ATMOSPHERE BY MICROWAVE SCAN WILL PROVIDE ADDITIONAL SYNOPTIC INFORMATION OF THE EARTH ATMOSPHERE IN WAVELENGTHS NOT AVAILABLE WITH THE OPTICAL TELESCOPES. THE RADIO TELESCOPE WILL PROVIDE FLUX DENSITY MEASUREMENTS IN THE RANGE APPROPRIATE
4 8 C9 21 C9	STUDY OF NONTERRESTRIAL PLANETARY ATMOSPHERE CIRCULATIONS - 4C IN. THE LUNAR BASE EQUIPPED WITH A LARGE ASTRONOMICAL TELESCOPE (4C INCH) WOULD PROVIDE AN EXCELLENT PLATFORM FROM WHICH TO CONDUCT LONG DURATION PHOTOGRAPHIC STUDIES OF PLANETARY ATMOSPHERE CIRCULATIONS. VENUS, MARS, AND JUPITER ARE PLANETS OF INTEREST TO THE METEOROLOGIC SCIENCES. PHOTOGRAPHS WILL BE TAKEN IN VARIOUS WAVELENGTHS FROM 0.000001 TO 0.01 CM.
4 8 1C 22 10	MEASUREMENT OF TEMPERATURES AND COMPOSITION OF PLANETARY ATMOSPHERE MEASUREMENT OF TEMPERATURES AND COMPOSITION OF PLANETARY ATMOSPHERES WILL PROVIDE ADDITIONAL DATA OF SIGNIFICANCE TO METEOROLOGY OF OTHER PLANETS. THE LUNAR BASE WILL PROVIDE A STABLE PLATFORM FROM WHICH COORDINATED MEASUREMENTS IN A WIDE VARIETY OF WAVELENGTHS CAN BE MADE. USE OF BOTH THE FORTY INCH AND 1CC INCH OPTICAL TELESCOPES AND THE RADIO TELESCOPE IS RECOMMENDED FOR THIS IMPORTANT STUDY. SPECTROGRAPHIC DETERMINATIONS IN THE WIDE VARIATION OF WAVELENGTHS WILL BE THE PRINCIPAL FORM OF DATA.
4 8 11 23 11	DETERMINATIONS OF PLANETARY ALBEDOES AND SPECTRAL REFLECTIVITIES USE OF THE 4C INCH TELESCOPE AT THE LUNAR BASE TO STUDY PLANETARY ALBEDOES AND SPECTRAL REFLECTIVITIES WILL PROVIDE OPPORTUNITY FOR DETERMINING ACCURATE VALUES OF THESE CHARACTERISTICS. THE MOST IMPORTANT INSTRUMENTS REQUIRED WILL BE THE BOLOMETER AND SPECTROGRAPH WITH READINGS TAKEN IN SEVERAL SPECTRAL RANGES.
4 9 C1 31 01	OCEAN HEAT BALANCE STUDY 1 . EARTH OCEAN SURFACE AND CLOUD COVER TEMPERATURES WILL BE MEASURED DURING THE DAY AND NIGHT TO SYNOPTICALLY DETERMINE SURFACE ISOTHERMS AND THEIR RELATIONSHIP TO TIME, GEOGRAPHY AND ATMOSPHERE. EARTH BASED OCEAN SURVEYS AND MONITORING STUDIES MUST BE CARRIED ON SIMULTANEOUSLY. REPEAT OBSERVATIONS DAILY,APPROX. 2 HRS PER DAY BY SHARED USE OF SIX INCH TELESCOPE WITH METEOROLOGY EXPTS SUCH AS 47011101 . BOLOMETER MEASUREMENTS WILL BE THE PRINCIPAL DATA GATHERED DURING THE SURVEYS OF THE OCEAN AREAS.
4 9 C1 31 C2	OCEAN HEAT BALANCE STUDY 2 SAME AS EXPT 4901 1C1 BUT PERFORMED DURING LATER EXPLORATION PHASE. OBSERVATIONS CONTINUE AT APPROX 1 AND 1/2 HR PER DAY WITH COORDINATION WITH EARTH BASED AND EARTH ORBITAL FINDINGS . WILL UTILIZE LARGER 4 IN ASTRONOMICAL TELESCOPE AS AVAILABLE IN ORDER TO ACHIEVE INCREASED SENSITIVTY OF BOLOMETER DATA.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJECT SPEC INVS EXPT	GEOPHYSICS
4 9 02 32 01	SEQUENTIAL MULTIBAND OCEAN PHOTOGRAPHY 1 VISUAL OBSERVATIONS,PHOTOGRAPHICLY RECORDED ON A SEQUENTIAL BASIS, WILL PROVIDE DATA ON EARTH CLOUD COVER, SEA SURFACE GLITTER, WATER COLOR, ICE FORMATION DEGRADATION AND MOVEMENT, AND RECOGNITION OF GROSS DYNAMIC PATTERNS. OBSERVATIONS TO BE REPEATED DAILY OVER A PERIOD OF APPROXIMATELY TWO HOURS EACH DAY FOR A TOTAL OF APPROXIMATELY 14 DAYS. THIS EXPERIMENT WILL DETERMINE THE FEASIBILITY OF UTILIZING THE LUNAR BASE FOR LONG PERIOD OBSERVATIONS OF OCEAN SURFACE FEATURES IN COMPARISON WITH SIMILAR OBSERVATIONS OBTAINED FROM THE RELATIVELY LOW ALTITUDE AND FAST MOVING EARTH SATELLITES. THE PRINCIPAL DATA FROM THIS EXPERIMENT WILL BE A COORDINATED SERIES OF COLOR PHOTOGRAPHS WHICH WILL BE INTERPRETED INITIALLY AT THE LUNAR BASE AND LATER RETURNED TO EARTH FOR COMPARISON WITH OTHER DATA SOURCES CONCERNING THE SAME PHENOMENA.
4 9 02 32 02	SEQUENTIAL MULTIBAND OCEAN PHOTOGRAPHY LATER PHASE SAME AS EXPT 49023201, BUT CONDUCTED DURING LATER EXPLORATION PHASE. USE OF LARGER ASTRONOMICAL TELESCOPES WHICH MAY BE AVAILABLE AT THE PERMANENT LUNAR BASE WILL ALLOW THE TESTING OF USEFUL OCEANOGRAPHIC INFORMATION WHICH MAY BE OBTAINED FROM THESE INCREASED CAPABILITY INSTRUMENTS. OBSERVATIONS MAY REQUIRE UP TO 2 MAN-HOURS PER DAY AS THE APPROPRIATE TELESCOPES ARE AVAILABLE, BEING DEPENDENT UPON HIGHER PRIORITY INVESTIGATIONS.
4 9 03 33 01	SURFACE HEIGHT MEASUREMENTS BY USE OF LASER RANGING DEVICE SYNOPTIC AND SPECIAL AREA SEA SURFACE HEIGHT MEASUREMENTS ARE TO BE MADE AND CALIBRATED WITH SPECIFIED EARTH TEST SITES. THE RESULTS WOULD BE COORDINATED WITH PREVIOUS INVESTIGATIONS AND EARTH SATELLITE RESULTS. LASER RANGING DEVICE WOULD REQUIRE SPECIAL DEVELOPMENT. OBSERVATION MANHOURS ESTIMATED UP TO TWO MANHR PER DAY AND COULD BE USEFULLY EXTENDED OVER A TWO YEAR PERIOD OF A PERMANENT BASE. LIMITED BY AVAILABILITY OF 40 IN OR OTHER LARGE TELESCOPE SHARED WITH OTHER EXPERIMENTS.

EXPERIMENT NUMBER AREA	OBJT	SPEC	INVS	EXPT	EXPERIMENT DESCRIPTION
					PARTICLES AND FIELDS
5	2	02	01	01	SOLAR CHARGED PARTICLE ENVIRONMENT AT SURFACE, 0.01-0.5MEV 1 MEASURE FLUX VS. CHARGE, ENERGY, TIME, DIRECTION RELATIVE TO SOLAR DIRECTION,OF CHARGED PARTICLES ORIGINATING AT SUN, ESPECIALLY IN ASSOCIATION WITH SOLAR FLARES. OBJECTIVE, TO EXPLORE ACCELERATION AND PROPAGATION OF PARTICLES IN SOLAR ATMOSPHERE AND INTERPLANETARY MEDIUM. PERFORM AT TIMES SPACED THRU SOLAR ACTIVITY CYCLE, DATA FOLLOW FOR FIRST EXPERIMENT. RELATED TO ALL OTHER EXPERIMENTS IN INVESTIGATIONS 520201, 520202, 520301, 520501. ANY SURFACE FEATURE. REPEAT EXPERIMENT IN TWO OR MORE LATER MISSIONS (52020102,52020103), SIMULTANEOUSLY WITH 52020201. ANY SURFACE FEATURE. SENSOR IN OPEN NEAR BASE SHELTER, CONTROLS AND DATA DISPLAY IN BASE SHELTER, WELL SHIELDED FROM SOLAR PARTICLES FOR CREW SAFETY.
5	2	02	01	02	SOLAR CHARGED PARTICLE ENVIRONMENT AT SURFACE, 0.01-0.5MEV 2 REPETITION OF 52020101, AT LATER STAGE OF SOLAR ACTIVITY CYCLE. PERFORM AT SAME TIME, PLACE AS 52020202.
5	2	02	01	03	SOLAR CHARGED PARTICLE ENVIRONMENT AT SURFACE, 0.01-0.5 MEV 3 REPETITION OF 52020101, 52020102, AT LATER STAGE OF SOLAR ACTIVITY CYCLE. PERFORM AT SAME TIME, PLACE AS 52020203 ANY SURFACE FEATURE. TWO STATIONS, AT OPPOSITE LIMBS.
5	2	02	02	01	SOLAR CHARGED PARTICLE ENVIRONMENT AT SURFACE, 0.04-1000MEV 1 MEASURE FLUX VS. CHARGE, ENERGY, TIME (WITH ALL INSTRUMENTS EXCEPT EMULSIONS, 31130), DIRECTION (RELATIVE TO SOLAR DIRECTION), OF PARTICLES ASSOCIATED WITH SOLAR ACTIVITY. SEE COMMENTS FOR 52020101. PERFORM AT SAME TIME, PLACE AS 52020101. AT LOW SOLAR ACTIVITY, OVERLAPS 52030101. ANY SURFACE FEATURE. INSTRUMENTATION COVERS ENERGY RANGES 0.04-1MEV, 1-10MEV, 10-1000MEV WITH 10 PERCENT RESOLUTION AT ANY ENERGY.
5	2	02	02	02	SOLAR CHARGED PARTICLE ENVIRONMENT AT LUNAR SURFACE,0.04-1000MEV 2 REPETITION OF 52020201 AT LATER STAGE OF SOLAR ACTIVITY CYCLE. PERFORM SAME TIME,PLACE AS 52020102. MAY OVERLAP 52030102. ANY SURFACE FEATURE.
5	2	02	02	03	SOLAR CHARGED PARTICLE ENVIRONMENT AT LUNAR SURFACE,0.04-1000MEV 3 REPETITION OF 52020201, 52020202 AT LATER STAGE OF SOLAR ACTIVITY CYCLE. PERFORM SAME TIME, PLACE AS 52020103. MAY OVERLAP 52030103. ANY SURFACE FEATURE. TWO STATIONS, AT OPPOSITE LIMBS.
5	2	02	03	01	ANISOTROPY VS. CHARGE AND ENERGY OF SOLAR AND GALACTIC PARTICLES BELOW 1 BEV. LUNAR ORBITING APOLLO (MANNED). PERFORM AT HIGH SOLAR ACTIVITY. GIVE FULL ATTENTION TO CREW RADIATION PROTECTION.
5	2	02	04	01	SOLAR AND GALACTIC RADIATION ENVIRONMENT AT LUNAR SURFACE SURVEY OF CHARGED PARTICLE, GAMMA-RAY, SOLAR NEUTRON ENVIRONMENT, AT ENERGIES FROM ABOUT 1 MEV TO A FEW BEV, INCLUDES GALACTIC CHARGED PARTICLES. AAP EMPLACED SCIENTIFIC STATION. CREW DEPLOYS, ACTUATES ESS WHICH OPERATES UNMANNED AND IS RECOVERED ON LATER MISSION.
5	2	02	04	02	SOLAR ENERGETIC ELECTRONS ASSOCIATED WITH SOLAR FLARES PERFORM AT TWO STATIONS AT OPPOSITE LIMBS, AT SAME TIMES, PLACES AS 52020203. DURING PERIODS OF HIGH SOLAR ACTIVITY. LATE PHASE.
5	2	02	04	03	SOLAR ENERGETIC ELECTRONS ASSOCIATED WITH SOLAR FLARES. PERFORM AT TWO STATIONS AT OPPOSITE LIMBS, AT SAME TIMES, PLACES AS 52020203. DURING PERIODS OF HIGH SOLAR ACTIVITY. LATE BASE.

EXPERIMENT NUMBER (A B E A / G J T / S P C / I N S / E X P T)	EXPERIMENT DESCRIPTION
	PARTICLES AND FIELDS
5 2 03 01 01	GALACTIC NUCLEI ENVIRONMENT AT SURFACE, 100MEV-100+BEV 1 MEASURE FLUX VS. ENERGY, CHARGE, DIRECTION (RIGHT ASCENSION AND DECLINATION) OF APPROACH, TIME (EXCEPT WITH EMULSIONS), OF PROTONS AND HEAVY NUCLEI +Z GREATER THAN 1+ AT LOCATION WITH NEGLIGIBLE ATMOSPHERE AND MAGNETIC FIELD. MOON IS 2-PI SHIELD, RESOLVES AMBIGUITY OF DIRECTION. OVERLAPS 52020201. PARTS OF 52030201, 54080101 USE SAME EQUIPMENT AT SAME TIME. DO AT LOW SOLAR ACTIVITY (1974-6). GIVES INFORMATION ON MODULATION OF GALACTIC PARTICLE FLUX BY SOLAR-INTERPLANETARY MAGNETIC FIELD, STRENGTH OF GALACTIC FIELD, GALACTIC ELEMENT ABUNDANCE.
5 2 03 01 02	GALACTIC NUCLEI ENVIRONMENT AT SURFACE, 100MEV-100+BEV 2 REPETITION OF 52030101 AT LATER STAGE OF SOLAR ACTIVITY CYCLE. OVERLAPS 52020202.PARTS OF 52030202 54080102 USE SAME EQUIPMENT. ANY SURFACE FEATURE.
5 2 03 01 03	GALACTIC NUCLEI ENVIRONMENT AT SURFACE, 100MEV-100+BEV 3 REPETITION OF 52030101, 52030102 AT LATER STAGE OF SOLAR ACTIVITY CYCLE. OVERLAPS 52020203.PARTS OF 52030203, 54080103 USE SAME EQUIPMENT. ANY SURFACE FEATURE.
5 2 03 02 01	GALACTIC ELECTRON ENVIRONMENT AT SURFACE, 100-1000MEV 1 MEASURE FLUX VS. ENERGY, DIRECTION (RIGHT ASCENSION AND DECLINATION), TIME(EXCEPT WITH EMULSION) OF ELECTRONS AND POSITRONS FROM SOURCES OUTSIDE SOLAR SYSTEM. GIVES INFORMATION ON INTERPLANETARY AND GALACTIC MAGNETIC FIELDS, STELLAR RADIO SOURCES (SYNCHROTRON RADIATION), ANTI-MATTER PROCESSES (POSITRONS). DO AT LOW SOLAR ACTIVITY, 1972-4. USES SOME OF SAME EQUIPMENT AS 52030101, 54080101. MAN-HOUR REQMTS BASED ON PERFORMANCE OF 52030101 ON SAME MISSION, OTHERWISE SUBSTITUTE 52030101 REQMTS. ANY SURFACE FEATURE.
5 2 03 02 02	GALACTIC ELECTRON ENVIRONMENT AT SURFACE, 100-1000MEV 2 REPETITION OF 52030202 AT LATER STAGE OF SOLAR ACTIVITY CYCLE. USES SOME OF SAME EQPT AS 52030102, 54080102. MAN-HOUR REQMTS BASED ON PERFORMANCE OF 52030102, OTHERWISE USE 52030102 REQMTS. ANY SURFACE FEATURE.
5 2 03 02 03	SURFACE GALACTIC ELECTRON ENVIRONMENT REPETITION OF 52030201, 52030202 AT LATER STAGE OF SOLAR ACTIVITY CYCLE. USES SOME OF SAME EQPT AS 52030103, 54080103. MAN-HOUR REQMTS BASED ON PERFORMANCE OF 52030103, OTHERWISE USE 52030103 REQMTS. ANY SURFACE FEATURE.
5 2 09 01 01	SOLAR AND GALACTIC NEUTRINO SOURCES MEASURE FLUX AND SOURCE DIRECTION OF EACH NEUTRINO TYPE (ORDINARY ELECTRON, ANTI ELECTRON, ORDINARY MUON, ANTI MUON). TO EXCLUDE OTHER PARTICLES, COVER DETECTOR WITH 2 DIFFERENT AMOUNTS OF LUNAR SOIL (SAY 10**4 AND 10**5 GM/CM**2). EXTRAPOLATE RESULTS TO ZERO COVER TO EXCLUDE NEUTRINOS PRODUCED IN SOIL. ABSENCE OF ATMOSPHERIC NEUTRINOS PERMITS BETTER EXTRAPOLATION THAN ON EARTH. COVER MASS PROHIBITS ORBITAL EXPERIMENT. PERFORM 1 KM FROM REACTOR.
5 3 01 01 01	SOLAR WIND INTERACTION WITH MOON AND GEOMAGNETOSPHERE 1 MEASURE FLUX VS. MASS, CHARGE, ENERGY OF SOLAR WIND ELECTRONS, PROTONS, HEAVY NUCLEI AS FUNCTION OF HEIGHT ABOVE LUNAR SURFACE, AND SUN ANGLE. WHEN EARTH AND SUN ARE NEAR SAME POSITION, SEARCH FOR GEOMAGNETICALLY TRAPPED ELECTRONS. EXAMINE PHOTOELECTRON-SOLAR WIND PLASMA SHEATH FROM FEW CM TO SEVERAL M ABOVE LUNAR SURFACE. CONDUCT SAME TIME, PLACES AS 53050101. CONDUCT AT LUNAR LOCAL SUNRISE OR SUNSET, NOON, MIDNIGHT, NEAR CENTER OF NEARSIDE, IN FLAT OPEN AREA AND ON MOUNTAIN PEAK (AT LEAST 200 M).

EXPERIMENT NUMBER

ABRE AJAT OBJECT SPECS INVESTS EXPT

EXPERIMENT DESCRIPTION

PARTICLES AND FIELDS

5 3 01 C1 02 — SOLAR WIND INTERACTION WITH MOON AND GEOMAGNETOSPHERE 2
SIMILAR TO 5301C101 WITH TRAVERSE TO LIMB TO STUDY DEPENDENCE ON EARTH ANGLE. AND WITH ADVANCED SPECTROMETER PERFORM WITH 5305C102.

5 3 01 C1 03 — SOLAR WIND INTERACTION WITH MOON AND GEOMAGNETOSPHERE 3
REPETITION OF 5301C102 WITH PERMANENT STATIONS AT DISK CENTER AND AT LIMB, LONGER OBSERVING PERIODS INCLUDING SOLAR ECLIPSE BY EARTH. PERFORM WITH 5305C103. RELATED TO 5306C1.1. 8 EGRESSES.

5 3 01 01 04 — MAGNETOHYDRODYNAMICS OF SOLAR WIND FLOW PAST EARTH AND MOON
REPETITION OF 5301C103 WITH LONGER OBSERVING PERIODS AND ADDED UNMANNED LUNAR SATELLITE IN POLAR ORBIT AT 1000 KM SURFACE ALTITUDE. EARTH IS LARGE OBJECT (COMPARED TO SOLAR WIND PROTON GYRORADIUS IN INTERPLANETARY MAGNETIC FIELD) WITH STRONG MAGNETIC FIELD, MOON IS LARGE OBJECT WITH WEAK FIELD, LUNAR SATELLITE IS SMALL OBJECT WITH WEAK FIELD. MOON AND SATELLITE INTERSECT ANTISOLAR TAIL OF GEOMAGNETOSPHERE. PERFORM WITH 5305C104.
DATA LINKS = ORBIT - SURFACE, SURFACE - EARTH.
12 EGRESSES. REQUIRES LONG RANGE ROVING VEHICLE AND LUNAR SATELLITE. PERFORM NEAR SOLAR ACTIVITY MAXIMUM TO OBSERVE DISTURBED FLOW.

5 3 01 C2 02 — SOLAR WIND PARTICLES IN SHOCK FRONT NEAR MOON
PERFORM SAME TIME AND PLACE AS 5305C202, SAME TIME AS 5305C203, 5301C201. UNMANNED LUNAR ORBITER, FIRST ORBIT 50-100 KM, THEN 100-2000 KM.

5 3 04 01 01 — ELECTRONS ESCAPING EARTH AURORAL ZONES DURING GEOMAGNETIC STORMS 1
GEOMAGNETIC STORMS WHICH CAUSE PRECIPITATION OF TRAPPED ELECTRONS AT HIGH GM LATITUDES AND HENCE AURORAE, MAY ALSO CAUSE ELECTRONS TO APPEAR IN ENHANCED NUMBERS IN ANTISOLAR TAIL OF GEOMAGNETOSPHERE OR IN SPACE OUTSIDE GMSPHERE. MEASURE 1-40 KEV ELECTRON FLUX AT LUNAR NEARSIDE WHEN (A) EARTH IS NEARLY BETWEEN SUN AND MOON AND (B) GM STORM EXISTS. ALSO (A) ALONE, (B) ALONE, NEITHER (A) NOR (B). CORRELATE W/ 5301C103, 5305C103. ASTRONOMICAL OBSERVATIONS FROM MOON OF BOTH AURORAL ZONES, EARTH-BASED AND EARTH-ORBITAL GM FIELD, TRAPPED ELECTRONS, AURORAE OBSERVATIONS. ANY SURFACE FEATURE.

5 3 01 02 01 — SOLAR WING PARTICLES AT LUNAR SURFACE (ALSEP)
PERFORM SAME TIME AND PLACE AS 5305C203, SAME TIME AS 5305C202, 5301C202.

5 3 04 C1 C2 — ELECTRONS ESCAPING EARTH AURORAL ZONES DURING GEOMAGNETIC STORMS 2
SIMILAR TO 5304C101, AT LATER STAGE OF SOLAR ACTIVITY CYCLE. CORRELATE W/ 5301C104, 5305C104. FEATURE.

5 3 05 C1 01 — INTERPLANETARY MAGNETIC FIELD AND DISTANT GEOMAGNETIC FIELD 1
MEASURE STRENGTH AND DIRECTION OF MAGNETIC FIELD NEAR LUNAR SURFACE. UNDER QUIET AND DISTURBED CONDITIONS OF SOLAR-INTERPLANETARY MAGNETIC FIELD, INCLUDING TIMES +2 TO 6 DAYS EACH 28 DAYS+ WHEN MOON PASSES THROUGH ANTISOLAR TAIL OF GEOMAGNETOSPHERE. PERFORM AT SAME TIME, PLACE AS 5301C101, NEAR CENTER OF NEARSIDE. SUBTRACT INTRINSIC LUNAR FIELD, FROM GEOPHYSICS EXPERIMENT.

5 3 05 C1 02 — INTERPLANETARY MAGNETIC FIELD AND DISTANT GEOMAGNETIC FIELD 2
SIMILAR TO 5305C101, WITH ADDED TRAVERSE TO LIMB. PERFORM AT SAME TIME, PLACE AS 5301C102.

5 3 05 01 03 — INTERPLANETARY MAGNETIC FIELD AND DISTANT GEOMAGNETIC FIELD 3
SIMILAR TO 5305C102, WITH PERMANENT STATIONS AT CENTER NEARSIDE AND LIMB. PERFORM WITH 5301C103. 8 EGRESSES.

EXPERIMENT NUMBER
A G S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

PARTICLES AND FIELDS

5 3 05 01 04 INTERPLANETARY MAGNETIC FIELD AND DISTANT GEOMAGNETIC FIELD 4
SIMILAR TO 53050104 WITH ADDED MEASUREMENTS FROM LUNAR SATELLITE IN POLAR ORBIT AT 1000 KM SURFACE ALTITUDE. PERFORM WITH 53010104. REQUIRES LONG RANGE ROVING VEHICLE AND LUNAR SATELLITE. 12 EGRESSES.
DATA LINKS = ORBIT - SURFACE, SURFACE - EARTH.

5 3 05 02 01 MONITOR MAGNETIC FIELD STRENGTH, DIRECTION AT LUNAR SURFACE
MEASUREMENT INCLUDES INTRINSIC LUNAR FIELD, INTERPLANETARY FIELD, DISTANT GEOMAGNETIC FIELD IN ANTISOLAR TAIL OF GMSPHERE. EMPLACED SCIENTIFIC STATION. SEE 53050201.

5 3 05 02 02 MAGNETIC FIELD IN SOLAR WIND-SHOCK FRONT NEAR MOON
PERFORM SAME TIME AND PLACE AS 53050202, SAME TIME AS 53050203, 53010201. LUNAR ORBITER, UNMANNED, FIRST ORBIT 50-100 KM, THEN 100-2000 KM.

5 3 05 02 03 MAGNETIC FIELD TIME VARIATION AT LUNAR SURFACE (ALSEP)
PERFORM SAME TIME AND PLACE AS 53010201, SAME TIME AS 53050202, 53010202. EMPLACED BY CREW, LEFT ON MOON.

5 3 07 01 01 STEADY AND SLOWLY VARYING ELECTROSTATIC FIELD NEAR LUNAR SURFACE
CONDUCT FEW CM TO 1 M ABOVE FLAT OPEN AREA. EMPLACED SCIENTIFIC STATION. SEE 52020401.
MEASURE 3 COMPONENTS OF STATIC AND VLF ELECTRIC FIELD.

5 3 07 01 02 VERTICAL COMPONENT OF ELECTROSTATIC FIELD AT AND ABOVE LUNAR SURFACE
3 LOCATIONS - (1)AT BASE, FLAT AREA, AT SURFACE. (2) AT SAME STATION, ON 10-M INSULATED POLE, (3) UNMANNED LUNAR ORBITER, 100 KM. PERFORM ONCE AT NOON, ONCE AT MIDNIGHT.

5 4 08 01 01 GALACTIC PARTICLE SCATTERING AND REACTIONS 1
MEASURE SCATTERING AND REACTION CROSS-SECTIONS AND ANGULAR DISTRIBUTIONS, AND DECAY MODES OF SECONDARY MESONS AND BARYONS, FOR GALACTIC ELECTRONS, PROTONS, HEAVY NUCLEI AT ENERGIES (100 BEV - 10**10 BEV) ABOVE ENERGIES AVAILABLE IN LABORATORY (50 BEV IN 1972, 100-200 BEV IN 1980). LUNAR BASE NEEDED TO SET UP LONG (ORDER 100 M) FLIGHT PATHS FOR GOOD GEOMETRY AND TO OBSERVE SECONDARY DECAY. NO VACUUM SYSTEM NEEDED ON MOON. PROOF-OF-PRINCIPLE EXPERIMENT TO ESTABLISH REQMTS FOR FOLLOW-ON EXPERIMENTS, DETERMINE REACTION TYPES, RATES. USES SOME OF SAME EQPT AS 52030101, 52030201. PERFORM AT LUNAR NIGHT DURING LOW SOLAR ACTIVITY, TO REDUCE BACKGROUND (EXCEPT COINCIDENT USE OF EQPT SHARED WITH 52030101, 52030201). SHARED EQPT NOT LISTED.

5 4 08 01 02 GALACTIC PARTICLE SCATTERING AND REACTIONS 2
SIMILAR TO 54080101 WITH MORE ADVANCED EQPT FOR EXTENDED COVERAGE OF PARAMETERS AND DETAILED STUDY OF SIGNIFICANT EVENT TYPES IDENTIFIED IN 54080101. USES SOME OF SAME EQPT AS 52030102, 52030202.

5 4 08 01 03 GALACTIC PARTICLE SCATTERING AND REACTIONS 3
SIMILAR TO 54080101, 54080102 WITH MORE ADVANCED EQPT FOR EXTENDED COVERAGE OF PARAMETERS AND DETAILED STUDY OF SIGNIFICANT EVENT TYPES IDENTIFIED IN 54080101, 54080102. USES SOME OF SAME EQPT AS 52030103, 52030203.

5 5 22 01 01 OUTER CORONA STRUCTURE
OUTER CORONA STRUCTURE, SPECTRA (VISIBLE, NEAR UV).
THE OBJECTIVE OF THIS EXPERIMENT IS TO OBSERVE SPECTRUM OF OUTER SOLAR CORONA. 8-INCH SOLAR TELESCOPE, AT WAVELENGTHS 1216 - 8000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 1A, ANGULAR RESOLUTION 0.5 SEC ARC.

EXPERIMENT NUMBER AREA	OBJT	SPEC	INVS	EXPT	EXPERIMENT DESCRIPTION
					PARTICLES AND FIELDS
5	5	22	02	01	FLARE UV SPECTRA (PRELIMINARY). THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE UV SPECTRUM OF SOLAR FLARES. 8-INCH SOLAR TELESCOPE, AT WAVELENGTHS 500-4000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.1A, ANGULAR RESOLUTION 1 ARC SEC.
5	5	22	03	01	SOLAR GRANULATION STRUCTURE. HIGH ANGULAR RESOLUTION, DWELL AT EACH WAVELENGTH, 1 SQ MIN ARC. THEN SCAN(AT 1 SQ SEC ARC)10-20 SEC TO FIND GRANULATION STRUCTURE, SMALL AREA, HIGH TIME RESOLUTION. THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE SIZE DISTRIBUTION VS. TIME OF PHOTOSPHERIC GRANULATIONS. THE PRIMARY INSTRUMENT IS A 40-INCH SOLAR TELESCOPE, WAVELENGTHS 1216 - 8000A, RESOLUTION 10A, ANGULAR RESOLUTION 0.1 ARC SEC.
5	5	22	03	02	GRANULATION VELOCITY FIELD THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE VELOCITY OF PHOTOSPHERIC MATERIAL IN GRANULATIONS. 40-INCH SOLAR TELESCOPE, AT WAVELENGTHS 1216 - 8000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.005A, ANGULAR RESOLUTION 0.1 SEC ARC.
5	5	22	04	01	SUNSPOT FORMATION, DEVELOPMENT 3 NEWLY FORMED SPOTS. THE OBJECTIVE OF THIS EXPERIMENT IS TO OBSERVE SIZE AND MAGNETIC FIELD OF SUNSPOTS VS. TIME. 40-INCH SOLAR TELESCOPE, AT WAVELENGTHS 1216 - 8000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.1A, ANGULAR RESOLUTION 0.1 SEC ARC.
5	5	22	05	01	PROMINENCE FINE STRUCTURE VS WAVELENGTH. HIGH TIME RESOLUTION. THE OBJECTIVE OF THIS EXPERIMENT IS TO OBSERVE STRUCTURE AND SUDDEN DISAPPEARANCES OF QUIESCENT PROMINENCES. 40-IN SOLAR TELESCOPE, AT WAVELENGTHS 1216 - 8000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.2A, ANGULAR RESOLUTION 0.5 SEC ARC.
5	5	22	06	01	FLARE EJECTION OF MATERIAL VIEW ON DISK AND AT LIMB. SEARCH FOR MECHANISMS OF FLARE ACCELERATION OF CHARGED PARTICLES, E. G., SUDDEN DISAPPEARANCES OF FILAMENTS, CORONAL MOTION, DUE TO HYDROMAGNETIC SHOCK WAVE IN CORONA. THE OBJECTIVE OF THIS EXPERIMENT IS TO OBSERVE MOTION OF CHROMOSPHERIC AND CORONAL MATERIAL IN AND ABOVE SOLAR FLARES. 40-INCH SOLAR TELESCOPE AT WAVELENGTHS 1216 - 8000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.1A, ANGULAR RESOLUTION 1 ARC SEC.
5	5	23	01	01	MODERATE DISPERSION SCAN, UV 4 POSITIONS ON DISK. THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE UV SPECTRUM OVER SOLAR DISK. 40-IN SOLAR TELESCOPE, AT WAVELENGTHS 1216 - 4000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 1A, ANGULAR RESOLUTION 1 SEC. ARC.
5	5	23	01	02	HIGH DISPERSION SCAN, UV 4 POSITIONS ON DISK. THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE VISIBLE AND UV SPECTRUM FROM POINT TO POINT OVER SOLAR DISK. DETERMINE CHEMICAL COMPOSITION. 40-INCH SOLAR TELESCOPE, AT WAVELENGTHS 500 - 8000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.0054, ANGULAR RESOLUTION 1 ARC SEC.
5	5	23	02	01	FLARE UV SPECTRA (ADVANCED). DO W/ ACTIVE REGION ON SUN. THE OBJECTIVE OF THIS EXPERIMENT IS TO MEASURE UV SPECTRUM OF SOLAR FLARES. 40-IN SOLAR TELESCOPE, AT WAVELENGTHS 500-4000A, IS THE PRIMARY INSTRUMENT, RESOLUTION 0.1A, ANGULAR RESOLUTION 0.1 ARC SEC.

EXPERIMENT NUMBER (AREA / OBJECT / SPEC / INVST / EXPT)	EXPERIMENT DESCRIPTION
	BIOLOGY
6 1 01 C2 01	BEHAVIOR AND RHYTHMS OF PLANTS AN ATTEMPT WILL BE MADE TO GERMINATE AND MAINTAIN HIGHER PLANTS UNDER 28-DAY-LONG CYCLE OF LIGHT AND DARKNESS NATURAL TO THE MOON. GROWTH RATE, GERMINATION, BRANCHING OF ROOTS AND STEMS, BUDDING AND LEAFING, PHOTOPERIODISM, TIME AND MANNER OF FLOWERING AND SEEDING, ABUNDANCE OF MITOSIS, AND MOVEMENTS WILL BE STUDIED. SOIL SAMPLES FROM ALL AVAILABLE SOURCES. FOUR REPETITIONS OF THIS INVESTIGATION ARE DESIRED.
6 1 01 03 01	GENETIC EFFECTS OF LUNAR CONDITIONS AND E/L TRIPS ON PLANTS GENETIC EFFECTS OF LUNAR CONDITIONS AND EARTH-LUNAR TRIPS-ON PLANTS. THE EXPERIMENT INCLUDES, AMONG OTHER SPECIFIC PROBLEMS, OBSERVATIONS OF POSSIBLE CYTOLOGICAL CHANGES OR GENE MUTATIONS INDUCED IN SOMATIC OR GERM CELLS BY CONDITIONS ENCOUNTERED ON THE MOON OR ON EARTH-LUNAR TRIPS. THE PROBLEM OF GREATEST CONCERN HERE INVOLVES THE EXTENT OF THE EFFECTS OF THE ADDITIONAL IONIZING RADIATION RECEIVED (PROVIDED THAT THEY ARE APPRECIABLE AT ALL BY AVAILABLE TECHNIQUES). SECONDLY, THERE IS THE QUESTION OF THE POSSIBLE GENETIC EFFECTS OF THE VIBRATION, ACCELERATION, ETC., TO WHICH THE CELLS ARE SUBJECTED DURING THE TRIPS. REPRESENTATIVE PLANTS WILL BE EMPLOYED IN THE STUDY. FOUR REPETITIONS OF THIS EXPERIMENT ARE DESIRED.
6 1 02 02 02	BEHAVIOR AND RHYTHMS OF ANIMALS FRUIT FLIES, MICE, DAPHNIA AND FOWL WILL BE EXAMINED FOR AT LEAST TWO GENERATIONS TO DETERMINE WHETHER THE PEAKS AND TROUGHS OF ECLOSION, EGG LAYING, ETC. WILL BE MODIFIED BY THE PERIODICITY OF THE LUNAR LIGHT/DARK CYCLE. FOUR REPETITIONS OF THIS EXPERIMENT ARE DESIRED.
6 1 03 03 03	GENETIC EFFECTS ON MICROORGANISMS. GENETIC EFFECTS OF LUNAR CONDITIONS AND EARTH-LUNAR TRIPS ON MICROORGANISMS-THE EXPERIMENT INCLUDES, AMONG OTHER SPECIFIC PROBLEMS, OBSERVATIONS OF POSSIBLE CYTOLOGICAL CHANGES OR GENE MUTATIONS INDUCED IN MICROORGANISMS BY CONDITIONS ENCOUNTERED ON THE MOON OR ON EARTH-LUNAR TRIPS. THE PROBLEM OF GREATEST CONCERN HERE INVOLVES THE EXTENT OF THE EFFECTS OF THE ADDITIONAL IONIZING RADIATION RECEIVED (PROVIDED THAT THEY ARE APPRECIABLE AT ALL BY AVAILABLE TECHNIQUES). SECONDLY, THERE IS THE QUESTION OF THE POSSIBLE GENETIC EFFECTS OF THE VIBRATION, ACCELERATION, ETC., TO WHICH THE ORGANISMS ARE SUBJECTED DURING THE TRIPS. SELECTED MICROORGANISMS, PARTICULARLY THOSE CONSIDERED FOR BIOREGENERATION SYSTEMS, WILL BE EMPLOYED IN THE STUDY. FOUR REPETITIONS OF THIS EXPERIMENT ARE DESIRED.
6 1 04 01 01	INDUCED PREBIOTIC CHEMISTRY THE PURPOSE OF THIS EXPERIMENT IS TO DETERMINE WHETHER A COMBINATION OF CHEMICALS, WHICH MAY REPRESENT THE COMPOSITION OF THE PRIMITIVE TERRESTRIAL OR LUNAR ATMOSPHERE, WHEN EXPOSED TO RADIATION ON THE SURFACE OF THE MOON WILL RESULT IN THE FORMATION OF COMPOUNDS SIMILAR TO THOSE OBTAINED IN TERRESTRIAL EXPERIMENTS AND, FURTHERMORE, TO DETERMINE WHETHER THE ADDITION OF LUNAR SOIL MATERIAL MODIFIES THE NATURE OR THE RATE OF FORMATION OF SUCH COMPOUNDS. CORE SAMPLES OBTAINED FOR OTHER GEOLOGIC OR GEOCHEMICAL STUDIES FROM ALL REPRESENTATIVE AREAS SHOULD BE INCORPORATED IN THIS PROGRAM. REACTION FLASKS MIXED WITH APPROPRIATE MIXTURES OF LIQUID, SOLID, AND GASEOUS CHEMICALS WILL BE SEALED AND EXPOSED TO THE APPROPRIATE LUNAR CONDITIONS. FOUR REPETITIONS OF THIS EXPERIMENT ARE DESIRED.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	BIOLOGY
6 1 04 C1 02	**EVICENCE OF EXISTING LIFE** THE PURPOSE OF THIS EXPERIMENT IS TO DETECT THE PRESENCE OF ORGANIC COMPOUNDS OF HIGH MOLECULAR WEIGHT IN THE LUNAR SOIL ANC,TO SEARCH FOR ORGANIZED REMAINS OF EXTINCT ORGANISMS, AND TO SEARCH FOR LIVING ORGANISMS IN AS MANY DIFFERENT SAMPLES OF LUNAR MATERIAL AS CAN BE MADE AVAILABLE FROM GEOLOGIC AND GEOCHEMICAL SOIL AND CORE COLLECTIONS.THIS WILL BE ACCOMPLISHED THROUGH CHEMICAL ANALYSIS, VISUAL,AND MICROSCOPIC EXAMINATION OF SOIL SAMPLES TAKEN DURING LUNAR DAY AND LUNAR NIGHT, FROM DIFFERENT STRATA. ASEPTIC SAMPLING TECHNIQUES WILL BE REQUIRED. CAREFUL LOGGING OF THE LOCATION,NATURE, DEPTH,ETC. IS ABSOLUTELY ESSENTIAL. FOUR REPETITIONS OF THIS EXPERIMENT PROGRAM ARE DESIRED.
6 2 03 C4 01	**SOIL BANK** LUNAR SAMPLE DEPOTS WILL BE ESTABLISHED AT VARIOUS LOCATIONS ON THE MOON AS EARLY AS POSSIBLE. SOIL SAMPLES FROM THE LUNAR SURFACE AND FROM CORES WILL BE ASEPTICALLY TAKEN FROM ALL AVAILABLE SITES, STORED ASEPTICALLY,AND PROTECTED FROM EXTERNAL INFLUENCES. AT A TIME LATER IN THE HISTORY OF MAN/S EXPLORATION OF THE MOON, SERVE AS PRACTICAL CONTROL SAMPLES, REFLECTING CONDITIONS WHEN THE MOON WAS RELATIVELY UNCONTAMINATED. THIS PROGRAM SHOULD BE CONDUCTED IN CONJUNCTION WITH THE GEOSCIENCES. ALL EQUIPMENT ITEMS REQUIRED FOR SPECIMEN COLLECTION WILL COME FROM THE GEOSCIENCES. ALL MAN HOURS ASSOCIATED WITH THE SOIL BANK SAMPLE COLLECTION ARE ASSUMED TO BE INCLUDED IN THE TIME ESTIMATES ALLOWED FOR THE RELATED GEOSCIENCE EXPERIMENTS.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJT SPEC INVS EXPT	ASTRONOMY
7 1 01 01 01	TEST OF SUITABILITY OF LUNAR LOCATION FOR ASTRONOMICAL OBSERVATORY 12-IN MEDIUM RESOLUTION REFLECTING TELESCOPE OPERATE AT F-50, RESOLUTION 0.15 SEC OF ARC AT 2500 ANGSTROMS. SET UP ON THE LUNAR SURFACE TO TEST THE LUNAR ENVIRNOMENT FOR OBSERVATORY SITE AND GAIN ENGINEERING EXPERIENCE FOR BUILDING LARGER INSTRUMENTS. TESTS ARE REQUIRED OF THE STABILITY OF TELESCOPE, INFLUENCE THERMAL CHANGES HAVE ON THE COLLECTION OF ASTRONOMICAL DATA, AND THE DETERIORATION OF THE OPTICAL SURFACES UNDER MICROMETEORITE AND SECONDARY PARTICLE BOMBARDMENT. AUXILLARY EQUIPMENT DESCRIBED IN EXPERIMENTS 2-4 ALSO TESTED. THREE REPETITIONS OF THIS EXPERIMENT DURING EARLY EXPLORATION PHASES WOULD BE DESIRABLE.
7 2 01 01 02	MEDIUM RESOLUTION ASTRONOMICAL PHOTOS - 12-INCH TELESCOPE MEDIUM RESOLUTION PHOTOGRAPHS OF PLANETS, NEBULAE, GALAXIES ETC. THROUGHOUT THE ACCESSIBLE SPECTRUM-PARTICULARLY IN THE WAVELENGTH INTERVAL 1000-3000 ANGSTROMS.
7 2 01 01 03	PHOTOELECTRIC OBSERVATIONS - 12-INCH TELESCOPE 12-INCH TELESCOPE--PHOTOELECTRIC RECORDING OF RADIATION FROM STARS, GALAXIES, ETC. PRIORITY GIVEN TO PECULIAR OBJECTS. DATA OBTAINED IN WAVELENGTH REGIONS INACCESSIBLE FROM EARTH. FLUX TO BE MEASURED AND INTEGRATED OVER SPECIFIC INTERVALS IN THE REGION OF TEN TO THE MINUS NINETEENTH TO TEN TO THE MINUS NINTH ERGS PER SQUARE CM PER SECOND PER ANGSTROM.
7 2 01 01 04	LOW DISPERSION SPECTROSCOPY OF STARS - 12-INCH TELESCOPE MEDIUM AND LOW DISPERSION SPECTROSCOPY OF STARS, PLANETS, GALAXIES, ETC. AT WAVELENGTHS INACCESSIBLE FROM THE EARTHS SURFACE.
7 2 01 02 05	PHOTO SURVEY OF SKY, 1000-3000 ANGSTROMS, 12-INCH TELESCOPE 12-INCH WIDE-FIELD REFLECTING TELESCOPE. 5 DEGREE FIELD. PHOTOGRAPHIC SURVEY OF THE SKY AT SEVERAL APPROPRIATE WAVELENGTHS IN THE INTERVAL 1000-3000 ANGSTROMS.
7 2 01 02 06	INVESTIGATE VARIABLE BRIGHTNESS EXTENDED SURFACE PHENOMENA 12-INCH WIDE FIELD TELESCOPE. INVESTIGATION OF VARIABLE, LOW BRIGHTNESS EXTENDED SURFACE PHENOMENON IN THE EARTH-MOON SYSTEM SUCH AS THE ZODIACAL LIGHT, GEGENSCHEIN, LUNAR LIBRATION CLOUDS, AND EARTHS EXTENDED MAGNETOSPHERE.
7 2 01 02 07	PHOTOELECTRIC SCANNING DATA ON EXTENDED OBJECTS 12-INCH WIDE FIELD TELESCOPE. PHOTOELECTRIC SCANNING MODE PHOTOMETER TO OBTAIN ISOPHOTOMETRIC DATA ON EXTENDED OBJECTS IN DIRECT DIGITIZED READOUT FORM. FLUX TO BE MEASURED AND INTEGRATED OVER SPECIFIC INTERVALS IN THE REGION OF TEN TO THE MINUS NINETEENTH TO TEN TO THE MINUS NINTH ERGS PER SQUARE CM PER SECOND PER ANGSTROM.
7 2 01 03 08	HIGH RESOLUTION PHOTOGRAPHIC STUDIES - 40-INCH TELESCOPE 40-INCH REFLECTING TELESCOPE. PHOTOGRAPHIC STUDIES OF FAINT AND BRIGHT OBJECTS AT HIGH RESOLUTION--0.1 SEC OF ARC AT 4000 ANGSTROMS REQUIRE F-10 OR HIGHER. OBSERVATIONS OBTAINED AT A VARIETY OF WAVELENGTHS. LARGE VARIETY OF FILTERS REQUIRED TO ISOLATE VARIOUS RADIATIONS. OBJECTS TO BE INVESTIGATED INCLUDE PLANETS, NEBULAE, GALAXIES, QUASARS, ETC.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJT SPEC INVS EXPT	ASTRONOMY
7 2 01 03 09	WIDE-BAND PHOTOGRAPHIC PHOTOMETRY - 40 INCH TELESCOPE 40-INCH TELESCOPE. WIDE-BAND PHOTOGRAPHIC PHOTOMETRY AT VERY FAINT LIMITS. USEFUL OBSERVATIONAL DATA TO MAKE TESTS OF COSMOLOGICAL . THEORIES, DETERMINE STELLAR CONTENT OF GALAXIES, ESTABLISHING THE COSMIC DISTANCE SCALE ETC. PHOTOGRAPHIC FILM TAKEN SPECIFICALLY FOR LATER PHOTOMETRIC REDUCTION.
7 2 01 03 10	PHOTOELECTRIC PHOTOMETRY - 40-INCH TELESCOPE PHOTOELECTRIC PHOTOMETRY OF SELECTED OBJECTS IN WAVELENGTHS NOT ACCESSIBLE FROM EARTHS SURFACE. PARTICULARLY OBJECTS THAT REQUIRE HIGH RESOLUTION CAPABILITIES OF 40-INCH. INTERCHANGEABLE DETECTORS TO ADEQUATELY COVER ALL SPECTRAL REGIONS. 40-INCH TEL. FLUX TO BE MEASURED AND INTEGRATED OVER SPECIFIC INTERVALS IN THE REGION OF TEN TO THE MINUS NINETEENTH TO TEN TO THE MINUS NINTH ERGS PER SQUARE CM PER SECOND PER ANGSTROM.
7 2 01 03 11	LOW DISPERSION SPECTROSCOPY - 40-INCH TELESCOPE MEDIUM AND LOW DISPERSION SPECTROSCOPY OF FAINT STARS NEBULAE ETC. AT PRIME OR CASSEGRAIN FOCUS. SPECTROGRAPHS DESIGNED TO OPERATE AT A VARIETY OF DISPERSIONS EFFICIENTLY IN THE UV AND IR REGIONS OF THE SPECTRUM INACCESSIBLE FROM THE EARTHS SURFACE. APPLICABLE FOR RED SHIFT MEASUREMENTS IN DISTANT GALAXIES AND QUASARS.
7 2 01 03 12	HIGH DISPERSION SPECTROSCOPY - 40-INCH TELESCOPE HIGH DISPERSION SPECTROSCOPY OF BRIGHT STARS, NEBULAE, PLANETS, ETC. AT COUDE FOCUS. DATA RECORDED ON PHOTOGRAPHIC FILM. 40-INCH TEL.
7 2 01 03 13	SPECTRAL SCANS OF VARIOUS OBJECTS - 40-INCH TELESCOPE SPECTRAL SCANS GIVING DIRECT INTENSITY READOUT OF RADIANT ENERGY OF VARIOUS OBJECTS AS A FUNCTION OF WAVELENGTH..SCANNER PLACED AT THE CASSEGRAIN OR COUDE FOCUS. 40-INCH TEL. FLUX TO BE MEASURED AND INTEGRATED OVER SPECIFIC INTERVALS IN THE REGION OF TEN TO THE MINUS NINETEENTH TO TEN TO THE MINUS NINTH ERGS PER SQ CM PER SEC PER ANGSTROM.
7 2 01 04 14	HIGH RESOLUTION PHOTOGRAPHIC STUDIES - 100-INCH TELESCOPE HIGH RESOLUTION PHOTOGRAPHY OF PLANETS, NEBULAE, QUASARS, STAR CLUSTERS ETC. INSTRUMENTATION--100 INCH DIFFRACTION LIMITED TELESCOPE OPERATING EFFICIENTLY IN THE WAVELENGTH INTERVAL 1000 TO 3000 ANGSTROMS AS WELL AS IN THE VISIBLE SPECTRUM.
7 2 01 04 15	HIGH DISPERSION SPECTROSCOPY - 100-INCH TELESCOPE HIGH DISPERSION SPECTROSCOPY OF STARS, PLANETS, NEBULAE, COMETS, QUASARS, ETC. 100 - INCH HIGH DISPERSION SPECTROGRAPH.
7 2 01 04 16	SYSTEMATIC OBSERVATIONS OF HIGH ENERGY STELLAR PHENOMENA SYSTEMATIC OBSERVATIONS OF HIGH ENERGY PHENOMENA IN SELECTED NORMAL STARS OF VARIOUS SPECTRAL TYPE, QUASISTELLAR OBJECTS, AND OTHER HIGH ENERGY GALACTIC AND INTERGALACTIC SOURCES. HIGH DISPERSION SPECTROGRAPH USED TO STUDY INTENSITIES AND TIME VARIATION OF HIGH EXCITATION LINES IN FAR UV THAT ARISE IN THE CHROMOSPHERIC AND CORONA REGIONS OF STARS.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AGSIE RBPNX EJEVP ATCST	ASTRONOMY
7 2 01 04 17	DETERMINATION OF NATURE AND EXTENT OF STELLAR OUTER ENVELOPES OBSERVATIONS TO DETERMINE THE EXTENT AND NATURE OF THE OUTER ENVELOPES OF STARS. APPLICATION OF CORONOGRAPH TECNIQUE NECESSARY TO ELIMINATE THE LIGHT OF STAR. OBSERVATIONS SECURED AT F-100 FOCUS OF 100-INCH DIFFRACTION LIMETED TELESCOPE. OBSERVATIONS SECURED IN THE UV WHERE HIGHEST RESOLUTION IS POSSIBLE.
7 2 C1 C4 18	PHOTO SURVEY FOR PLANET-LIKE COMPANIONS OF STARS - 100-INCH TELESCOPE PHOTOGRAPHIC SURVEY TO ATTEMPT TO FIND PLANET-LIKE COMPANIONS OF STARS, UTILIZE THE HIGH RESOLUTION OF THE 100-INCH TELESCOPE TO SEARCH FOR FAINT OBJECTS IN THE PROXIMITY OF THE NEARBY STARS. AN OCCULTING DISK CAN BE EMPLOYED TO ELIMINATE THE IMAGE OF THE BRIGHT STAR.
7 2 C1 C4 19	PHOTOLECTRIC MAGNITUDE AND COLOR INDEX MEASUREMENTS OF STARS PHOTOELECTRIC MAGNITUDE AND COLOR INDEX MEASUREMENTS OF THE FAINTEST GALAXIES AND QUASARS TO PROVIDE BASIC DATA NECESSARY TO ESTABLISH ACCURATELY THE COSMIC DISTANCE SCALE. FLUX TO BE MEASURED AND INTEGRATED OVER SPECIFIC INTERVALS IN THE REGION OF TEN TO THE MINUS NINETEENTH TO TEN TO THE MINUS NINTH ERGS PER SQ CM PER SEC PER ANGSTROM.
7 2 C1 C5 21	LYMAN ALPHA SURVEY OF THE SKY MAP THE SKY IN BOTH DIRECTION AND MAGNITUDE. EMPLOY SMALL CAMERA WITH A TUNEABLE FILTER TO COMPENSATE FOR DOPPLER SHIFTS OF INTERSTELLAR CLOUDS. FLUX TO BE MEASURED AND INTEGRATED OVER SPECIFIC INTERVALS IN THE REGION OF TEN TO THE MINUS SIXTEENTH TO TEN TO THE MINUS TWELFTH ERGS PER SQ CM PER SEC PER ANGSTROM.
7 3 C2 C6 22	X-RAY RADIATION STUDY 10.-0.1 ANGSTROMS INVESTIGATION OF THE X-RAY RADIATION FROM SUN, STARS, GALAXIES AND X-RAY SOURCES (10-0.1 ANG.) MOON OFFERS A STABLE BASE, HIGH POINTING ACCURACY, AND LOW RADIATION BACKGROUND. SPECTRAL CHACTERISTICS AND ROUGH ANGULAR POSITION OF SOURCES PROVIDED BY MEASUREMENTS MADE WITH GEIGER COUNTER MODULE TELESCOPE ASSEMBLY AND GAS FILLED FILTER PLACED OVER TELESCOPE. MAP ENTIRE SKY. INSTRUMENT MOUNTED TO MAKE USE OF THE HORIZON AS AN OCCULTING EDGE.
7 3 02 C6 23	HIGH RESOLUTION STUDY OF X-RAY SOURCES 10.-0.1 ANGSTROMS OBSERVATIONS OF X RAY SOURCES WITH HIGH ANGULAR RESOLUTION. (10-0.1 ANGSTROMS). EMPLOY LARGE AREA GRAZING INCIDENCE REFLECTOR
7 3 02 C6 24	INTERSTELLAR MEDIUM DISTRIBUTION INVESTIGATION - X-RAY OBSERVATION INVESIGATION OF INTERSTELLAR MEDIUM DISTRIBUTION BY OBSERVING X-RAY RADIATION IN THE 10-20 ANGSTROM REGION WHERE X-RAY RADIATION IS ABSORBED BY INTERSTELLAR ATOMS. INSTRUMENTATION SIMILIAR TO EXPERIMENTS 23 AND 24.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA OBJT SPEC INVS EXPT	ASTRONOMY
7 3 03 07 25	DETECTION OF HIGH ENERGY GAMMA RAYS +50MEV DETECTION OF GAMMA RAY RADIATION WITH ENERGIES GREATER THAN 50 MEV. PROVIDE DATA ON HIGH ENERGY COLLISIONS IN THE INTERSTELLAR MEDIUM AND A POSSIBLE LINK TO ENERGETIC PROCESSES OCCURING IN QUASARS. INSTRUMENTATION-- SOLID STATE DETECTOR UTILIZING BREMSSTRAHLUNG, COMPTON, AND PAIR PRODUCTION EFFECTS. SYSTEM OF COLLIMATORS TO OBTAIN ANGULAR RESOLUTION. ROTATE TUNGSTEN FILAMENT ALTERNATELY BELOW THE TOP OF THE SCINILLATER BUT ABOVE THE GAS CERENKOV DETECTOR.
7 4 01 05 20	EINSTEIN ECLIPSE PROBLEM EINSTEIN ECLIPSE PROBLEM-PHOTOGRAPHS OF SAME STAR FIELD--ONE WITH SUN PRESENT AND OTHER WITH ONLY STARS. CRITICAL PHOTOGRAPH WITH SUN PRESENT OBTAINED JUST BEFORE SUNRISE OR WITH OCCULTING DISK. 5-INCH PHOTOGRAPHIC REFRACTOR 144-INCH FOCAL LENGTH.
7 5 04 01 01	NON-DIRECTIONAL RADIO ASTRONOMY THIS EXPERIMENT UTILIZES SIMPLE ANTENNA/RADIOMETER SYSTEMS TO MONITOR RADIO EMISSIONS FROM DISCRETE SOURCES IN THE TIME DOMAIN. JUPITER DECAMETER BURSTS AND SOLAR METER-WAVE BURSTS WILL BE OF PRIME IMPORTANCE, BUT SEARCHES FOR LOW FREQUENCY EMISSION FROM OTHER OBJECTS IN THE SOLAR SYSTEM, ESPECIALLY THE TERRESTRIAL PLANETS, WILL ALSO BE OF INTEREST. THE EXPERIMENT WILL BE CONDUCTED IN THE FREQUENCY BAND FROM 300 KHZ TO 20 MHZ.
7 5 05 01 02	DIRECTIONAL RADIO ASTRONOMY THIS EXPERIMENT INVOLVES THE DEPLOYMENT OF AN INTERFEROMETER ON THE LUNAR SURFACE TO STUDY THE TWENTY MAJOR DISCRETE RADIO SOURCES AT AND NEAR 1 MHZ. TWO ELEMENTS OF LENGTH 1800 METERS, EACH CONSISTING OF 12 IN-LINE DIPOLES ARE ARRANGED TO FORM AN INTERFEROMETER WITH AN EAST-WEST BASELINE. THE SPACING BETWEEN THE CENTERS OF THE TWO ELEMENTS IS 5 KM. ONE ELEMENT IS DEPLOYED AT THE CENTRAL SITE AND ANOTHER AT A REMOTE SITE. A RADIO LINK CONNECTS THE REMOTE ELEMENT TO THE CENTRALLY LOCATED RADIOMETER. SOURCE FLUX DENSITY, OR MORE PRECISELY, ANTENNA TEMPERATURE, IS RECORDED CONTINUOUSLY. THE RECORD REVEALS THE SPATIAL DISTRIBUTION (IN RIGHT ASCENSION) AND INTENSITY OF THE SOURCES TO BE STUDIED.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
AREA / OBJECT / SPEC / INVS / EXPT	ASTRONOMY
7 5 C6 C1 01	SUBMILLIMETER RADIO ASTRONOMY EXPERIMENTS THIS SET OF EXPERIMENTS IS DESIGNED TO TEST AND IMPROVE THE EFFICIENCY OF SUBMILLIMETER ASTRONOMY IN THE SPECTRAL RANGE OF 1 MILLIMETER DOWN TO 10 OR 20 MICRONS. IT IS PROPOSED TO INSTALL AND TEST-OPERATE A SUITABLE RADIOMETRIC SYSTEM WITH A STEERABLE 100-FOOT ANTENNA ON THE LIMB OF THE MOON IN THE 1975 TIME ERA. THE RESULTS WILL GUIDE THE SUBSEQUENT DESIGN OF PERMANENT-BASE EQUIPMENT, PROBABLY TO BE LOCATED ON THE FAR SIDE OF THE MOON IN THE POST-1980 ERA. PRIOR DATA WILL BE REQUIRED ON LUNAR SURFACE AND SUBSURFACE INTEGRITY AND THERMAL ENVIRONMENT, ALONG WITH AN INTENSIVE DESIGN AND DEVELOPMENT PROGRAM TO PRODUCE EQUIPMENT OF THE REQUISITE STABILITY, ACCURACY, SENSITIVITY, AND DURABILITY. THE INSTALLATION AND CALIBRATION PROCESS ITESELF WILL CONSTITUTE AN EXPERIMENT, SUPPORTED BY ASSOCIATED GEOPHYSICAL AND ENVIRONMENTAL SUBEXPERIMENTS. RADIO-ASTRONOMY OBSERVATIONS TO BE PERFORMED MAY INCLUDE FREQUENCY-VERSUS-INTENSITY READINGS OF THE LOWER SOLAR CHROMOSPHERE, OF GALACTIC, EXTRAGALACTIC, AND QUASI-STELLAR SOURCES, POLARIZATION MEASUREMENTS FOR MAPPING THE MAGNETIC FIELDS IN RADIO SOURCES, SCANNING OF LOW-TEMPERATURE OBJECTS PEAKING IN THE 10-TO-20-MICRON RANGE, AND POSSIBLY SPECTROSCOPIC OBSERVATIONS. MANY THOUSANDS OF READINGS MAY BE MADE OVER POSSIBLY A SIX-MONTH PERIOD. AMPLE PROVISION SHOULD BE MADE FOR RECORDING AND FOR A 2-WAY SURFACE LINK BETWEEN THE INSTALLATION AND THE MANNED BASE, PROVIDING FOR REMOTE COMMAND AND CONTROL AND FOR DATA RETURN, E.G. 1013 TOTAL BITS. PERIODICAL MANNED MAINTENANCE AT LEAST TWICE A MONTH IS INDICATED (E.G. 20 EGRESSES). THE EXTENT OF MOON-TO-EARTH TRANSMISSION WILL DEPEND ON THE 1975 STATE-OF-THE-COMMUNICATIONS-ART. FOLLOWING THE EXPERIMENT, THE PERMANENT PHYSICAL RECORD WILL BE RETURNED TO EARTH.
7 6 07 C1 02	LUNAR WAVE PROPAGATION EXPERIMENT A TRANSMITTER AND A RECEIVER WILL BE DEPLOYED SEPARATED BY A DISTANCE OF 1-10 KILOMETERS. THE FREQUENCY RANGE WILL BE 1 KHZ TO 30 MHZ. THE TRANSMITTING ANTENNA WILL BE A BEVERAGE WAVE ANTENNA SUPPLEMENTED BY A VERTICAL WHIP OR DIPOLE. THE RECEIVER WILL BE A PORTABLE FIELD STRENGTH METER WITH BUILT-IN ANTENNA. THE OPERATING TIME WILL BE APPROXIMATELY TEN MINUTES FOR EACH FREQUENCY RUN MEASUREMENT AT EACH RECEIVER POSITION. THE OBSERVATION SEQUENCE WILL BE MADE DURING SPECIAL EVENTS, SUCH AS DURING SOLAR FLARES AND PASSING THROUGH THE TAIL OF THE EARTH MAGNETOSPHERE, AND DURING THE LUNAR DAY AND LUNAR NIGHT. THE ASTRONAUT'S TIME WILL BE REQUIRED IN POSITIONING OF THE FIELD STRENGTH METER AND CHECKING CALIBRATION.
7 7 07 01 01	LUNAR AMBIENT VECTOR MAGNETIC FIELD MEASUREMENTS A TRI-AXIS MAGNETOMETER WILL BE UTILIZED TO MEASURE THE MAGNITUDE AND DIRECTION OF THE AMBIENT MAGNETIC FIELD VECTOR. THESE MEASUREMENTS WILL BE CONDUCTED AT A SAMPLE RATE OF ONCE PER SECOND, (DURATION 5 MINUTES) AND THE EXPERIMENT WILL BE CARRIED OUT TWICE EACH 24-HOUR PERIOD DURING THE LUNAR DAY AND LUNAR NIGHT. THE EXPERIMENT DURATION WILL BE EXTENDED AS REQUIRED DURING PERIODS OF SOLAR WIND ACTIVITY. THE SENSOR SHOULD BE PLACED AT A LOCATION WHERE UNWANTED STRAY MAGNETIC FIELDS ARE LESS THAN 0.25 GAMMA.

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

ASTRONOMY

7 8 C7 01 01

CISLUNAR WAVE PROPAGATION-STUDY OF MEDIUM

UTILIZING TRANSMITTERS DEPLOYED ON THE EARTH, PERHAPS AT SITES IN THE DEEP SPACE NET, AND A TRANSPONDER DEPLOYED ON THE LUNAR SURFACE, PHASE MODULATED CARRIER FREQUENCIES OF 50 AND 400 MHZ ARE TRANSMITTED TO THE MOON WHERE THEY ARE COHERENTLY TRANSLATED IN FREQUENCY AND RETRANSMITTED TO THE EARTH. MEASUREMENT OF THE DIFFERENTIAL GROUP PATH UNDERGONE BY THE TWO SIGNALS THEN ALLOWS THE DETERMINATION OF THE ABSOLUTE VALUE OF THE INTEGRATED ELECTRON DENSITY BETWEEN THE EARTH AND THE MOON.
DIFFERENTIAL FARADAY POLARIZATION MEASUREMENTS ARE CONDUCTED USING A SIDE-BAND OF THE MODULATED 50 MHZ SIGNAL. FOR THIS EXPERIMENT ONLY LUNAR-BASED TRANSPONDER IS REQUIRED. MEASUREMENT OF DIFFERENTIAL FARADAY POLARIZATION ALLOWS THE DETERMINATION OF THE INTEGRATED ELECTRON DENSITY AS WEIGHTED BY THE LONGITUDINAL COMPONENT OF THE MAGNETIC FIELD ALONG THE PROPAGATION PATH. THIS CONSTITUTES A MEASURE OF THE INTEGRATED ELECTRON DENSITY IN THE EARTH'S IONOSPHERE. EXTRA-TERRESTRIAL CIS-LUNAR INTEGRATED ELECTRON DENSITY CAN BE DETERMINED BY SUBTRACTING THIS VALUE FROM THE VALUE OBTAINED FOR TOTAL INTEGRATED ELECTRON DENSITY BY MEASUREMENT OF DIFFERENTIAL GROUP PATH.
UTILIZING THE TRANSPONDERS AT 50 AND 400 MHZ, DIFFERENTIAL DOPPLER MEASUREMENTS ARE CONDUCTED. THIS ALLOWS THE DETERMINATION OF DOPPLER EXCESS FREQUENCY WHICH IS A MEASURE OF THE TIME RATE OF CHANGE OF THE INTEGRATED ELECTRON DENSITY BETWEEN THE EARTH AND THE MOON. VARIATIONS INJECTED INTO THE MEDIA BY THE SUN AND THE EARTH CAN BE INVESTIGATED BY THIS TECHNIQUE.

7 8 C7 01 02

CISLUNAR WAVE PROPAGATION-ADVANCED CENTRAL STATION

THIS EXPERIMENT WILL BE AN ADVANCED MODIFIED VERSION OF EXPERIMENT 78C1C1C1 WHICH WAS CONDUCTED DURING THE EARLY EXPLORATION PERIOD (1972-3). THE MODIFIED VERSION WILL INCORPORATE A THREE-FREQUENCY TRANSPONDER CAPABLE OF OPERATING AT NOT ONLY 50 AND 400 MHZ BUT ALSO 2300 MHZ. MODULATED CARRIERS TRANSMITTED FROM EARTH ARE RECEIVED BY THE LUNAR-BASED TRANSPONDER, COHERENTLY SHIFTED IN FREQUENCY, AND RETRANSMITTED TO EARTH. ON EARTH, SIMULTANEOUS MEASUREMENTS OF GROUP AND PHASE PATH DELAY ARE CONDUCTED FOR EACH OF THE RETURNED SIGNALS.
UTILIZING THE SIMULTANEOUS MEASUREMENT OF DIFFERENTIAL GROUP PATH (WHICH GIVES INTEGRATED ELECTRON DENSITY), THE TECHNIQUE ALLOWS THE EFFECTS OF THE CIS-LUNAR MEDIUM TO BE ACCOUNTED FOR, THUS GIVING EXTREMELY ACCURATE EARTH-MOON RANGE (IN PRINCIPLE WITHIN A FEW CENTIMETERS) CONTINUOUSLY AS A FUNCTION OF TIME. THE EXPERIMENT CONTRIBUTES VALUABLE DATA FOR INVESTIGATING EARTH-MOON DYNAMICS.

7 8 C7 01 03

CISLUNAR WAVE PROPAGATION-ADVANCED OUTLYING STATION A

THIS STATION WILL BE THE SAME AS DESCRIBED IN EXPERIMENT 78C2C1C1. IT WILL BE IMPLEMENTED AT A REMOTE OUTLYING POINT, 1000 KM DISTANT FROM THE CENTRAL STATION IN LUNAR EQUATORIAL REGION (EXPERIMENT 742XX01). SIMULTANEOUS WITH THIS IMPLEMENTATION, ANOTHER SIMILAR STATION WILL BE IMPLEMENTED 1000 KM FROM THE CENTRAL STATION, BUT TOWARD THE POLE. THESE THREE STATIONS, WELL SEPARATED IN LUNAR LATITUDE AND LONGITUDE, WILL ALLOW PRECISION STUDIES OF EARTH-MOON DYNAMICS TO BE CARRIED OUT.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	ASTRONOMY
7 8 07 C1 04	CISLUNAR WAVE PROPAGATION-ADVANCED OUTLYING STATION B THIS STATION AND EXPERIMENT IS IDENTICAL TO THE IMPLEMENTATION DESCRIBED IN EXPERIMENT 78020102 EXCEPT FOR LOCATION. IT IS LOCATED NEAR THE POLAR REGION, WHILE EXPERIMENT 7802C102 IS IMPLEMENTED IN THE EQUATORIAL ZONE.
7 9 07 C1 01	ELECTRIC FIELD MEASUREMENT FROM LUNAR ORBIT THE PURPOSE OF THE EXPERIMENT IS TO MEASURE THE EXISTENCE, IF ANY, AND THE MAGNITUDE OF THE ELECTRICAL FIELD NEAR THE MOON, E.G. AT 100-KILOMETER ALTITUDE, ALSO TO COMPLETE THE VERTICAL PROFILE OBTAINED BY ELECTRICAL READINGS AT THE SURFACE AND 10-METER ALTITUDES. IN ORBIT, AS AT LOWER LEVEL, FIELD STRENGTH IS BELIEVED TO BE CLEARLY RELATED TO THE INTERACTION OF THE SOLAR WIND WITH THE LUNAR SURFACE. ORBITAL MEASUREMENTS MAY BE MADE BY AN ELECTRIC METER SIMILAR TO THAT PLANNED FOR THE SURFACE PACKAGE. THE INSTRUMENTS WILL BE PLACED IN AN UNMANNED SUBSATELLITE, TO BE LAUNCHED FROM THE MANNED ORBITER, IN ORDER TO PROVIDE CORRELATED SATELLITE-LEVEL READINGS FOR THE LIFETIME OF THE SURFACE INSTRUMENT PACKAGE. DATA WILL BE TRANSMITTED TO EARTH. THOUSANDS OF INDIVIDUAL READINGS MAY BE MADE DURING THE LIFE OF THE EXPERIMENT.
7 9 07 01 02	AGNETIC FIELD MEASUREMENT FROM LUNAR ORBIT IN CORRELATION WITH SURFACE MEASUREMENTS, ORBITAL MEASUREMENTS WILL BE MADE OF THE LUNAR MAGNETIC FIELD TO PROVIDE DATA ON THE GROSS ELECTRICAL CONDUCTIVITY OF THE MOON, THE FLOW OF SOLAR WIND PAST IT, AND THE RESULTING POSSIBLE FORMATION OF A STANDING SHOCK FRONT. TWO TYPES OF ORBITS ARE INDICATED FOR THE WORK (1) THE STANDARD 100-KILOMETER CIRCULAR ORBIT TO STUDY DAY-NIGHT CHANGES, AND (2) AN ELLIPTICAL 100-TO-2000-KILOMETER ORBIT, SO AS TO PENETRATE ANY SHOCK FRONT. INSTRUMENTATION WILL BE SIMILAR TO THE SURFACE EXPERIMENT, PROBABLY A 3-AXIS HELIUM MAGNETOMETER. THE INSTRUMENTS WILL BE PLACED IN UNMANNED SUBSATELLITES, TO BE LAUNCHED FROM THE MANNED ORBITER, IN ORDER TO PROVIDE CORRELATED SATELLITE-LEVEL READINGS FOR THE LIFETIME OF THE SURFACE INSTRUMENT PACKAGE. DATA WILL BE TRANSMITTED TO EARTH. THOUSANDS OF INDIVIDUAL READINGS MAY BE MADE DURING THE LIFE OF THE EXPERIMENT.
7 9 07 C1 03	PARTICLE FLUX MEASUREMENTS FROM LUNAR ORBIT IN CORRELATION WITH SURFACE MEASUREMENTS, ORBITAL MEASUREMENTS WILL BE MADE OF THE FLUX DIRECTIONALITY AND ENERGY DISTRIBUTION OF ELECTRONS AND PROTONS WITHIN THE 10 EV TO 100 KE V ENERGY RANGE, DURING BOTH LUNAR DAY AND NIGHT. THE STANDARD 100-KILOMETER ORBIT IS INDICATED. THE FARADAY CUP AND ELECTROSTATIC ANALYSER ARE PROPOSED FOR THIS EXPERIMENT, BACKED BY A SUITABLE PROGRAMMING DEVICE. THE EQUIPMENT WILL BE PLACED IN AN UNMANNED SUBSATELLITE, TO BE LAUNCHED FROM THE MANNED ORBITER, IN ORDER TO PROVIDE CORRELATED SATELLITE-LEVEL READINGS FOR THE LIFETIME OF THE SURFACE INSTRUMENT PACKAGE. DATA WILL BE TRANSMITTED TO EARTH. THOUSANDS OF INDIVIDUAL READINGS MAY BE MADE DURING THE LIFE OF THE EXPERIMENT.

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3.0 MISSION SUPPORT INVESTIGATIONS, AND MISCELLANEOUS BASIC AND APPLIED RESEARCH

3.1 INTRODUCTION

It is assumed that the greater portion of the investigation effort expended on the Moon will be fundamental in nature. However, to ensure assessment of a complete spectrum of mission support requirements for extended lunar exploration, two additional categories of investigations are considered in the present study. These categories have been designated as "Mission Support Investigations" and "Miscellaneous Basic and Applied Research," and have been identified respectively as "Discipline Area 8" and "Discipline Area 9."

Mission Support Investigations include the following types of experiments:

1. Experiments that are critical for lunar fundamental investigations and lunar surface operations

2. Experiments that may dictate sequence of operations or fundamental investigations or may affect lunar exploration phasing

3. Experiments that may improve technical or operational capability to perform fundamental investigations

4. Experiments to prove feasibility of the utilization of lunar resources

The Miscellaneous Basic and Applied Research category includes research activities on the lunar surface that are not directly oriented toward answering fundamental questions concerning the Moon or the other planets and stars, but take advantage of the unique characteristics of the lunar environment to extend basic and applied scientific knowledge and technological capabilities.

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3.2 MISSION SUPPORT INVESTIGATIONS

3.2.1 OBJECTIVES

The objectives of Mission Support Investigations are: (1) to contribute to the effectiveness of the fundamental investigations program; (2) to support implementation of lunar exploration by advancement of subsystems and operations technology in the lunar environment; and (3) to assess and demonstrate the feasibility of lunar resources utilization.

3.2.2 ORGANIZATION

Thirty investigational categories were established within this discipline area. These categories were further organized into six "Functional Specialty", groups.

Table 6 presents the organization, and distribution of investigations and experiments of Mission Support Investigations into functional specialties.

3.2.3 APPROACH

The approach followed for the compilation of experiments and investigations included in the Mission Support Investigations category differs markedly from that followed for the Fundamental Investigations category because very little formal background exists in the definition of supporting investigations and experiments to be performed in the lunar environment. As a result, a series of preliminary activities preceded the review, collation, condensation, and final experiment definition. These activities consisted of a requirements definition phase, a preliminary concept phase and an assessment phase.

The requirements definition phase was initiated first. This was an iterative activity supported in part by a document source review, particularly in problem areas which were already defined or wherever recommendations for supporting research were offered. Requirements for direct support to fundamental investigations were identified by the NAA scientists responsible for the respective scientific discipline areas.

A separate, selective review of NASA-supplied source data was performed subsequent to the major source data review for Fundamental Investigations. This review was required because the literature generally

Table 6. Organization of Mission Support Investigations—
(Discipline Area 8)

Functional Specialty Grouping	Number Submitted
AUGMENTATION OF LUNAR DATA TO SUPPORT ENGINEERING MODEL	
Lunar surface/subsurface engineering properties	10
Lunar environment characteristics	9
Total	19
DIRECT SUPPORT TO FUNDAMENTAL INVESTIGATIONS	
Support to geodesy and cartography	0
Support to geology	5
Support to geophysics	4
Support to geochemistry/petrology	1
Support to bioscience	1
Support to particles and fields	0
Support to meteorology/oceanography	0
Support to radio astronomy	3
Support to optical astronomy	2
Support to X-ray and gamma-ray astronomy	0
Total	16
APPLIED LIFE SCIENCES INVESTIGATIONS	
Applied biomedical and human factors investigations	8
Life support applied research	10
Total	18
BASIC SUBSYSTEMS SUPPORT INVESTIGATIONS	
Environmental control applied research	1
Lunar communications applied research	6
Power systems applied research	3
Materials technology support	12
Lunar structures research	2
Fluid mechanics research	3
Total	27

Table 6. Organization of Mission Support Investigations—
(Discipline Area 8) (Cont)

Functional Specialty Grouping	Number Submitted
MOBILITY AND DEPLOYMENT SUPPORT INVESTIGATIONS	
Land locomotion research	2
Land navigation research	2
Lunar flying vehicle and ballistic mode research	0
Surface modification technology	2
Lunar construction technology	1
Total	7
LUNAR RESOURCES UTILIZATION FEASIBILITY	
Lunar resources prospecting and analysis	6
Mining and materials handling technology	1
Materials extraction and processing technology	1
Manufacturing techniques	0
Resources application techniques	1
Total	9
TOTAL DISCIPLINE AREA 8	96

identifies problems and suggests Earth-based supporting research but does not follow up with the final phase of the supporting research programs, which deals with experiment performance and interaction with the lunar environment

Preliminary mission support investigations and experiments were developed in response to the requirements inferred in the literature and defined by study participants. These were reviewed internally, employing the ground rule that the investigations should be consistent with the objectives; compatible with the lunar environment; and implementable. The experiment definition did not include qualification tests, demonstration tests, or general monitoring tests for checking equipment performance.

A preliminary set of experiment and investigation descriptions was subsequently submitted to NASA. This descriptive set was reviewed by the Office of Advanced Research and Technology at Headquarters and by the U. S. Army, Office of the Chief Engineer. In these reviews, the investigations and experiments were rated as follows:

Top priority—shoud be accomplished as soon as possible.
Very important—should be done early in the exploration program
Not very high priority or importance
May be important, but not necessary until much later in the lunar program
Of questionable or doubtful value

These ratings and associated guidance were then acted upon by (1) deleting or redefining investigations or experiments, (2) defining phasing, importance, and urgency in the summary type 1 cards of the experiment data system (see Section 4.5), and (3) utilizing them as a guide in preparing the Exploration Phase and Composite Sequence, Sections 7.4 and 7.5.

3.2.4 GENERAL DISCUSSION

The investigation and experiment contents of the Mission Support Investigations category are discussed briefly within the format provided by the functional specialty groupings (Table 6).

3.2.4.1 Augmentation of Lunar Data to Support Engineering Model

Acquisition of lunar surface and subsurface data and lunar environment data clearly will be valuable to science and to engineering; therefore the question arises as to when an investigation or experiment is basic (or fundamental), and when it should be categorized for mission support. The approach adopted considers that information obtained from fundamental investigations of the surface and environment will be utilized to provide much needed basic data for engineering models. In part, the augmentation is directed toward obtaining data for specific missions and operations, however it is directed primarily toward developing detailed engineering models that will establish design and operations criteria for both scientific exploration and mission support equipment and operations.

Investigations that extend surface and subsurface properties data concern macroscopic characteristics of the surface; the mechanical, thermal, electrical, and chemical properties of lunar materials; and subsurface motions and seismic activity. Typical of special macroscopic characteristics rated as top priority-early is the "Topography of Proposed AAP LEM Landing Sites" (see Table 8). Mechanical, thermal, and electrical property data requirements will be very extensive for the full spectrum of lunar missions. The roughness and the mechanical properties of the lunar surface are basic to performing vehicular operations, equipment placement, and core drilling. Nuclear and chemical properties, such as hydrogen content, will affect reactor emplacement and radiation shielding effectiveness. Additional requirements for chemical property data will

arise from possible corrosion of transmission lines and buried components. The electrical conductivity, dielectric constant, and magnetic permeability of subsurface materials and strata will require measurements at d-c levels and at various frequencies to assess the feasibility of surface and subsurface electromagnetic propagation. These measurements also support radio-astronomy technology. Lunar seismic data will be required to support site selection and operation of a lunar observatory.

Surface environmental properties that will affect mission operations and equipment performance include meteoroids, secondary ejecta and dust, thermal radiation, and plasma and electromagnetic frequencies. Dust may be spread by natural causes, such as meteoroid and radiation bombardment, and by human activities, such as excavation, walking, and vehicular activities. This indicates a requirement for a program of monitoring dust collection in relation to the mechanisms of collection. Accumulation of electrically insulating dust on antennas and radio telescopes will also be a potential problem. The electron density, plasma frequency, and electromagnetic radiation frequency spectrum near the surface establish the background for communications and for radio-astronomy investigations.

3.2.4.2 Direct Support to Fundamental Investigations

Direct support requirements to implement fundamental investigations and to interpret the results with confidence have led to the preliminary definition of investigations for performance in lunar missions. Figure 6 lists the disciplines for which supporting investigations have been defined and indicates the principal technology orientation of suggested investigations for each discipline. Disciplines supported are grouped into three blocks: geosciences, biology, and astronomical and observational sciences.

Geology support investigations include ground-truth survey in support of sample collection, "Calibration of Remote Sensing Techniques" (suggested in Reference 2), and improvement of core drilling technology. Applied geophysics investigations include determination of "Relative Electrode Electrical Coupling Properties in the Lunar Surface: and reference (calibration) measurements. Cratering studies provide data on explosive energy coupling in lunar materials in support of seismic exploration. A geochemistry support investigation provides for correlation and assessment of techniques employed in hydrogen detection in lunar materials.

In the astronomical and observational sciences, the performance of optical astronomical observations from the moon depends in part on the effects of the lunar environment on telescopes. Pointing accuracy, stability under thermal and seismic changes, meteoritic erosion, and thermal expansion of optical surfaces require evaluation. These applied investigations can be conducted with the 12-inch reflector used in the fundamental

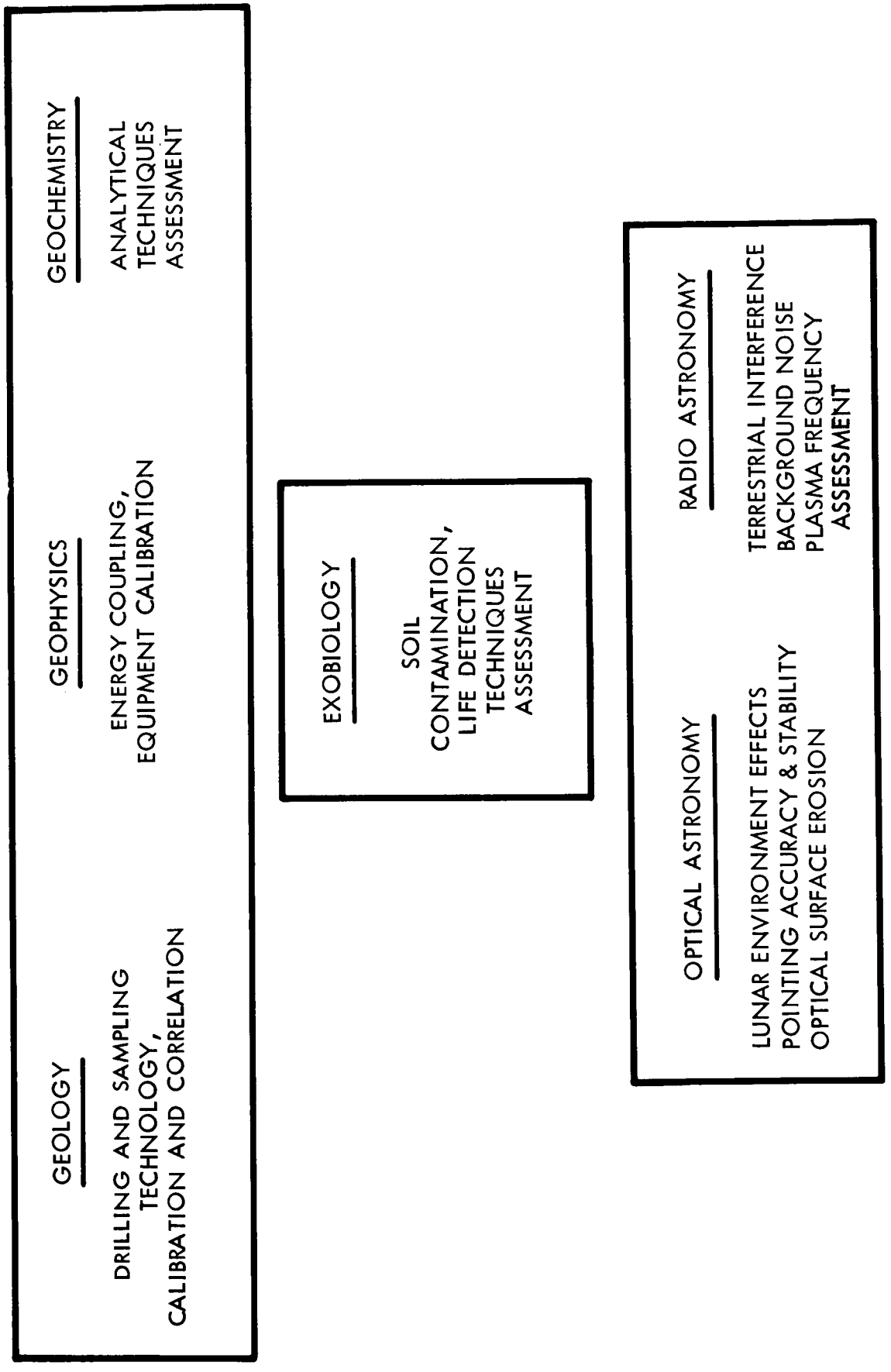

Figure 6. Support to Fundamental Investigations

astronomy programs. Radio-astronomy technology should be supported by measurements of terrestrial interference, background noise, and the plasma frequencies encountered in cislunar space. Although initially rated "important-later," performance of the two basic radio astronomy orbital investigations "Earth RFI and Background Radio Noise" (81021701) and "Dielectric Properties of the Lunar Sphere" (81021702) is feasible during AAP orbital missions. Therefore, it is recommended they be conducted before the surface investigations which are scheduled later in the AAP period as required to support fundamental experiments.

3.2.4.3 Applied Life Sciences

Investigations that relate to the safety and well-being of the astronaut-scientist are rated top-priority or very important-early. It is anticipated, however, that investigations such as "Clinical Monitoring," which are routine, will be performed to varying degrees in all missions. Other biomedical investigations included in the program are "Bioassays of Body Fluids," "Physiological Studies," "Cardiovascular Phenomena," and "Bone Demineralization." As defined, these investigations assess the effects of prolonged missions; therefore, they apply to later exploration phases. However, this does not preclude interest in these biomedical effects due to 10- to 14-day lunar surface missions. A continuing investigation program during the lunar exploration phases may evolve from subsequent studies in this area.

Human factors investigations which permit assessment of man's capabilities and work-support needs in the lunar environment are "Mechanical Efficiency at Reduced Gravity," "Work Capability," and "Vision Studies."

Advanced life support systems, involving partly closed ecological cycles, present requirement for investigations in the "Use of Lunar Soil in Ecological Systems," "Algae Strains," and the "Growth, Reproduction, and Survival of Plants and Animals." These investigations were submitted by Dr. James A. Bassham and Dr. Hermann J. Muller in Reference 3. Because of weight, volume, man-hour, and duration requirements, the ecology and genetic effects investigations are more logically performed in later missions.

3.2.4.4 Basic Subsystems Support

General technology support is provided by investigations in materials technology, fluid mechanics in the lunar environment, and lunar properties data. This support is not limited to the subsystems specialties but applies to fundamental investigations as well. Materials technology support provides test data on damage to materials in the lunar environment and on

special problems such as "Static and Dynamic Seals" and "Adhesion of Machined Elements." These investigations include examination and/or return of operational items and of special test packages. The need for a vacuum laboratory removed from the base facility is indicated. Fluid mechanics support includes heat-transfer characteristics and stratifications in cryogenic liquids at one-sixth g. Lunar properties data and miscellaneous basic and applied research are shown in parentheses for reference.

Environmental control system technology requirements can be satisfied with earth and space environments utilizing lunar environmental data. Lunar communications technology advancement is highly dependent on investigations performed on the lunar surface. "Lunar Environmental Effects on Antenna Systems," "RF and Laser Forward Scatter Techniques," "RF Ground Wave Propagation," and "RF Subsurface Propagation" are typical investigations suggested for performance on the moon. Early technology support investigations in power systems provide answers to grounding problems of electrical systems and the feasibility of laying power transmission lines on the lunar surface. A preliminary review of structures requirements indicates the need for experiments in repair techniques and on extensible antenna towers.

3.2.4.5 Mobility and Deployment Support

Mobility support investigations submitted in this study are described with reference to the early exploration (AAP) period. These investigations would be performed from the Lunar Scientific Survey Module (LSSM) for application to AAP mission performance and safety and to provide experiment data in support of larger traverse vehicle development.

In the area of deployment support, explosives techniques, as applied to surface modification, are expected to be built upon lunar explosives technology developed in support of active seismic exploration. Digging and cutting tools (as would be required for a trench digger or bucket) represent an area requiring performance assessment. "Metal Joining Techniques in Lunar Surface Construction and Repair" is defined herein as a priority investigation consistent with an extended mission capability. It appears logical for future planning to consider phasing of this investigation (as with biomedical investigations) with simpler experiments conducted early and more extensive experiments performed later.

3.2.4.6 Lunar Resources Utilization Feasibility

Determination of the feasibility of utilizing lunar resources for mission support is expected to require diverse lunar surface investigations backed up by extensive supporting research performed in Earth-based laboratories. Lunar surface investigations would include the search for usable resources to be conducted in all provinces explored.

Investigations which support the development of mining and materials handling techniques, materials extraction and processing, manufacturing technology, and the application of resources (as to foundations and pads) are scheduled for performance during the extended exploration phases. Only a representative group of investigations are currently included under the "Lunar Resources" functional specialty. Depending on early exploration findings, lunar resources may become highly significant to the total lunar exploration program.

3.3 MISCELLANEOUS BASIC AND APPLIED RESEARCH

3.3.1 OBJECTIVES

The objective of Miscellaneous Basic and Applied Research is to take advantage of the unique properties and environment of the Moon and of lunar laboratory and base facilities to perform investigations to advance scientific and technical knowledge and capabilities.

Lunar environmental conditions, advantageous to the performance of research are: (1) an extensive ultra-high vacuum, (2) a low-gravity environment, (3) focusable, unfiltered thermal energy from the sun, (4) the availability of deep space as a heat sink, (5) foundation stability for emplacement and alignment, and (6) potentially usable materials. Factors such as these can be utilized in basic research to permit the performance of experiments as in atomic physics, for example, where practical Earth-based laboratory limitations are restrictive or compromise results.

In the applied research area, the same lunar environmental conditions may be utilized for investigations which advance applied technologies. Although this study has been oriented to lunar applications, Earth and planetary applications are also potentially highly significant.

Present predictions of scientific equipment and systems support capabilities are based on modest extrapolations of current and future Earth technologies. These extended technologies can be made adequate to accomplish lunar scientific missions and even limited planetary exploration. However, much equipment, based primarily on Earth technology, operates most effectively in the Earth environment. Electronic components, (e. g., transistors) require near room-temperature conditions in space to obtain maximum life and reliability. The lunar environmental attributes, listed earlier, can be utilized in applied research to open new technologies especially in electronics and material development. As the space program progresses toward planetary exploration, lunar-based research may prove to be a valuable supplement to Earth-based and orbit-based supporting programs.

3.3.2 ORGANIZATION

As noted previously, Miscellaneous Basic and Applied Research, the third category of lunar investigations for this study, is incorporated in the experiment data management system as Discipline Area 9. The preliminary organization of this discipline area into specialties is presented in Table 7. The data system includes only the five specialty areas for which investigations are submitted. Other potential specialties include microelectronics (including thin films), vacuum-vented electronics, and miscellaneous materials research.

Table 7. Organization of Miscellaneous Basic and Applied Research Investigations (Discipline Area 9)

Subject	No. of Studies
Electromagnetics	2
Electro-optics	1
Thermodynamics	3
Chemistry	1
Fundamental physics	2
Total Discipline Area 9	9

3.3.3 DISCUSSION

Discipline Area 9 investigations are listed in Figure 7. Basic research fields or technology applications are also indicated.

In the electromagnetics area, the ability to generate high-intensity arcs, electron beams, and ion beams in the open (i.e., without a vacuum chamber) may be used to advance extraction, welding, and other materials processing techniques. These techniques may be applicable to lunar materials processing and to lunar-based operations on terrestrial materials; they may also be eventually extended to Earth-based fabrication processes.

A single investigation in the electro-optics specialty examines the utilization of field emission techniques for analysis of lunar materials. This technique should permit studies of atomic structures of materials.

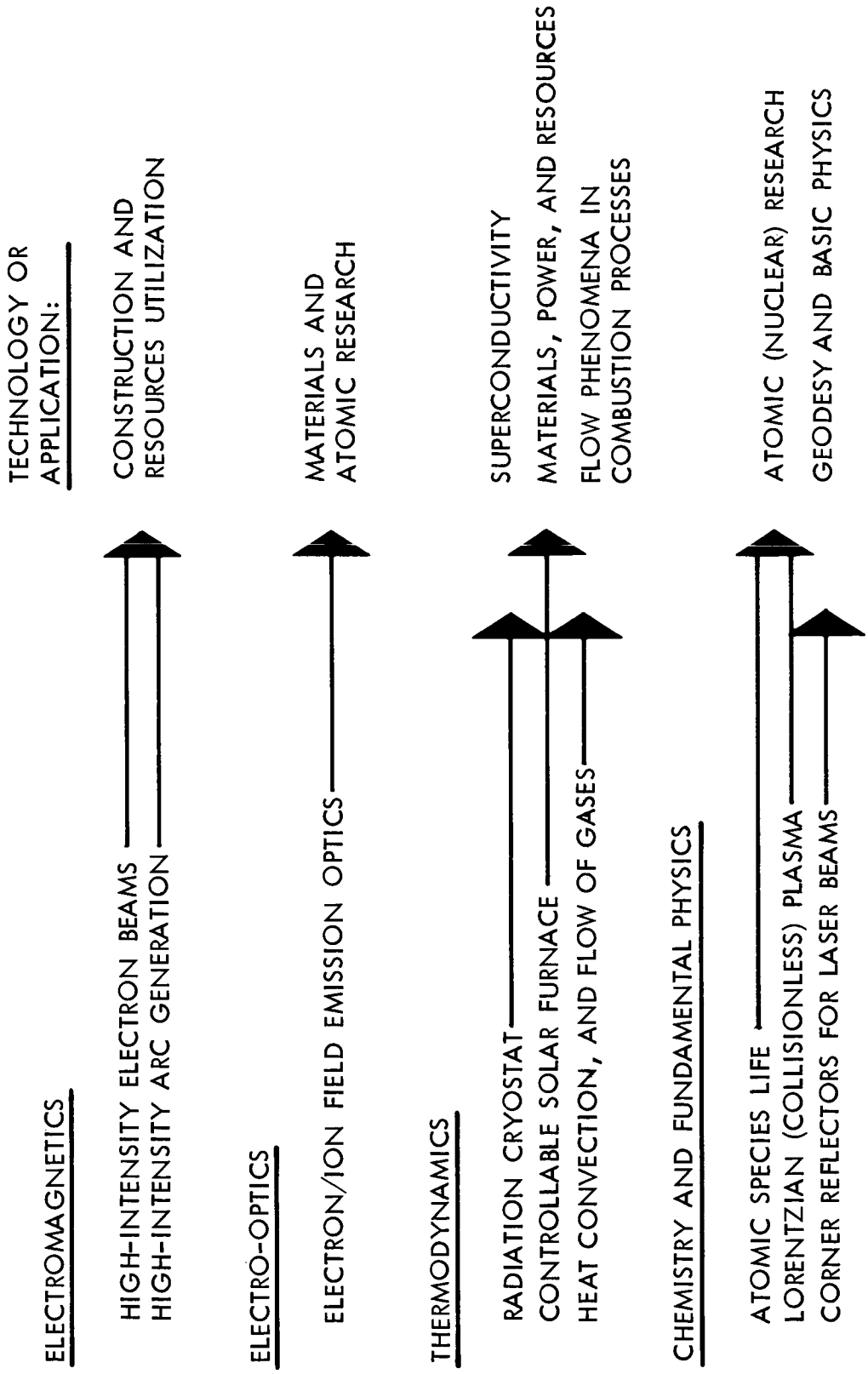

Figure 7 Miscellaneous Basic and Applied Research Investigations

The broad area of thermodynamics is sampled by three widely differing investigations. The first, entitled "Radiation Cryostat," examines the thermal characteristics and operational feasibility of cryostats formed by a cavity that is superinsulated from the lunar surface thermal environment and sees only the distant stellar sky. Based on the postulated success of this investigation, other investigations in the field of superconductivity would be candidates for performance in the hard vacuum/cryogenic environment. The second investigation, "Solar Furnace with Controllable Focal Energy Flux," in effect, proves techniques for a research tool that can support other investigations in materials research and materials extraction and processing. The third experiment, "Heat Convection and Flow of Gases in Enclosed Spaces," is conceived as the lunar portion of a three-part, Earth (one g)/ lunar (one-sixth g)/orbit (zero g), investigation of flow phenomena associated with combustion.

Two atomic experiments are included which appear very promising. One is entitled "Atomic Species Lifetimes"; the other, referred to as "Fully Ionized Plasmas" is incorporated as part of the investigation, "Lorentzian Plasma Environmental Physics." The basic equipment for these plasma experiments, with some expansion, may support additional related plasma experiments.

"Atomic Species Lifetimes" was described in References 4 and 5 as measurement of lifetimes of long-lived atomic species requiring times on the order of several seconds. An atomic or molecular beam is produced so that a well-collimated beam is emitted by a source parallel to the lunar surface. The beam traverses an ionization region, near the source, produced by an electron beam in a direction perpendicular to the atomic or molecular beam. The decay of excitation and ionization states may be observed at various points along the beam. Since the lifetimes are on the order of seconds and the velocity of the atoms or molecules of the beam are on the order of miles per second, several miles along the beam path must be used for observation. The apparent advantages of the Moon for this experiment is that it provides a large enough vacuum with an adequate mean free path.

The "Fully Ionized Plasma" experiment may be implemented by setting up magnetic fields on the lunar surface and then producing or injecting an ionized plasma into the magnetic field. Plasma particles lost from the magnetic field would not be reflected back, and few extraneous particles would enter the field. The advantage of performing this experiment on the Moon would be the elimination of the recombination of the species with the vacuum chamber walls or with other species in the imperfect vacuum that is encountered in experiments conducted in the earth's environment.

"Corner Reflectors for Laser Beams" is an Earth-Moon investigation suggested in Reference 1 by the Space Science Board. The lunar surface portion of the investigation involves emplacement of three widely separated corner reflectors. Measurements from Earth permit investigation of lunar distances, secondary and tidal accelerations, gravitation constant, geodetic applications, libration, and possibly gravitational waves.

3.4 SUMMARY AND CONCLUSIONS

3.4.1 SUMMARY

Selected summary data for Mission Support and Miscellaneous Basic and Applied Research Investigations are presented in Tables 8 and 9, respectively. The presentation is in the order of the discipline sequences for the two Discipline Areas, 8 and 9. Investigations which consist of Earth-based analyses of data obtained from other referenced experiments are described by Type-0 cards exclusively and appear as the last four investigations in these summary tables.

The sequences in which the investigations are listed are, in effect, updated discipline sequences (see Section 7.2) which reflect importance criteria prepared by the NASA Office of Advanced Research and Technology and the U.S. Army Office of the Chief Engineer. With few exceptions, the first forty investigations listed in Table 8 were generally rated "top priority-accomplish as soon as possible" or "very important - perform early," in both reviews. Exceptions are as follows:

1. No. 81021201, "Electrode Electrical Coupling Properties in Lunar Materials," is desired earlier by geophysicists to establish validity and to support interpretation of fundamental surface measurements.

2. Radio-astronomy orbital investigations 81021701, "Earth RFI and Background Radio Noise," and 81021702, "Dielectric Properties of the Lunar Sphere," are desired by radio astronomers as basic to assessment of radio astronomy potential of the Moon. Since they are both performed solely in lunar orbit, their order, with respect to surface-supported investigations, is somewhat arbitrary at this time.

3. The other two exceptions are 82010208, "Effects of Leakage from Vehicles, Shelters and Space Suits," and 82010205, "Lunar Atmosphere Contamination Effects of Rocket Exhausts." They are sequenced herein to provide validity and interpretive data in conjunction with the concurrent materials dynamic tests and fundamental geophysics/atmospheric studies.

The next 19 investigations, beginning with 83064104 also could be supported by projected AAP capabilities. In this sequence they would be performed in the latter portion of the early exploration phase. Ratings are mixed, with a preponderance of "important - later" designations. Four of this group were given "very important - perform early" ratings. Of these, it appears that two might be expanded in time scale to reflect a program of measurements over a series of missions. The subject investigations are 82010108, "Shelter Shielding and Construction Support Properties of Lunar Soil," which would also be performed in extended exploration missions; and 82043402, "Damage to Lunar Equipment," which is more routine in nature.

The remaining 31 Mission Support Investigations in Table 8, beginning with 82054001 "Metal Joining Techniques in Lunar Construction and Repair," are best performed in the extended exploration phases. In general, either the experiment performance requirements, such as duration, or support requirements, such as mass or man-hours indicate performance during extended exploration.

In addition to the guidance provided by the OART and OCE ratings, priorities on the Mission Support Investigations were also based on the following criteria:

1. Investigations necessary for astronaut safety and mission success are of paramount importance.

2. Investigations for which validity degrades with time (biological contamination) are most urgent for fundamental support.

3. Investigations which support assessment of validity or interpretation of data for priority investigations directed to fundamental questions should be performed as early as feasible.

4. Investigations which define and improve the effectiveness of man in the lunar environment are vital to the total manned exploration program and should be initiated at the earliest opportunity.

5. The sequencing should present a balanced program of support to both fundamental experiment needs and engineering implementation needs in recognition of the interdependence of science and technology in lunar exploration.

Table 8. Mission Support Experiment Summary Information (SMS-ELE)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82010101	Topography of proposed AAP LEM landing sites	Orbit	None	Orbital studies	1	18	5.0	0	10	X$^{\Delta}$	X$^{\Delta}$	100
82010103	Soil bearing strength of proposed LEM landing sites	Orbit	None	Orbital studies	1	45	93	1.0	250	$4,000,000 200,000	2	0
82010102	Engineering properties of the lunar surface	Site	Walk	Initial landings	1	1.8	0	2.0	0.0	$ 100,000 20,000	3	0
81021301	Biological contamination of lunar soil	Site	Walk	Early exploration	1	15	600	2.2	80	$2,000,000 200,000	2	1.0
82032001	Clinical monitoring	Site	None	Early exploration	2	14	70	14	5	$ 0 20,000	-	1.0
81021104	Lunar geological-geochemical sample cassets	Site	Walk	Initial landings	1	20	0	4.0	0.0	$ 500,000 50,000	2	1.0
82010201	Lunar surface dust environment	Various locations	Walk	Early Exploration	1	2.0	0	2.0	0.0	$ 100,000 10,000	1	1.0
82043401	Dust removal techniques	Site	Walk	Initial landings	1	10	5.0	1.0	500	$ 500,000 100,000	1	0
82043101	Simulated personnel shielding from solar event protons	Site	None	Early exploration	1	0.3	0	0.2	0.0	$ 0 2,000	0	0.3
82043310	Electrical systems grounding	Site	LSSM	Early exploration	1	3.0	0.2	2.0	1	$ 300,000 50,000	1	0
81021201	Electrode electrical coupling properties in lunar surface	Geological area	LSSM	Early exploration	1	2.0	0.02	4.0	5	$ 400,000 50,000	3	0
81021103	Calibration of remote sensing techniques	Selected geophysics sites	LSSM	Early exploration	1	0	0	1.0	0.0	$ 0 0	0	0
82032002	Mechanical efficiency of man at reduced gravity	Site	None	Early exploration	2	18	16	4.0	4	$ 0 50,000	-	0
82032003	Work capability determinations on lunar surface	Site	None	Early exploration	2	18	2.1	2.0	10	$ 200,000 30,000	2	0
82043502	Repair techniques for major structural damage	Site	Walk	Early exploration	2	10	1,000	3.0	1,000	$ 400,000 70,000	2	0
82032005	Vision studies	Site	None	Early exploration	1	2.3	20	0.5	40	$ 100,000 20,000	1	0.1
81021102	Lunar drill bit technology	Selected drilling sites	LSSM	Early exploration	1	0.5	0	0	0.0	$ 0 0	0	0
81021101	Gas requirements for lunar core drilling	Selected drilling sites	LSSM	Early exploration	1	0.1	0	1.0	0.0	$ 0 0	0	0
81021203	Explosive energy coupling in lunar materials	Geological area	LSSM	Early exploration	1	10	2.7	8.0	30	$1,000,000 100,000	1	0
82053901	Explosive techniques for surface modification	Geological area	LSSM	Early exploration	1	100	0	10	0.0	$ 500,000 50,000	2	0
83064106	Detection of hydrogen in lunar materials using infrared spectrometer	Site	None	Early exploration	1	16	600	40	30	$ 200,000 100,000	5	0
83064101	Detection of hydrogen in lunar materials using neutron activation	Geological area	LSSM	Early exploration	1	16	250	5.0	25	$ 0 0	3	2.0

$^{\Delta}$'X' Indicates classified information.

Table 8. Mission Support Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
81021205	Sterophotogrammetry	Orbit	None	Orbital studies	2	700	2,000	8	25	$2,000,000 300,000	2	180
81021701	Earth RFI and background radio noise	Orbit	None	Orbital studies	1	15	40,000	0	10	$1,000,000 100,000	2	0
81021702	Dielectric properties of the lunar sphere	Orbit	None	Orbital studies	1	30	40,000	0	10	$1,000,000 100,000	2	0
82043414	Elastomer and polymer behavior	Site	Walk	Early exploration	1	2.5	0	2.0	0.0	$ 500,000 100,000	2	1.0
82043403	Static exposure effects on materials	Site	Walk	Early exploration	1	2.0	0	0.5	0.0	$ 200,000 40,000	1	1.0
82043404	Exposure effects on radiator materials	Site	Walk	Early exploration	1	5.0	100	1.5	100	$ 200,000 40,000	1	0
82010104	Corrosive action of lunar surface material	Site	Walk	Early exploration	1	1.0	0	1.0	0.0	$ 0 0	0	1.0
82010208	Effects of leakage from vehicles, shelters and space suits	Site	Walk	Early exploration	1	4.6	0.003	0.8	0.003	$ 500,000 100,000	1	0
82010205	Lunar atmosphere contamination effects of rocket exhaust	Site	Walk	Early exploration	1	4.6	0.003	0.8	0.003	$ 500,000 100,000	1	0
82043406	Early materials dynamic tests - machine elements	Site	Walk	Early exploration	1	20	5,000	2.0	500	$1,000,000 300,000	2	1.0
82043407	Early materials dynamic tests - thin film bearings	Site	Walk	Early exploration	1	10	2,000	2.0	200	$ 500,000 100,000	2	1.0
82043408	Early materials dynamic test - electrical components	Site	Walk	Early exploration	1	5.0	1,000	1.0	100	$ 500,000 100,000	2	1.0
82043415	Static and dynamic seals	Site	Walk	Early exploration	1	5.0	0	1.5	0.0	$ 300,000 80,000	2	2.5
82053701	Visual techniques in land navigation - astronaut vision	Geological area	LSSM	Early exploration	2	4.0	0	4.3	0.0	$ 200,000 40,000	1	0
82053702	Visual techniques in land navigation - land recognition	Geological area	LSSM	Early exploration	2	1.0	0	3.3	0.0	$ 200,000 50,000	3	0
82053602	Dangerous terrain warning techniques	Geological area	LSSM	Early exploration	1	20	2,000	2.0	20	$ 800,000 200,000	2	0
82053601	Soil value variations in lunar terrain	Geological area	LSSM	Early exploration	2	15	0	6.2	0.0	$ 600,000 100,000	2	0
83064105	Quantitative analysis of hydrogen in lunar material	Site	None	Early exploration	1	20	40	4.0	25	$ 0 0	4	2.0
83064104	Detection of hydrogen with a phosphorus pentoxide conductance cell	Site	None	Early exploration	1	10	40	4.0	10	$ 300,000 70,000	4	2.0
82010109	Lunar surface and subsurface electrical parameters	Geological area	LSSM	Early exploration	2	35	200	14	5	$ 300,000 40,000	2	0
82043501	Dynamics and surface environment effects on long antenna structures	Site	Walk	Early exploration	2	8.0	0	2.0	0.0	$ 300,000 50,000	1	0

Table 8. Mission Support Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82010202	Lunar RF noise, Part 1, low-frequencies	Geological area	LSSM	Early exploration	2	70	4,000	10	20	$ 400,000 70,000	1	0
82010203	Lunar RF noise, Part 2	Site	LSSM	Early exploration	1	6.0	2,000	6.5	10	$2,000,000 300,000	3	0
82010204	Antenna dust accumulation	Site	Walk	Early exploration	1	2.0	200	2.0	3	$ 300,000 50,000	1	0
81021703	Critical plasma frequencies of orbit-to-moon transmissions	Orbit	None	Orbital studies	1	12	300	5	25	$2,000,000 100,000	1	0
82043203	RF ground wave propagation	Geological area	LSSM	Early exploration	2	7.5	260	8.0	100	$1,000,000 200,000	3	0
81021801	Lunar optical astronomy test program	Site	Walk	Early exploration	2	120	1,000	20	20	$9,000,000 3,000,000	4	5.0
82023413	Solid state materials, effect of lunar environment	Site	Walk	Early exploration	1	4.0	1,000	0.2	20	$ 700,000 100,000	2	2.0
82023202	RF forward scatter techniques	Geological area	LSSM	Early exploration	2	10	150	5.0	3	$ 500,000 100,000	3	0
82010105	Radiation shielding effectiveness of lunar soil	Site	Walk	Early exploration	2	10	0.2	13	1	$1,000,000 300,000	2	0
82010108	Shelter shielding and construction support properties of lunar soil	Geological area	LSSM	Early exploration	2	6.5	2.0	5.0	2	$ 800,000 200,000	2	0
82043301	Lunar surface transmission line interactions	Site	Walk	Early exploration	1	2.0	0	2.0	0.0	$ 200,000 50,000	1	2.0
82043402	Damage to lunar equipment	Site	Walk	Early exploration	1	0	0	3.0	0.0	$ 0 0	2	0
82010206	Thermal radiation intensities and surface temperature gradients	Geological area	LSSM	Early exploration	1	10	100	2.0	50	$ 200,000 50,000	1	0
82043201	Lunar environment effects on antenna systems	Geological area	LSSM	Early exploration	1	7.0	100	3.0	2	$ 400,000 80,000	2	0
82043206	Retrodirective optical system techniques	Geological area	LSSM	Early exploration	2	3.0	50	1.0	5	$ 300,000 50,000	1	0
82010122	Lunar strata electromagnetic propagation parameters	Geological area	LSSM	Early exploration	2	3.0	250	7.5	100	$1,000,000 200,000	2	0
82045003	Temperature/density stratification of cryogenic liquids	Site	None	Early exploration	1	1.0	0.01	0	0.001	$ 200,000 50,000	1	0
82054001	Metals joining techniques in lunar surface construction and repair	Site	Walk	Extended exploration	2	20	10,000	18	10,000	$ 300,000 80,000	3	0
82043405	Materials dynamic test program	Site	LSSM	Extended exploration	1	80	20,000	20	800	$1,000,000 400,000	2	3
82043204	RF subsurface propagation	Geological area	Rover	Extended exploration	3	20	350	11	100	$ 800,000 200,000	3	0
82043205	Laser scatter propagation	Traverse	Rover	Extended exploration	3	80	100	4.0	50	$ 500,000 200,000	2	0
82032011	Bone demineralization studies	Site	None	Extended exploration	2	65	10,000	55	1,000	$ 0 50,000	0	1.0

Table 8. Mission Support Experiment Summary Information (SMS-ELE) (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82033004	Effects of breathing various gas mixtures	Site	None	Extended exploration	2	30	0	23	0.0	$ 300,000 50,000	2	0
82033002	Use of lunar soil for microrganisms and higher plants	Site	LSSM	Extended exploration	1	300	34,000	140	1,700	$2,000,000 300,000	3	0
81021207	Earth reference gravimeter	Site	Walk	Extended exploration	2	5.0	8,000	16	1	$2,000,000 200,000	2	5.0
82032006	Psychological studies	Site	None	Extended exploration	2	7.0	0	20	0.0	$ 100,000 1,000	1	0
82032004	Bioassays of body fluids	Site	None	Extended exploration	2	3.5	0	21	0.0	$ 0 5,000	0	0
82032010	Cardiovascular phenomena	Site	None	Extended exploration	2	7.3	900	55	20	$ 100,000 20,000	1	0.5
82045001	Heat transfer in liquids through natural convection	Site	None	Extended exploration	1	7.0	5.0	10	300	$ 200,000 40,000	2	0
82045002	Heat transfer in film and drop condensation processes	Site	None	Extended exploration	1	3.0	2.0	10	100	$ 200,000 50,000	2	0
83064201	Characteristics of lunar ores - self welding	Geological Area	LSSM	Extended exploration	1	5.0	0	4.5	0.0	$ 200,000 50,000	2	0.5
83064303	Particle adhesion in mechanical processing	Geological Area	LSSM	Extended exploration	1	400	10,000	24	1,500	$1,000,000 300,000	3	4.0
83064501	Lunar dry cement and concrete applications	Geological area	Rover	Extended exploration	2	110	7,000	51	1,500	$ 500,000 100,000	4	5.0
83064102	Chemical and differential thermal analysis for oxygen and CO_2 sources	Site	None	Extended exploration	1	15	320	10	100	$ 0 0	2	1.0
83064103	Differential thermal analysis of potentially castable materials	Site	None	Extended exploration	1	5.0	15	10	100	$ 0 0	2	1.0
82043409	Long-term static exposure effects on materials	Site	Walk	Extended exploration	1	5.0	40	3.0	40	$ 400,000 100,000	1	2.0
82010207	Lunar impact sferics	Site	Walk	Extended exploration	1	20	1,000	2.4	1	$ 600,000 100,000	1	0
81021802	Remote occulting disk as solar coronograph	Geological area	LSSM	Extended exploration	2	20	0	6.7	0.0	$ 300,000 50,000	1	0.2
82010107	Lunar seismic environment	Site	LSSM	Extended exploration	1	10	20,000	1.0	5	$ 200,000 40,000	3	0
82033001	Evaluation of algae strains	Site	None	Extended exploration	1	320	14,000	210	1,700	$2,000,000 300,000	3	4.5
82033003	Evaluation of hydrogenomonas strains	Site	None	Extended exploration	1	320	2,000	210	120	$2,000,000 300,000	2	15
82033006	Evaluation of hydrocarbon utilizing organisms	Site	None	Extended exploration	1	320	14,000	110	1,700	$2,000,000 300,000	2	0.2
82033005	Biological monitor and eco-system prototype	Site	None	Extended exploration	1	10	12,000	10	50	$ 200,000 50,000	3	0.01

Table 8. Mission Support Experiment Summary Information (SMS-ELE)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82010106	Nuclear reactor emplacement assessment	Site	LSSM	Extended exploration	2	16	0.47	10	0.49	Common usage equipment	2	0
82043302	Electrical transmission line routes	Site	LSSM	Extended exploration	2	0	1,000	6.0	100	$ 0 200,000	0	1.0
82033007	Effects of lunar conditions on plants	Site	None	Extended exploration	1	470	500	85	10	$2,000,000 400,000	2	10
82033008	Growth, development, reproduction and survival of plants	Site	None	Extended exploration	2	470	6,000	500	60	$2,000,000 400,000	2	200
82033009	Genetic effects of lunar conditions and earth-lunar trips on animals	Site	None	Extended exploration	1	470	0	100	0.0	$2,000,000 400,000	2	0
82033010	Growth development reproduction and survival of animals	Site	None	Extended exploration	2	470	0	500	0.0	$2,000,000 400,000	2	68
81021503	Lunar plasma properties near surface	–	–	Early exploration	These experiments have no lunar surface support requirements. The information from other experiments is correlated on Earth to obtain other desired information. See type-0 card.							
81021105	Sampling survey techniques	–	–	Early exploration								
83064107	Hydrogen detection and analysis techniques	–	–	Early exploration								
82053902	Digging and cutting tool assessment	–	–	Early exploration								

Table 9 presents similar summary data for the investigations included in Miscellaneous Basic and Applied Research, (Discipline Area 9). The first two investigations are reasonably implementable in the early exploration phase; the last seven are better performed with extended exploration facilities. All but the convective effects experiment, 90030301, are rated as "important - later."

Figure 8 presents, in matrix format, the relationship of the Mission Support and Miscellaneous Basic and Applied Research Investigations to the thirty-three fundamental questions.

3.4.2 CONCLUSIONS

The Mission-Support Investigations are valuable complements to the Fundamental Investigations. They provide basic data on the lunar surface, subsurface, and environment. They support Fundamental Investigations by providing data for experiment planning, equipment design, operations, and interpretation of results. They support mission performance capability by contributing to mission safety and man's effectiveness, to fixed-support equipment, and to mobile-support systems. They also provide data through which an assessment of the feasibility of lunar-resource utilization can be made.

The Miscellaneous Basic and Applied Research Investigations generate new techniques and new knowledge, taking advantage of the unique properties and environment of the Moon. Such scientific advances could also lead to longer range utilization of the Moon, its resources and eventual facilities.

The results of this study indicate that the Mission Support and Miscellaneous Basic and Applied Research Investigations, in conjunction with the Fundamental Investigations, enhance the value of the total mission program. A balanced program not only extends the capability and therefore value of lunar missions, but offers advancements in science and technology for exploration of the planets, moons of other planets, and for application to Earth needs as well.

Additional work should be accomplished for the applied science and technology investigations. This study effort, while identifying some key experiments, was insufficient to provide a total spectrum of typical experiments. In addition, the experiments should be defined to a degree comparable with the Fundamental Investigations.

Table 9. Miscellaneous Basic and Applied Research Experiment Summary Information (SMS-ELE)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (Watt-hr)	Total Man-hours	Peak Power (Watts)	Nonrecurring and First Item Costs	Development Time (Years)	Earth Return Weight (kg)
90050201	Corner reflectors for laser beams	Emplaced points	LSSM	Early exploration	1	30	0	0.4	0.0	$ 200,000 50,000	1	0
90030301	Heat convection and flow of gases in enclosed spaces	Site	Walk	Early exploration	1	20	100	3.0	20	$ 500,000 100,000	2	0
90010101	Generation of high-intensity electron beams	Site	Walk	Extended exploration	1	15	10,000	20	50,000	$1,000,000 200,000	2	0
90030201	Solar furnace with controllable focal energy flux	Site	Walk	Extended exploration	1	100	1,000	15	50	$ 800,000 200,000	2	0
90010201	High-intensity arc generation in lunar environment	Site	Walk	Extended exploration	1	25	3,000	15	10,000	$1,000,000 300,000	2	0
90030101	Radiation cryostat	Site	Walk	Extended exploration	1	10	100	20	1	$ 500,000 100,000	2	0
90020101	Field emission optics	Site	Walk	Extended exploration	1	3.0	1,000	15	100	$ 800,000 200,000	2	0.5
90050101	Lorentzian plasma environmental physics	Site	Walk	Extended exploration	2	10	40	4.0	20	$ 400,000 100,000	2	0
90040101	Lifetimes of atomic species	Geological area	Rover	Extended exploration	2	100	2,000	70	200	$1,000,000 300,000	4	0

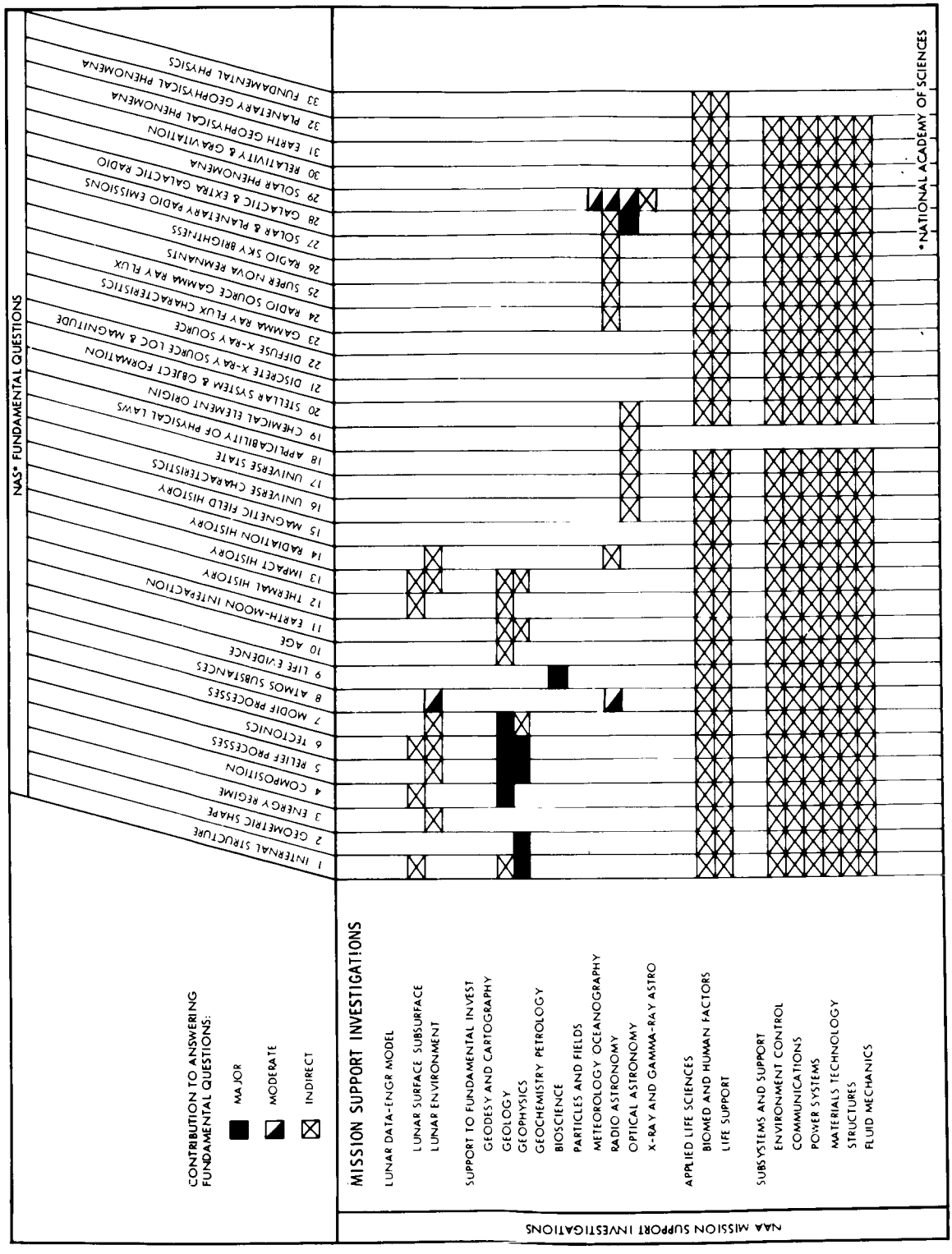

Figure 8a. Correlation of Mission Support Investigations With Fundamental Questions Raised by Space Science Board, National Academy of Sciences.

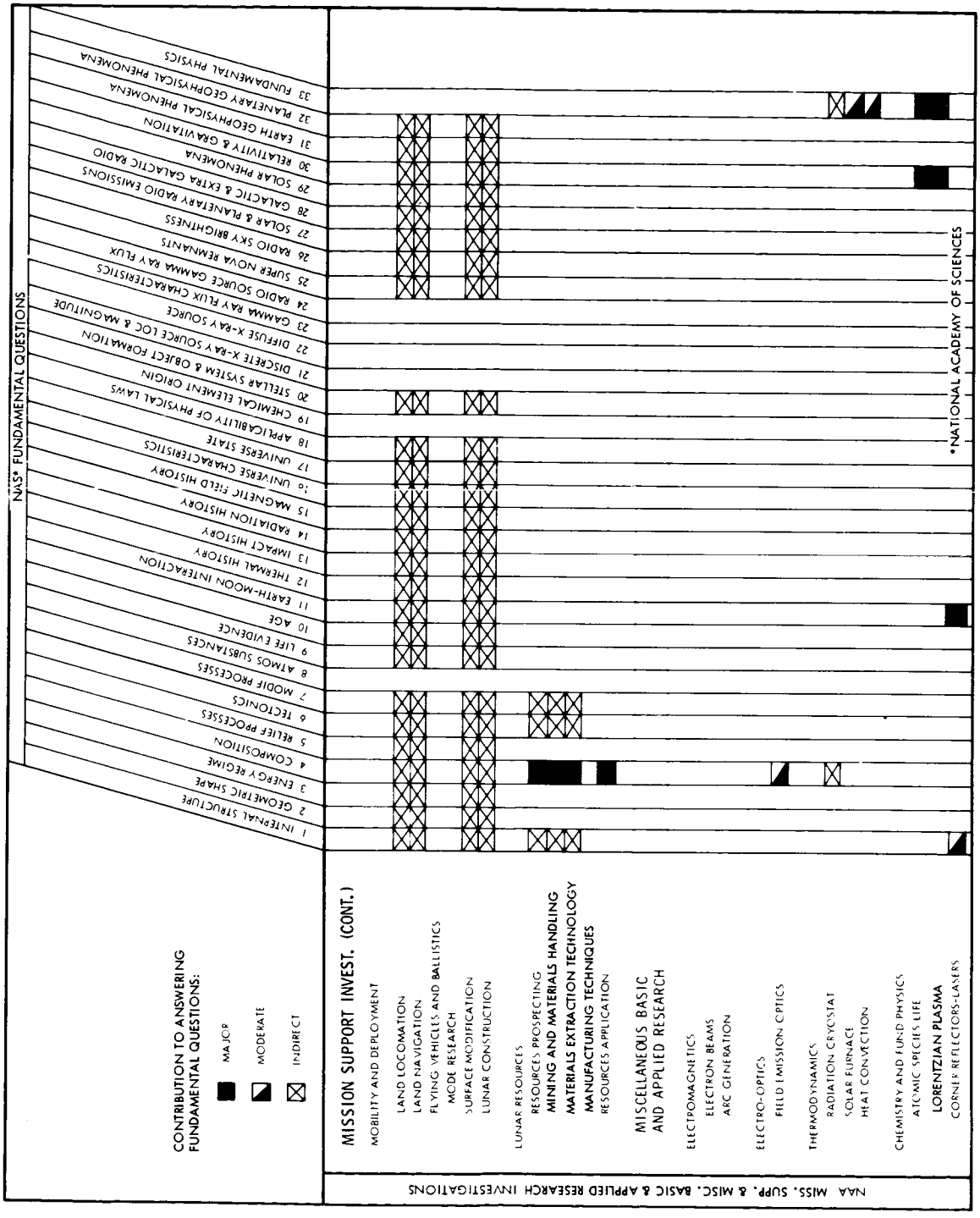

Figure 8b. Correlation of Mission Support and Miscellaneous Basic & Applied Research Investigation With Fundamental Questions Raised by Space Science Board, National Academy of Sciences.

3.5 EXPERIMENT DESCRIPTIONS

Following are descriptions of experiments that have been compiled under the categories Mission Support Investigations and Miscellaneous Basic and Applied Research.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 01 01 01 TOPOGRAPHY OF PROPOSED AAP LEM LANDING SITES

VERIFIES THAT SITE CHARACTERISTICS ARE WITHIN LEM DESIGN LIMITS FOR SAFE LANDING. CHARACTERISTICS TO BE DETERMINED ARE (1) PROTUBERANCES, INCLUDING BOTH RAISED OBSTACLES AND DEPRESSIONS WHICH COULD CAUSE BOTTOMING OF THE LEM, (2) EFFECTIVE SLOPES CONSISTING OF THE LOCAL SLOPE WITH SUPERIMPOSED PROTUBERANCES. INVOLVES HIGH-RESOLUTION PHOTOGRAPHIC MAPPING FROM ORBIT WITH COMPLEMENTARY SPECTRAL MAPPING. APOLLO MAPPING AND SURVEY SYSTEM USED INITIALLY. GEODETIC/CARTOGRAPHIC CAMERA SYSTEM RECOMMENDED BY NASA 1965, FALMOUTH CONFERENCE, TO BE EMPLOYED WHEN AVAILABLE.

8 2 01 01 03 SOIL SURFACE BEARING STRENGTH OF PROPOSED LEM LANDING SITES

THE MISSION SUPPORT OBJECTIVE OF THIS INVESTIGATION IS TO OBTAIN DIRECT MEASUREMENT OF SURFACE MECHANICAL PROPERTIES OF PROPOSED LEM LANDING SITES TO CERTIFY THAT THE CHARACTERISTICS ARE WITHIN LEM DESIGN LIMITS FOR SAFE LANDING. THE INVESTIGATION IS TO BE PERFORMED AS PART OF AN EARLY LUNAR MANNED ORBITAL MISSION. IT INVOLVES DEPLOYMENT OF PROBE PACKAGES FROM WHICH PENETROMETERS ARE DEPLOYED TO IMPACT UPON THE LUNAR SURFACE. (A SURVIVABLE CAPSULE ALSO IS INCLUDED.) EACH PENETROMETER CONTAINS A ACCELERATION-MEASURING PAYLOAD ENCASED IN AN IMPACT-LIMITING, BALSA SPHERE. ACCELERATION MEASUREMENTS DUE TO IMPACT ARE TO BE TRANSMITTED VIA A RELAY. THE ACCELERATION TIME SIGNATURES INDICATE THE TYPE OF MATERIAL AND LAYERING AND CAN BE INTEGRATED TO YIELD VELOCITY AND TOTAL PENETRATION FOR DERIVATION OF PENETRATION RESISTANCE AND BEARING STRENGTH. 45 KG MASS INCLUDES PENETROMETER SYSTEM, DATA RELAY, STRUCTURE, AND EJECTING MECHANISM.

8 2 01 01 02 ENGINEERING PROPERTIES OF THE LUNAR SURFACE

EARLY MANNED EXPERIMENTS TO DETERMINE CAPABILITY OF SURFACE TO SUPPORT MISSION OPERATIONS INCLUDING WALKING, VEHICULAR AND EQUIPMENT PLACEMENT MODES. MECHANICAL PROPERTIES INCLUDE BEARING STRENGTH, SHEAR STRENGTH, PENETRATION RESISTANCE, AND INTERNAL PROPERTIES. CONSISTS OF SIMPLE TESTS PERFORMED BY ASTRONAUT UTILIZING STAFF PENETROMETER AND OTHER PORTABLE SOIL TESTERS. AN EXTENSION OF THIS EXPERIMENT IN THE VEHICULAR MODE EMPLOYS THE PENETROMETER SUBSYSTEM FOR THE PRIMARY SURVEYOR VEHICLE (5 LB) OR FOR THE SLRV (2.75 LB) ON MANNED LUNAR VEHICLES. PARAMETERS TO BE MEASURED ARE FORCE ON TIP AND RATE OF PENETRATION, FROM WHICH STRENGTH AND COMPRESSIBILITY CAN BE INFERRED. THE 2.75 LB SUBSYSTEM HAS A STROKE OF 32 IN. MAX FORCE OF 16 LB, AND PENETRATION RATE OF 0.5 IN/SEC. THE 5 LB SUBSYSTEM HAS A STROKE OF 10 FT OR MORE, EXERTS A MAX FORCE OF 75 LB, AND HAS A PENETRATION RATE OF 0.1 TO 0.2 IN/SEC. OPERATION IS PERFORMED IN AUTOMATED MODE DURING SELECTED VEHICLE STOPS. DENSITY MEASUREMENTS MAY BE PERFORMED IN CONJUNCTION WITH SHEAR AND COMPRESSIBILITY BY MOUNTING A NUCLEAR DENSITY PROBE (1.1 LB IN THE PENETROMETER TIP.) ASSOCIATED OBSERVATIONS OF SURFACE APPEARANCE AND PHOTOGRAPHIC COLOR RECORDING WITH COMMON-USAGE CAMERA WILL YIELD VALUABLE DATA CORRELATING APPEARANCE WITH BEARING STRENGTH. TO BE PERFORMED AS MISSION SUPPORT EXPERIMENT TO THE EXTENT THAT FUNDAMENTAL EXPERIMENTS DO NOT FULFILL ENGINEERING NEEDS. (SOIL VALUE TESTS FOR WHEELED LOCOMOTION ARE DESCRIBED IN 82053601.)

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 01 01 08

SHELTER SHIELDING AND CONSTRUCTION SUPPORT PROPERTIES OF LUNAR SOILS

THE OBJECT OF THE INVESTIGATION IS TO DETERMINE PROPERTIES OF LUNAR SOILS FOR CONSTRUCTION AND ENGINEERING PURPOSES SUCH AS SHELTER SHIELDING, EQUIPMENT DEPLOYMENT AND TELESCOPE FOUNDATIONS. THIS WILL CONSIST PRIMARILY OF DETERMINING COHESIVENESS AND PARTICLE SIZE DISTRIBUTION, AND MECHANICAL PROPERTIES OF THE SURFACE AND NEAR SURFACE SOILS SUCH AS BEARING STRENGTH, BEARING STRENGTH GRADIENT WITH DEPTH, SHEAR STRENGTH, PENETRATION RESISTANCE, DENSITY, COMPRESSIBILITY, UNSUPPORTED COMPRESSIVE STRENGTH, ANGLE OF REPOSE, AND SLOPE STABILITY. THIS WILL PERMIT THE SAFE DESIGN OF LUNAR STRUCTURES, FOUNDATIONS, ROADS AND HEAVY EQUIPMENT STAGING AREAS, AS WELL AS DEFINING THE WORKABILITY AND SUITABILITY OF NATIVE MATERIALS FOR USE IN CONSTRUCTION. DEPENDING UPON THE OUTCOME OF THIS EXPERIMENT, REQUIREMENTS FOR CONSTRUCTION AND PROCESSING EQUIPMENT WILL BE ESTABLISHED. THE INITIAL EQUIPMENT UTILIZED FOR THIS PURPOSE WILL BE THE SCIENTIFIC EXPLORATION EQUIPMENT IN THE GEOSCIENCE AREA I.E. SOIL SAMPLING, IMPACT AND PROBE PEMETROMETERS, DRILLING AND CORING EQUIPMENT. THE FIELD EVALUATION OF POTENTIAL SITES WILL BE SUPPORTED BY SCIENTIFIC MISSION GEOLOGY AND GEOPHYSICS INVESTIGATIONS AND BY GEOCHEMICAL AND MECHANICAL ANALYSIS OF SAMPLES RETURNED TO EARTH. THE MAJOR REMAINING PARAMETERS REQUIRING SPECIALIZED EQUIPMENT ARE THE FOLLOWING= FOR LOAD-BEARING AND SHEAR STRENGTH A CYLINDRICAL DEVICE MEASURING THE SINKAGE OF A FLAT PLATE AS A FUNCTION OF THE APPLIED AXIAL LOAD (SIMILAR TO A PROTOTYPE DEVELOPED BY JPL) IS REQUIRED. FOR THE GRADIENT WITH DEPTH THE SAME DEVICE WOULD BE EMPLOYED REGIDLY FIXED TO BOREHOLE OR TRENCH WALLS, CRUSTAL SHEAR STRENGTH IN A PLANE PARALLEL TO THE SURFACE OR BOREHOLE BOTTOM WOULD BE MEASURED WITH THE SAME DEVICE BY ADDITION OF A SPUDDED ANNULAR RING AND AN APPLIED TORQUE. SCIENTIFIC SUPPORT EQUIPMENT IS NOT INCLUDED IN WEIGHT AND COST ESTIMATES.

8 2 01 01 06

NUCLEAR REACTOR EMPLACEMENT ASSESSMENT

THE OBJECTIVE OF THIS INVESTIGATION IS TO ACQUIRE SUFFICIENT SURFACE AND SUBSURFACE DATA TO SUPPORT SITE SELECTION AND LUNAR SUBSURFACE EMPLACEMENT EVALUATION FOR NUCLEAR REACTORS WITH OPERATIONAL SAFETY AS THE PRIME CONCERN. A SOIL SURVEY PORTION INCLUDES DRILLING, CORING AND SAMPLE RECOVERY USING SCIENTIFIC EXPLORATION EQUIPMENT AND CORING PROCEDURES AND DATA TO DETERMINE OPTIMUM SOIL FOR EXCAVATION AND BURYING OF NULCEAR REACTOR. DENSITY AND CHEMICAL COMPOSITION MEASUREMENTS, PARTICULARLY HYDROGEN CONTENT WILL DETERMINE REQUIRED SHIELDING THICKNESS. (EARLIER CHEMICAL ANALYSIS OF CROSS-SECTION OF SAMPLES RETURNED TO EARTH AND RESULTS OF EXPERIMENTS 82010105, LUNAR SOIL SHEILDING, WILL HAVE PROVIDED DATA FOR ASSESSMENT OF FEASIBILITY OF UTILIZING LUNAR MATERIALS FOR SHEILDING). THIS INVESTIGATION ALSO INCLUDES EARTH-RETURN OF SAMPLES FROM CANDIDATE SITES TO ASSESS THE POTENTIAL RADIATION HAZARD OF NEUTRON ACTIVATION BY AN ESSENTIALLY-SHIELDED REACTOR. INDUCED RADIOATIVITY CAN BE DETERMINED ON THE RETURNED SAMPLES BY NEUTRON BOMBARDMENT OR INFERRED FROM ISOTOPIC ANALYSIS OF THE SAMPLES. THE REACTOR SITE SELECTION REQUIRES A MICRO-SEISMIC SURVEY TO DETERMINE THE SEISMIC ENVIRONMENT, A GEOPHYSICAL SURVEY TO DETERMINE THE PRESENCE OF POTENTIALLY HAZARDOUS FAULT SYSTEMS IN THE REACTOR SITE AREA, AND A SOIL PERMEABILITY SURVEY TO DETERMINE RATES OF GASEOUS RADIONUCLIDE DIFFUSION IN THE EVENT OF REACTOR RUPTURE. EQUIPMENT FOR THE SITE SURVEYS WILL BE DRAWN FROM THE FUNDAMENTAL GEOSCIENCE EXPERIMENTS NUMBERS (41C20108, PASSIVE SEISMIC RECORDING, 40010103, 40010104, SEISMIC PROFILING SHALLOW REFLECTION AND REFRACTION, 40130774, SURFACE AND SUBSURFACE GAMMA RAY SPECTROSCOPY). ADDITIONAL EQUIPMENT REQUIRED WILL BE A CASSETTE OF GASEOUS RADIO NUCLIDE FOR SUBSURFACE RELEASE TO SERVE AS A TRACER IN SOIL PERMEABILITY STUDIES.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	MISSION SUPPORT INVESTIGATIONS
8 2 01 01 05	RADIATION SHIELDING EFFECTIVENESS OF LUNAR SOIL MEASURE DOSE RATE, PRIMARY AND SECONDARY PARTICLE AND PHOTON ENERGY SPECTRA, AT 10 TO 1000 GM/CM*3 LUNAR SOIL DEPTH. USE TISSUE EQUIVALENT DOSIMETERS (5), SOLID STATE PARTICLE SPECTROMETER, SCINTILLATION GAMMA SPECTROMETER. EMPLACE AT VARIOUS DEPTHS AT LOW SOLAR ACTIVITY LEAVE AT ONE DEPTH AND TAKE REMOTE READINGS DURING SOLAR PROTON EVENT. SUPPORTS EVALUATION OF UTILIZING LUNAR MATERIALS FOR SHIELDING.
8 2 01 01 09	LUNAR SURFACE AND SUBSURFACE ELECTRICAL PARAMETERS MEASUREMENT OF ELECTRICAL PARAMETERS OF LUNAR SURFACE AND SUBSURFACE AT SEVERAL FREQUENCIES IN THE RANGE OF 1KHZ TO 30MHZ. PARAMETERS ARE CONDUCTIVITY, PERMEABILITY AND DIELECTRIC CONSTANT. UTILIZES TWO HORIZONTAL ANTENNAS OF APPROXIMATELY 2 KM LENGTH, ONE LYING ON SURFACE AND THE OTHER AT 3-10 METERS ABOVE THE SURFACE. A VECTOR IMPEDANCE METER IS USED TO MEASURE THE ANTENNA IMPEDANCE AND TO DETERMINE THE ABOVE PARAMETERS. DEPLOYED BY TWO ASTRONAUTS USING LSSM. SUPPORTS RADIO ASTRONOMY AND COMMUNICATIONS INVESTIGATIONS.
8 2 01 01 22	LUNAR STRATA ELECTROMAGNETIC PROPAGATION PARAMETERS INVESTIGATION TO DETERMINE CONDUCTIVE PARAMETERS AND RELATE THESE TO BOUNDARY CONDITIONS AND PHYSICAL FEATURES SUCH AS LEVEL THICKNESS IN LUNAR SUBSURFACE STRATA. PURPOSE IS TO ASSESS FEASIBILITY OF SUBSURFACE RF PROPAGATION. EXPERIMENT UTILIZES SEPARATE, LOCAL DRILL HOLES FOR EMPLACEMENT OF TRANSMITTER AND RECEIVER. KNOWN SIGNALS ARE TRANSMITTED AND RECEIVED AT DIFFERENT DEPTHS CORRESPONDING TO KNOWN STRATA FROM PRIOR CORING.
8 2 01 01 04	CORROSIVE ACTION OF LUNAR SURFACE MATERIAL MEASUREMENT OF CORROSION OF TEST ITEMS AND OPERATIONAL EQUIPMENT, EMPLACED ON OR BENEATH THE LUNAR SURFACE, DUE TO INTERACTION WITH LUNAR SURFACE MATERIALS. PROVIDES MODEL SURFACE DATA AFFECTING SURFACE TRANSMISSION LINE CORROSION, EMPLACED INSTRUMENTS, SUPPORT EQUIPMENT IN DIRECT CONTACT WITH SURFACE, AND DUST-COVER EQUIPMENT. CHEMICAL CORROSIVITY AT ELEVATED TEMPERATURES IS NEEDED FOR DESIGN OF TRANSMISSION LINES, RADIATORS, REACTOR JACKETS AND EXTERNAL STRUCTURE, AND OTHER THERMAL SOURCES. INVOLVES CURSORY PHYSICAL AND CHEMICAL ANALYSIS TO INDICATE EXTENT AND NATURE OF CORROSION. EMPLOYS COMMON ANALYTICAL EQUIPMENT FROM GEOCHEMICAL LABORATORY. SELECTED CORRODED SAMPLES (WIRE SECTIONS, CONNECTORS, ETC.) MAY BE VACUUM-PACKAGED FOR EARTH RETURN IF CORROSION IS SIGNIFICANT.
8 2 01 01 07	LUNAR SEISMIC ENVIRONMENT MEASUREMENT AND RECORDING OF ACCELERATIONS OR SHOCKS WHICH MAY BE EXPERIENCED AT PERMANENT LUNAR BASE. THESE MAY BE (1) TRUE LUNAR SEISMIC SHOCKS, (2) TIDAL FLEXURE, (3) THERMALLY-INDUCED MICRO-SHOCKS, (4) SPHERICAL LUNAR OSCILLATIONS, AND (5) METEOROIDAL IMPACT. PROVIDES DATA FOR EXPERIMENT AND EQUIPMENT DESIGN, PARTICULARLY FOR ASTRONOMY INVESTIGATIONS, AND CONTINUOUS MONITORING DATA FOR LUNAR ASTRONOMY PROGRAM. MAY BE CORRELATED WITH FUNDAMENTAL GEOPHYSICS INVESTIGATION 41020208, SEISMIC RECORDING, LONG PASSIVE PERIOD, AND 40010102, SEISMIC RECORDING, SUBSURFACE LOGGING.

EXPERIMENT NUMBER
AREA OBJECT SPECIFIC INVESTIGATION EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 01 02 01 LUNAR SURFACE DUST ENVIRONMENT

INTEGRATED PROGRAM OF MEASUREMENT OF THE RATES OF PARTICLE (DUST) COLLECTION ON SCIENTIFIC AND SUPPORT EQUIPMENT AND PERSONNEL IN BASIC LUNAR OPERATIONS. IDENTIFICATION OF MECHANISMS OF ACCUMULATION. INVESTIGATION IS EXTENSIVE AND INVOLVES MONITORING OF PARTICLE ACCUMULATION IN DIVERSE LUNAR OPERATIONS INCLUDING (1) DUST AND DEBRIS EFFECTS OF ROCKET EXHAUST IN LANDING AND TAKE-OFF, (2) DUST ACCUMULATION DUE TO NATURAL ENVIRONMENT EJECTA, RADIATION, AND ELECTRIC CHARGE ACCUMULATIONS ON THE LUNAR SURFACE (POSSIBLY TIME-VARIENT) (3) DUST ACCUMULATIONS IN WALKING (4) THROWING OF PARTICLES BY WHEELS (TO DETERMINE FENDER REQUIREMENTS) (5) DUST PRODUCED BY DRILLING (6) RESIDUAL DUST FROM BLASTING (7) DUST FROM SURFACE MATERIAL MOVEMENTS IN SHIELDING EMPLACEMENT AND SURFACE MODIFICATION OPERATIONS, AND (8) ATTRACTION OF LUNAR DUST BY RADIATION AT HIGH POWER LEVELS. PORTIONS TO BE CORRELATED WITH LOCOMOTION ELECTRICAL POTENTIAL MEASUREMENTS. UTILIZES SMALL TEST PATERNS ATTACHED TO-OR PAINTED ON SECTIONS OF EXPOSED AREAS TO BE MONITORED. PROCEDURE INVOLVES POST-EXPOSURE PHOTOGRAPHY WITH NON-EXPOSED CONTROL PATTERN, UTILIZING EXISTING CAMERA, AND REMOVAL OF ATTACHED PATTERNS FOR DUST MEASUREMENTS. INCLUDES RETURN OF SELECTED DUST COVER PATTERNS IN VACUUM CONTAINERS.

8 2 01 02 07 LUNAR IMPACT SPHERICS

MEASUREMENT OF RF NOISE GENERATED BY THE IMPACT OF MICROMETEORITES AND EJECTA ON THE LUNAR SURFACE, AND BY ELECTROSTATIC DISCHARGES OF IONIZED DUST CLOUDS FLOATING NEAR THE SURFACE. TO BE PERFORMED WITH A GROUND ANTENNA ARRAY CONNECTED TO A BROAD-BAND RF RECEIVER ACTING AS A NULL BRIDGE FOR RF SIGNALS FROM DISTANT SOURCES, BUT SENSITIVE TO RF SIGNALS GENERATED NEAR THE ARRAY. AUTOMATIC SIGNAL SORTING AND COUNTING WOULD BE COMBINED WITH SELECTIVE OSCILLOGRAPH STORAGE AND PHOTOGRAPHIC RECORDING OF THE SHAPES AND FREQUENCY SPECTRUM OF SPHERICS TO EXPLORE IMPACT SIGNATURES.

8 2 01 02 06 THERMAL RADIATION INTENSITIES AND SURFACE TEMPERATURE GRADIENTS

MEASUREMENTS OF SURFACE THERMAL ENVIRONMENT THROUGH LUNATION CYCLE AND AS A FUNCTION OF TOPOGRAPHY AND SURFACE CONDITIONS. INCLUDES SECONDARY INFRARED AND FLUORESCENT FLUX LEVELS IN SHADED AREAS AND TEMPERATURE GRADIENT CHANGES IN TERMINATOR ZONES. INSTRUMENTATION CONSISTS OF A BROADBAND CASSEGRAIAN TELESCOPE WITH A ROTARY SET OF SPECTRAL BAND FILTERS COVERING A RANGE OF 0.3 TO 20 MICRONS, A SET OF EQUALIZED SENSORS IN THE FOCAL AREA, AND A SINGLE CHANNEL RECORDER. DURING THE AUTOMATIC SCANNING MOTION OF THIS DEVICE, A SMALL FRAME SEQUENTIAL CAMERA WOULD BE EMPLOYED TO OBTAIN CORRELATING SURFACE PHOTOGRAPHS. RESULTS TO SUPPORT ENGINEERING MODEL OF THERMAL ENVIRONMENT FOR USE IN EXPLORATION EQUIPMENT THERMAL DESIGN AND IN ENVIRONMENTAL CONTROL.

8 1 02 15 03 LUNAR PLASMA PROPERTIES NEAR SURFACE

DETERMINES PLASMA FREQUENCY, THUS ELECTRON DENSITY, NEAR SURFACE. ANOMALIES OCCUR IN ANTENNA IMPEDANCE NEAR THE PLASMA FREQUENCY. UTILIZING A VECTOR IMPEDANCE METER IN CONJUNCTION WITH AN ANTENNA 2 KM IN LENGTH DEPLOYED 3-10 METERS ABOVE THE LUNAR SURFACE, THE PLASMA FREQUENCY MAY BE DEDUCED FROM MEASUREMENTS OF ANTENNA IMPEDANCE IN THE FREQUENCY RANGE OF 20-100 KHZ. SUPPORTS RADIOASTRONOMY EXPERIMENT PROGRAM. PERFORMED IN CONJUNCTION WITH LUNAR SURFACE AND SUBSURFACE ELECTRICAL PARAMETERS, EXPERIMENT NO. 8 2 01 01 09, AND PARTICLES AND FIELDS FUNDAMENTAL EXPERIMENT NO. 53010102 AND 53010103, SOLAR WIND INTERACTION OF MOON AND GEOMANETOSPHERS. UTILIZES EQUIPMENT FROM 8 2 01 01 09 AND REQUIRES NO ADDITIONAL EXPERIMENT SUPPORT. THEREFORE, ONLY THE C-CARD IS INCLUDED UNDER THIS EXPERIMENT NUMBER.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	MISSION SUPPORT INVESTIGATIONS

8 2 01 02 02 — LUNAR RF NOISE - PART 1 LOW FREQUENCIES

THE MAIN FEATURES OF THE MOON'S ELECTROMAGNETIC ENVIRONMENT IN THE FREQUENCY RANGE 10HZ TO 300 KHZ ARE EXPLORED WITH THIS EXPERIMENT. NOISE POWER AND DYNAMIC SPECTRUM ARE RECORDED DURING SPECIAL EVENTS (E.G., VLF EMISSIONS OR 'WHISTLER' TYPE ACTIVITY), AND PARTIAL CAPABILITY EXISTS TO DETERMINE NOISE WAVE IMPEDANCE, POLARIZATION, AND DIRECTION OF ARRIVAL. INSTRUMENTS INCLUDE 5 NARROW-BAND STEP-FREQUENCY RECEIVERS TO COVER THE DESIRED FREQUENCY RANGE. THE RECEIVERS ARE STEPPED IN SYNCHRONISM BY INCORPORATING A SINGLE LOCAL OSCILLATOR AND SUITABLE FREQUENCY DIVIDERS. TWO BROADBAND RECEIVERS ARE ALSO EMPLOYED SO THAT BROADBAND SPECTRA MAY BE RECORDED TO FACILITATE THE INTERPRETATION OF THE STEP-FREQUENCY RECEIVER RECORDINGS OF DYNAMIC SPECTRA.

8 2 01 02 03 — LUNAR RF NOISE - PART II

PERIODIC SWEEP SAMPLING OF LUNAR BACKGROUND IN FREQUENCIES BETWEEN 20 MHZ AND 70 GHZ. DISCRETE AND DISTRIBUTED NOISE TO BE MEASURED WITH DIRECTION AND TIME BEING RELEVANT VARIABLES. INFORMATION TO BE GATHERED FROM SEVERAL SMALL, ERECTABLE ANTENNAS COVERING FREQUENCY RANGE. EXPERIMENT DEPLOYED BY ASTRONAUTS AND OPERATED IN SUBSEQUENT UNMANNED MODE. (NOTE FREQUENCY RANGE FROM 300 KHZ TO 20 MHZ IS INVESTIGATED IN RADIO ASTRONOMY FUNDAMENTAL EXPERIMENT.) FOUR SWEEPING RECEIVERS COVERING THE ABOVE RANGE, AND FOUR WIDE BAND ANTENNAS ARE REQUIRED.

8 2 01 02 04 — ANTENNA DUST ACCUMULATION

THIS EXPERIMENT UTILIZES AN ELECTROSCOPE-TYPE INSTRUMENT TO MONITOR THE POTENTIAL DIFFERENCE BETWEEN SUSPENDED ANTENNAS AND LUNAR GROUND. THIS CONSTITUTES A MEASURE OF CHARGED DUST ACCUMULATION ON THE ANTENNA. THE EXPERIMENT PROVIDES CRITICAL DATA RELATIVE TO THE EFFECT OF LUNAR DUST ON RADIO ASTRONOMY ANTENNA.

8 2 01 02 05 — LUNAR ATMOSPHERE CONTAMINATION EFFECTS OF ROCKET EXHAUST.

LUNAR ATMOSPHERE CONTAMINATION BY ROCKET EXHAUST IS MEASURED WITH TIME-OF-FLIGHT MASS SPECTROMETER. INSTRUMENT MEASURES SPECIES CONCENTRATION VS DISTANCE AND TIME FROM SOURCE NEAR LUNAR SURFACE. DEFINES DYNAMIC AND RESIDUAL (SURFACE OUTGASSING) EFFECTS OF ROCKET EXHAUST FOR DEFINITION OF CONTAMINATION AND LANDING SITE CONSTRAINTS.

8 2 01 02 08 — EFFECTS OF LEAKAGE FROM VEHICLES, SHELTERS AND SPACE SUITS.

MEASUREMENT OF SPECIES CONCENTRATION OF ATMOSPHERIC CONTAMINANTS NEAR VEHICLES, CREW SHELTERS, AIR LOCKS (PARTICULARLY DURING EGRESS OPERATIONS), INSTRUMENT PACKAGES AND SUITED ASTRONAUTS. SPECIES CONCENTRATION TO BE MEASURED WITH TIME-OF-FLIGHT MASS SPECTROMETER AS FUNCTION OF TIME, DISTANCE AND ORIENTATION FROM SOURCE. RESULTS ARE BASIC TO LOCATION OF ENVIRONMENT-INFLUENCED EXPERIMENTS AND INTERPRETATION OF RESULTING DATA.

8 1 02 11 01 — GAS REQUIREMENTS FOR LUNAR CORE DRILLING

HIGH PRIORITY EXPERIMENT IN THE LUNAR ENVIRONMENT TO DETERMINE THE OPTIMUM GAS UTILIZATION FOR CORE DRILLING IN DISTINCT LUNAR LITHOLOGIES. GAS UTILIZATION RATE IS VARIED DURING ACTUAL DRILLING OPERATIONS. EXPERIMENTS ARE PERFORMED INITIALLY WITH HELIUM AND ARE REPEATED WITH ALTERNATE INERT GAS SUCH AS NITROGEN. EXPERIMENT PROVIDES DATA SUPPORTING OPTIMAL GAS UTILIZATION FOR COOLING, LUBRICATION, PREVENTION OF ADHESION OF LUNAR MATERIAL IN THE DRILL SYSTEM, AND REMOVAL OF CUTTINGS. TECHNIQUES FOR COMPRESSING AND RECIRCULATING THE GAS ALSO WILL BE EVALUATED. THUS, THE INVESTIGATION PROVIDES TECHNOLOGY ADVANCEMENT FOR BASIC CORE DRILLING AND SUPPORTS DEVELOPMENT OF DEEP-DRILLING SYSTEM. THIS INVESTIGATION IS TO BE PERFORMED AT SELECTED DRILLING SITES FOR FUNDAMENTAL GEO-SCIENCES INVESTIGATIONS AND MAY BE REPEATED OR MODIFIED FOR OTHER MISSIONS AND EXPLORATION PHASES. GAS FLOW RATES, VOLUMES AND DRILL BIT TEMPERATURE WILL BE RECORDED AUTOMATICALLY AS WELL AS THE DRILLING RATES. THE UTILIZATION OF THE EXPERIMENTERS TIME CAN BE INTEGRATED WITH THE EXPLORATION OPERATIONS. ADDITIONAL EQUIPMENT IS NOT NEEDED SINCE THE NECESSARY DATA WILL BE OBTAINED FROM THE NORMAL DRILLING MONITORING INSTRUMENTS.

EXPERIMENT NUMBER
A G S I E
R B P N X
E J E V P
4 T C S T

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 1 02 11 02 **LUNAR DRILL BIT TECHNOLOGY**

EXPERIMENT TO OBTAIN RELATIVE DRILLING EFFECTIVENESS AS MEASURED BY RATE OF PENETRATION, AND RELATIVE LIFE OF ALTERNATE DRILL BITS. SPEED OF ROTATION, RATE OF PENETRATION, AND BIT TEMPERATURE ARE CONTROLLED IN ORDER TO PERMIT BIT EVALUATION DURING CORE DRILLING OPERATIONS FOR EACH TYPE OF LITHOLOGY ENCOUNTERED. EXPERIMENT IS PERFORMED SEPARATELY FROM, AND SUBSEQUENT TO 81021101. "GAS REQUIREMENTS FOR LUNAR CORE DRILLING" IN ORDER TO DIFFERENTIATE EFFECTS OF VARIABLES. BASED ON EXTENSIVE EARTH-TESTING UNDER SIMULATED LUNAR CONDITIONS. PERFORMED IN CONJUNCTION WITH CORE DRILLING FOR FUNDAMENTAL INVESTIGATIONS. INVESTIGATIONS TO BE PERFORMED AT SELECTED SITES AND DURING EACH EXPLORTATION PHASE AS REQUIRED. FREQUENCY AND REPETITION SHALL BE ON A AS REQUIRED BASIS. UTILIZATION OF THE EXPERIMENTERS TIME CAN BE INTEGRATED WITH OTHER SIMULAR INVESTIGATIONS. THE TIMES AND EQUIPMENT ARE INCLUDED IN THE FUNDAMENTAL DRILLING EXPERIMENTS.

8 1 02 11 05 **SAMPLING SURVEY TECHNIQUES**

THIS ACTIVITY HAS AS ITS OBJECTIVE THE SUPPORT OF SITE SELECTION FOR SAMPLE COLLECTION TO MAXIMIZE INFORMATION VALUE FROM SAMPLE DATA. SELECTIONS ARE TO BE MADE WITH RESPECT TO TOPOGRAPHY, LITHOLOGY, COMPOSITION, STRUCTURE, DEPTH, ORIGIN (LUNAR OR METEORITIC) AND SPECIAL CHARACTERISTICS. THE ACTIVITY PROVIDES FOR CALIBRATION AND INTERPRETATION OF DATA FROM MULTIPLE SENSORS INCLUDING OPTICAL THERMAL, SEISMIC, SONIC, MAGNETIC, ELECTRIC, RADIOACTIVE, AND DENSITY. IT INCLUDES DATA CORRELATION AND MAPPING, AND RECORDING, AND IT IS TO BE PERFORMED AT DIFFERENT GEOLOGICAL AND GEOGRAPHICAL SITES. THIS TECHNIQUE APPLICATION ACTIVITY IS TO BE IMPLEMENTED AS A MISSION PROCEDURE INTEGRAL WITH FUNDAMENTAL GEOSCIENCES INVESTIGATIONS. THEREFORE, ONLY THIS C-CARD IS INCLUDED IN MISSION SUPPORT.

8 1 02 11 03 **CALIBRATION OF REMOTE-SENSING TECHNIQUES**

PROGRAM OF MEASUREMENTS ON THE LUNAR SURFACE TO ASSIST IN THE CALIBRATION OF REMOTE-SENSING TECHNIQUES, AND TO CORRELATE AND VALIDATE MAP DATA. MEASUREMENTS WOULD BE SELECTED TO SUPPLEMENT APPLICABLE FUNDAMENTAL GEOLOGY AND GEOPHYSICS INVESTIGATIONS. SURFACE MEASUREMENTS TO BE PERFORMED SELECTIVELY IN THIS PROGRAM ARE (1) MEASUREMENT OF ELECTROMAGNETIC ATTENUATION / REFLECTANCE COEFFICIENT AT MICROWAVE AND RADAR WAVELENGTHS, (2) GONIOMETRIC MEASUREMENTS OF REFLECTED SUNLIGHT, (3) GONIOMETRIC MEASUREMENTS OF SPECTRAL EMISSION AND REFLECTANCE OF IR ENERGY, (4) POROSITY MEASUREMENTS IN SITU, AND (5) DENSITY GRADATIONS IN DEPTH MEASURED IN SITU. CORRELATION WITH 81021104, "SAMPLING SURVEY TECHNIQUES", WILL AID IN MAKING SAMPLES MOST MEANINGFUL IN THE INTERPRETATION OF REMOTE SENSOR DATA DURING EACH EXPLORATORY PHASE. THE PERFORMANCE OF THIS INVESTIGATION WILL BE WHOLLY ACCOMPLISHED DURING FUNDAMENTAL GEOPHYSICS EXPERIMENTS. THE ONLY ADDITIONAL EFFORT WILL BE TO INSURE SIMULTANEITY AND COMPATIBILITY OF CONTACT AND REMOTE SENSING EXPERIMENTS. EQUIPMENT IS INCLUDED IN THE GEOPHYSICS EXPERIMENTS AND IS NOT DUPLICATED FOR THIS INVESTIGATION.

EXPERIMENT NUMBER
AREA GROUP SPECIAL EXPERIMENT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 1 02 11 04 LUNAR GEOLOGICAL - GEOCHEMICAL SAMPLE CASETTES

THE CONCEPT OF RETURN OF THE MAJORITY OF LUNAR SURFACE AND SUBSURFACE SAMPLES FOR EARTH ANALYSIS IS DICTATED BY OPERATIONAL CONSTRAINTS OF EARLY LUNAR SURFACE MISSIONS. THE SOPHISTICATION AND VALIDITY OF EARTH BASED ANALYSIS WILL DIRECTLY DEPEND UPON THE ADEQUACY OF PROCEDURES EMPLOYED FOR SAMPLE COLLECTION, HANDLING, PROCESSING AND PACKAGING. THIS WILL REQUIRE MEASUREMENT, DUPLICATION AND PRESERVATION OF THE ORIGINAL ENVIRONMENT IN WHICH THE SAMPLE IS FOUND. THIS EXPERIMENT WILL ASSESS THE RELATIVE EFFECTIVENESS OF EARTH DEVELOPED TECHNIQUES FOR PRESERVING LUNAR ENVIRONMENT CHARACTERISTICS IN SAMPLE CASSETTES. THESE INCLUDE 1) PRESERVATION OF THERMODYNAMIC ENVIRONMENT TO PREVENT PHYSICAL CHANGES OF STATE (E.G., TEMPERATURE, OVER BURDEN PRESSURE AND HARD VACUUM), 2) CHEMICAL ISOLATION OF SAMPLES TO PREVENT CONTAMINATION, 3) PRESERVATION OF MAGNITUDE AND VECTOR DIRECTION OF WEAK REMNANT MAGNETIZATION PARTICULARLY FOR ORIENTED SAMPLES, AND 4) MECHANICAL ISOLATION OF FRAGILE SAMPLES. EXPERIMENTAL EQUIPMENT WILL CONSIST OF SETS OF ALTERNATE SAMPLE CASSETTES AND PERIPHERAL COLLECTION AND PROCESSING EQUIPMENT TO BE PROVED ON IDENTICAL SAMPLES AND COMPARED ANALYTICALLY UPON RETURN TO EARTH.

8 1 02 12 01 RELATIVE ELECTRODE ELECTRICAL COUPLING PROPERTIES IN LUNAR SURFACE

SURFACE ELECTRICAL CONDUCTIVITY OR RESISTIVITY, SELF POTENTIAL, AND OVER VOLTAGE OR INDUCED POLARIZATION TECHNIQUES ALL DEPEND UPON THE THE USE OF CONTACT ELECTRODES. VARIABILITY IN CONTACT POTENTIALS ON A TRAVERSE WILL RESULT IN INCORRECT DETERMINATIONS AS TO IN SITU SUBSURFACE ANOMALIES. CHEMICAL INTERACTION OF LUNAR SURFACE MATERIALS WITH TYPICAL PROBE MATERIALS MUST BE CONSIDERED FOR SELECTION OF CANDIDATE PROBES. CONSISTENT WITH THE OBJECTIVE OF MINIMIZING CONTACT POTENTIALS, THIS INVESTIGATION INCORPORATES A VARIETY OF PROBE EMPLACEMENT STUDIES INCLUDING PRESSURE TECHNIQUES, USE OF MOLTEN OR PLASTIC MATERIALS, EXPLOSIVES, ETC. THE INVESTIGATION WILL ESTABLISH REQUIREMENTS FOR SURVEY ARRAY CONFIGURATIONS, POWER REQUIREMENTS, ETC. THE INVESTIGATION IS TO BE PERFORMED AT EARLY LANDING SITES SUITABLE FOR TRAVERSES AND SHOULD COVER THE GREATEST POSSIBLE RANGE OF REPRESENTATIVE MATERIALS LIKELY TO BE ENCOUNTERED.

8 1 02 12 03 EXPLOSIVE ENERGY COUPLING IN LUNAR MATERIALS

INVESTIGATION UTILIZES A SERIES OF SMALL-SCALE CRATERING STUDIES EMPLOYING DIRECTED AND NON-DIRECTIONAL CHARGES OF VARYING ENERGY YIELDS AT VARYING DEPTHS OF EMPLACEMENT. DRILL HOLES FROM FUNDAMENTAL INVESTIGATIONS MAY BE UTILIZED FOR EMPLACEMENT OF CHARGES, BOTH TAMPED AND UNTAMPED. SINCE GEOLOGY KIT MAY BE UTILIZED, PRIMARY ADDITIONAL WEIGHT IS THAT OF EXPLOSIVE CHARGES. EXPERIMENTAL MONITORING INCLUDES NOTATION OF LUNAR MATERIAL AND EJECTA PHYSICAL PROPERTIES, AND CONTROLLED PHOTOGRAPHIC RECORDING OF CRATER GEOMETRIES AND EJECTION PATTERNS. COINCIDENT SEISMIC RECORDINGS OF ENERGY, TRANSFER MUST BE MADE TO PERMIT PRECISE SPECIFICATION OF REQUIREMENTS FOR THE EXTENSIVE SUBSEQUENT SEISMIC EXPERIMENT. (AN EXPANSION OF THE INVESTIGATION WOULD INCLUDE COINCIDENT EVALUATION OF ALTERNATE ENERGY SOURCES FOR ACTIVE SEISMIC WORK, I. E., ELECTRICAL SPARKED TRANSDUCERS AND MECHANICAL THUMPER TRANSDUCERS, IN IDENTICAL MATERIALS.) COLLATERAL BENEFITS WOULD BE THE SUBSEQUENT USE OF SHOT HOLES FOR INSTRUMENT EMPLACEMENT HOLES, INTERPRETATION OF THE VELOCITY INFORMATION FROM THE SEISMIC DATA FOR SURFACE PROPERTY STUDIES, AND, IF ANY ARRAY IS USED, A FIRST LOCATION OF A POSSIBLE SEISMIC HORIZON. SEVERAL GEOPHONE DETECTORS APPROPRIATELY SPACED WOULD MONITOR THE SEISMIC DISTURBANCES INCLUDING BOTH A TIME PULSE AND LUNAR VIBRATIONS.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 1 02 12 05 **STEREOPHOTOGRAMMETRY**

THE FUNDAMENTAL REQUIREMENTS OF 1 METER OR BETTER RELATIVE ELEVATION DETERMINATION ACCURACY FOR TRAVERSE EXPERIMENTS (E.G., A CORRESPONDING GRAVITY CORRECTION OF ABOUT .1 M GAL) CAN BEST BE MET BY PROVIDING A STEROPHOTO BASE MAP OF THE EXPLORATION ZONE. FIELD TESTS OF THE HALCON SYSTEM (HIGH ALTITUDE LONG AXIS CONVERGENCE SYSTEM) HAVE DEMONSTRATED A PRECISION OF 3 INCHES FOR CONTOURING NUCLEAR TEST CRATERS FROM 5000 FEET ALTITUDE. TESTS OF A SIMILAR SYSTEM FOR EARLY EXPLORATION IS RECOMMENDED. USE OF SUCH A BASE MAP IN CONJUNCTION WITH THE EARTH REFERENCE GRAVIMETER AT KNOWN LAND MARKS WILL PERMIT ACHIEVEMENT OF THE REQUIRED (SELENODESY AND CARTOGRAPHY) 10-METER ABSOLUTE ELEVATION CONTROL.

8 1 02 12 07 **EARTH REFERENCE GRAVIMETER**

PROVIDES A CONTINUOUS OPERATION GRAVIMETER TO RECORD GRAVITY VARIATION IN THE CISLUNAR ENVIRONMENT, AND PROVIDES AN EARTH REFERENCE FOR CALIBRATION OF LUNAR GRAVITY SURVEY METERS. SINCE THE CONVENTIONAL GRAVITY METER USED FOR SURVEY IS BASICALLY A MASS SUSPENDED ON A SPRING, IT IS SENSITIVE TO DEFORMATION AND TEMPORAL VARIATIONS IN ENVIRONMENTAL CONDITIONS AND MUST BE FREQUENTLY CALIBRATED EVEN TO PROVIDE A RELATIVE PROFILE FOR A DAY'S TRAVERSE. TO EMPLOY A PENDULUM GRAVIMETER AS AN ABSOLUTE DEVICE, NOT ONLY ITS PERIOD BUT ITS LENGTH MUST BE MEASURED. ULTRA-HIGH VACUUM TECHNIQUES TESTED AT AIR FORCE CAMBRIDGE RESEARCH LABS HAVE RESULTED IN VERY SMALL DECREMENTS IN SEVERAL DAYS OF SWINGING. DIRECT AND REVERSE PERIOD AGREEMENTS OF 10-7 SECONDS HAVE BEEN ACHIEVED WITH INDIVIDUAL PENDULA. REFINEMENT OF THIS DEVICE FOR THE DURATION OF A LUNAR MISSION IS RECOMMENDED. (ALTERNATE CONCEPTS TO BE CONSIDERED FOR THE EXPERIMENT INCLUDE A PORTABLE FALLING BODY DEVICE EMPLOYING A FREE FALLING INTERFEROMETER MIRROR AND A GAS LASER VISIBLE LIGHT SOURCE, AND DETECTION OF GRAVITATIONAL ACCELERATION OF CHARGED PARTICLES.)

8 1 02 13 01 **BIOLOGICAL CONTAMINATION OF LUNAR SOIL**

THE OBJECTIVES OF THIS INVESTIGATION ARE TO PROVIDE AN EXTRA-TERRESTRIAL TEST OF A PLANETARY LIFE DETECTION PACKAGE, AND TO DETERMINE THE SURVIVABILITY OF BIOLOGICAL CONTAMINANTS IN LUNAR SOIL SAMPLES AND CONTAINERS. UNCONTROLLED CONTAMINATION OF LUNAR SAMPLES COULD LEAD TO ERRONEOUS CONCLUSIONS REGARDING THE HISTORY OF THE MOON OR THE PRESENCE OF LIFE ON THE MOON. THE STUDY REQUIRES AUTOMATED ACQUISITION, PREPARATION AND ANALYSIS OF SOIL, AND SUBSEQUENT AUTOMATED MICROBIAL INOCULATION OF LUNAR SOIL OPEN TO LUNAR ENVIRONMENT THROUGH A BILOLOGICAL FILTER. EXAMINATION OF VIABILITY AND/OR REPRODUCTION OF ORGANISMS WOULD BE PERFORMED AFTER EXPOSURE IN STANDBY PHASE OF AAP MISSION. THE EXPERIMENTAL PACKAGE UNDER CONSIDERATION BY THE NASA AMES RESEARCH CENTER FOR DETECTION OF LIFE ON THE SURFACE OF MARS WOULD BE ADVANTAGEOUS FOR THIS LUNAR INVESTIGATION. THE APPROACH UTILIZES SAMPLE ACQUISITION, SAMPLE PREPARATION, AND CHEMICAL AND BIOLOGICAL ANALYSIS SUBSYSTEMS. SAMPLE ACQUISITION CONSISTS OF CORE DRILL, SURFACE SCRAPER AND DUST COLLECTOR. DISTRIBUTION IS VIA A SEIVE AND CONVEYOR. EXTRACTION FUNCTIONS ARE PERFORMED IN PREPATATION FOR CERTAIN CHEMICAL ANALYSIS, INVOLVING SPECIFIC COLORIMETRIC ANALYSIS AND OPTICAL DETECTION OF ACTIVITY. OTHER CHEMICAL ANALYSES ARE-ORGANIC CARBON DETECTION AND GAS CHROMATOGRAPHY AND MASS SPECTROMETRY FROM PYROLYSIS. BILOGICAL ANALYSIS CONSISTS OF REPLICATION AND METABOLISN EXPERIMENTS. SUBSEQUENT CONFIRMATION BY ASTRONAUT DURING OCCUPANCY PHASE AND EARTH-RETURN OF PRE-SEALED BATCH SAMPLES PROVIDES EVALUATION OF LIFE DETECTION TECHNIQUES.

EXPERIMENT NUMBER (AGE SUBJECT SPECIES INVESTIGATION EXPERIMENT)	EXPERIMENT DESCRIPTION
	MISSION SUPPORT INVESTIGATIONS
8 3 06 41 07	HYDROGEN DETECTION AND ANALYSIS TECHNIQUES THE OBJECTIVE IS TO SUPPORT A COMPARATIVE EVALUATION OF METHODS FOR DETECTING AND MEASURING HYDROGEN CONTENT IN LUNAR MATERIALS. TECHNIQUES INCLUDE (1) DETECTION OF HYDROGEN IN LUNAR MATERIALS WITH AN N-GAMMA SPECTROMETER. MOBILE INSTRUMENTS TO BE AVAILABLE FOR ALL SURFACE TRAVERSES. (2) DETECTION OF HYDROGEN IN LUNAR MATERIALS WITH AN ATTENUATED TOTAL REFLECTION SPECTROMETER AT LUNAR BASE. (3)DETECTION OF HYDROGEN IN LUNAR MATERIALS WITH A PHOSPHORUS PENTOXIDE CONDUCTANCE CELL. AND (4) QUANTITATIVE ANALYSIS OF HYDROGEN IN LUNAR MATERIALS WITH A NUCLEAR MAGNETIC RESONANCE SPECTROMETER AT LUNAR BASE. THE ABOVE TECHNIQUES ARE TO BE EMPLOYED IN 83064101, 83064102, 83064103, 83064104, AND 83064105 TO PROVIDE COMPARATIVE DATA. SINCE THE SUPPORT REQUIREMENTS ARE DEFINED IN THESE PROSPECTING-TYPE EXPERIMENTS, 83064107 IS DESCRIBED BY THIS O-CARD ONLY. (THE OVERALL DETECTION TECHNIQUE EVALUATION WOULD BE PERFORMED ON EARTH UTILIZING CORRELATING ANALYSIS OF EARTH-RETURN SAMPLES.)
8 1 02 17 01	EARTH RFI AND BACKGROUND RADIO NOISE OBJECTIVE IS TO MEASURE NATURAL AND MAN MADE RF FREQUENCIES AT LUNAR ORBITS. IMPORTANT BEARING ON COMPUTATIONS OF BACKGROUND NOISE AND SUBSEQUENT DESIGN AND PLACEMENT OF LUNAR ASTRONOMY BASES. WIDE BAND (100KHZ TO 3 GHZ) SWEEP FREQUENCY RECEIVERS WITH WHIP (OR YAGI) ANTENNAS (LESS THAN 10MHZ) AND DISH ANTENNAS (GREATER THAN 100 MHZ) TO BE MOUNTED ON AN UNMANNED LUNAR SATELLITE MONITORING EARTH-ORIGINATING RFI AND COSMIC BACKGROUND NOISE ON THE EARTHWARD AND ANTI EARTHWARD HEMISPHERES OF THE MOON. OBSERVATIONS ON THE FAR SIDE ARE RECORDED FOR LATER TRANSMISSION.
8 1 02 17 02	DIELECTRIC PROPERTIES OF THE LUNAR SPHERE THE EXPERIMENT IS DESIGNED TO TEST THE POSSIBILITY THAT THE MOON MAY BEHAVE AS A DIELECTRIC SPHERE, FOCUSING ENERGY FROM THE SUN ON THE OPPOSITE SIDE OF THE MOON. IF THIS IS THE CASE, THE SOLAR BACKGROUND NOISE IN THE ANTIPODAL ZONE WOULD BE DETRIMENTAL TO RADIO ASTRONOMY EXPERIMENTS AND WOULD DISCOURAGE THE PLACEMENT OF ASTRONOMICAL BASES AT THE LUNAR EQUATOR. TO PROVIDE LONG-TERM READINGS, AN UNMANNED SUB-SATELLITE TO BE LAUNCHED FROM THE MANNED ORBITER-WILL CARRY WIDEBAND RADIOMETERS, EQUIPPED WITH WHIP OR YAGI ANTENNAS FOR RECEIVING RADIATIONS BELOW 100 MHZ, AND DISH ANTENNAS FOR HIGHER FREQUENCIES.
8 1 02 17 03	CRITICAL PLASMA FREQUENCIES OF ORBIT-TO-MOON TRANSMISSIONS THE PURPOSE OF THE EXPERIMENT IS TO INVESTIGATE THE LUNAR IONOSPHERE CRITICAL FREQUENCY BELOW WHICH ALL INCIDENT ENERGY IS REFLECTED BACK, A FREQUENCY EXPECTED TO VARY WITH DAY, NIGHT, AND SOLAR CONDITIONS. THE DATA WILL AID IN SETTING LOW-FREQUENCY BOUNDS FOR LUNAR RADIO ASTRONOMY AND IN THE DESIGN OF POSSIBLE LONG-DISTANCE LUNAR IONOSPHERIC COMMUNICATION LINKS. TO PROVIDE LONG-TERM READINGS, AN UNMANNED SUB-SATELLITE--TO BE LAUNCHED FROM THE MANNED ORBITER--WILL CARRY THE SWEEP-FREQUENCY GENERATOR, TRANSMITTING TO ONE OR MORE LUNAR-SURFACE RECEIVERS. UTILIZES RADIO-ASTRONOMY EQUIPMENT EMPLACED ON THE LUNAR SURFACE FOR FUNDAMENTAL EXPERIMENTS.
8 1 02 18 01	LUNAR OPTICAL ASTRONOMY TEST PROGRAM PURPOSE IS TO MAKE A PRELIMINARY EVALUATION OF THE ASTRONOMICAL POTENTIAL OF THE MOON. BASIC EXPERIMENTS ARE EXPECTED TO INCLUDE 1) POINTING ACCURACY ATTAINABLE. 2) STABILITY OF THE TELESCOPE, CHANGES IN THE ALIGNMENT INTRODUCED BY THERMAL AND SESMIC EFFECTS, 3) FOCUS-HOLDING, 4) METEORITIC EROSION OF THE OPTICAL SURFACES, 5) EFFECT OF THERMAL ENVIRONMENT ON FIGURE OF OPTICAL SURFACES, INCLUDING FLAT HELIOSTAT-COELOSTAT AND DYNAMIC AUTOMATICALLY ADJUSTING OPTICAL SYSTEM USING LASER LIGHT AS THE MEASUREMENT STANDARD AND PRECISE SEGMENT ACTUATORS. USES 12 INCH ENVIRONMENTAL TEST TELESCOPE.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVST	EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 1 02 18 02 **REMOTE OCCULTING DISK AS SOLAR CORONOGRAPH**
OBJECTIVE IS TO EVALUATE EXTERNAL OCCULATING DISK AS SIMPLE MEANS OF VIEWING SOLAR CORONA. SETUP DISK 100 METERS OR MORE FROM SOLAR TELESCOPE TO SUBTEND 0.5 DEGREES. OBSERVE AND PHOTOGRAPH CORONA AND CHROMOSPHERE WHEN SUN PASSES BEHIND DISK. PARAMETERS TO BE MEASURED ARE SHAPE OF SOLAR CORONA AND INTENSITY OF LIGHT ABOVE BACKGROUND OF SCATTERED SUNLIGHT, FROM 0.5 TO 2.0 DEGREES FROM CENTER OF SOLAR DISK. UTILIZES 12 INCH REFLECTING TELESCOPE FROM INVESTIGATION NO. 81021801, A DISK 1 METER IN DIAMETER, WITH SUPPORT, AND PHOTOGRAPHIC PLATES.

8 2 03 20 01 **CLINICAL MONITORING**
THE PRIMARY PURPOSE IS TO MONITOR HEALTH AND SAFETY OF LUNAR CREWS. THE SECONDARY PURPOSE IS ESTABLISHMENT OF EFFECTS OF REDUCED GRAVITY ON CREW PHYSIOLOGY. THE INVESTIGATION INCLUDES MEASUREMENTS OF BODY WEIGHT AND TEMPERATURE, BLOOD PRESSURE, HEMOGLOBIN WHITE AND RED CELL COUNT, URINE VOLUME SPECIFIC GRAVITY AND ANALYSIS, AND HEART RATE. ACQUISITION AND ANALYSIS OF DATA ARE TO BE DONE INSIDE THE LUNAR SHELTER. MEASUREMENTS ARE TO BE TAKEN ONCE EVERY THREE DAYS PER SUBJECT USING A MEDICAL KIT SIMILAR TO THE USAF-SAC FLIGHT SURGEONS FLY-AWAY KIT.

8 2 03 20 02 **MECHANICAL EFFICIENCY OF MAN AT REDUCED GRAVITY**
THE EXPERIMENT IS DESIGNED TO ESTABLISH ENERGY EXPENDITURES REQUIRED TO PERFORM WORK ON THE LUNAR SURFACE. TO DO THIS, COMPOSITION AND VOLUME OF INSPIRED AND EXPIRED AIR MUST BE OBTAINED UNDER CONTROLLED CONDITIONS, INCLUDING WORK AND REST PERIODS INSIDE THE SHELTER. MEASUREMENTS ARE TO BE TAKEN ONCE EVERY THIRD DAY PER SUBJECT. EQUIPMENT REQUIRED IS A FLOW TRANSDUCER/GAS CHROMOTOGRAPH WITH MOUTH PIECE AND HOSE ATTACHED AS ONE UNIT.

8 2 03 20 03 **WORK CAPABILITY DETERMINATIONS ON LUNAR SURFACE.**
OBJECTIVES ARE TO DETERMINE FORCE LIMIT CAPABILITY AND OTHER WORK LIMITS WHICH COULD LIMIT MAN'S ABILITY TO PERFORM USEFUL WORK ON THE LUNAR SURFACE. THIS COULD INFLUENCE CONSTRUCTION AND MAINTENANCE, EXPERIMENT PERFORMANCE, VEHICLE OPERATION AND OTHER TASKS. THE EXPERIMENT IS TO BE PERFORMED WITHIN THE SHELTER UNDER CONTROLLED CONDITIONS ONCE A WEEK PER SUBJECT. EQUIPMENT REQUIRED IS AN ERGOMETRIC KIT WITH A MULTIPURPOSE LOAD SHAFT FORCE TEST UNIT PERMITTING TESTING OF BOTH ISOMETRIC AND ISOTONIC WORK FORCES.

8 2 03 20 04 **BIOASSAYS OF BODY FLUIDS**
THE EXPERIMENT REPRESENTS THE LUNAR-BASED PORTION OF AN INVESTIGATION TO DETERMINE PHYSIOLOGICAL COST OF PROLONGED EXPOSURE TO THE LUNAR ENVIRONMENT. IT IS PERFORMED BY MEASURING URINE AND PLASMA 17 HYDROXY CORTICOSTEROIDS AND CATECHOLAMINES BEFORE, DURING AND AFTER LUNAR FLIGHT TO DETECT CHANGES IN ENDOCRINE FUNCTIONING. URINE IS COLLECTED AND VOLUME MEASURED FOR EACH SUBJECT EVERY DAY FOR THE FIRST 30 DAYS, AND EVERY THIRD DAY THEREAFTER. A 40 CC SAMPLE IS RETAINED FOR FURTHER ANALYSIS WHICH WILL BE CONDUCTED AFTER RETURN TO EARTH. EQUIPMENT INCLUDES A URINE VOLUME MEASUREMENT SYSTEM CONTAINING 800 CC URINE RECEIVER AND CARTRIDGE WITH RADIOACTIVE TRACER FLUID BUILT WITH QUICK DISCONNECT FROM WASTE COLLECTION SYSTEM. PLASTIC SELF-SEALING URINE SAMPLE CONTAINERS (40 CC) WILL ALSO BE REQUIRED.

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

EXPERIMENT NUMBER (AREA, OBJECT, SPEC, INVS, EXPT)	
8 2 03 20 05	**VISION STUDIES** THE OBJECTIVE IS TO DETERMINE EFFECTS OF LUNAR ENVIRONMENT ON VISUAL CAPABILITIES. THESE INCLUDE VISUAL ACUITY, FORM DISCRIMINATION, BRIGHTNESS DISCRIMINATION AND DEPTH PERCEPTION. VISUAL STIMULUS MATERIALS ARE TO BE PRESENTED TO SUBJECTS ON SETS OF SLIDES IN A MODIFIED ORTHORATER LOCATED WITHIN LUNAR SHELTER, AND SUBJECT'S RESPONSE RECORDED ON A TAPE RECORDER FOR EARTH-BASED ANALYSIS.
8 2 03 20 06	**PSYCHOLOGICAL STUDIES.** PSYCHOLOGICAL STUDIES EXPERIMENT IS DESIGNED TO DETERMINE EFFECT OF LONG TERM CONFINEMENT AND OTHER CONSTRAINTS OF LUNAR ENVIRONMENT ON PSYCHOLOGICAL BEHAVIOR. THESE TESTS WILL BE PAPER AND PENCIL AND SCORED ON THE LUNAR SURFACE. THESE TESTS IN CONJUNCTION WITH PERSONAL OBSERVATION BY THE LUNAR BASED MEDIC AND EARTH PHYSICIAN VIA TV WILL BE THE PRINCIPAL MEANS OF MONITORING PSYCHOLOGICAL BEHAVIOR OF LUNAR BASED PERSONNEL. ALL STUDIES TO BE DONE INSIDE LUNAR BASE.
8 2 03 20 10	**CARDIOVASCULAR PHENOMENA** THE OBJECTIVE OF THIS INVESTIGATION IS TO DETERMINE THE EFFECTS OF LIVING IN PARTIAL GRAVITY FOR LONG PERIODS OF TIME ON CARDIO-VASCULAR PERFORMANCE. RESULTS WOULD SUPPORT EVALUATION OF MISSION DURATION CAPABILITIES FOR LUNAR-BASED PERSONNEL. THE INVESTIGATION CONSISTS OF EKG MONITORING AND OXYGEN CONSUMPTION MEASUREMENTS ASSOCIATED WITH THE PERFORMANCE OF STANDARD TASKS DURING THE LUNAR SURFACE STAY. THE TESTS ARE OF 27 MINUTES DURATION (8 MINUTES OF PRE-WORK REST, 10 MINUTES OF WORK, AND 7 MINUTES OF REST) TO BE PERFORMED EVERY THIRD DAY. EQUIPMENT CONSISTS OF A CLOSED CYCLE REBREATHER SYSTEM OF 30 LITER CAPACITY, EKG AND RECORDER, AND A STANDARD WORK DEVICE SUCH AS A ROWING MACHINE.
8 2 03 20 11	**BONE DEMINERALIZATION STUDIES** THE OBJECTIVE IS TO DETERMINE THE EFFECTS OF EXTENDED EXPOSURE TO REDUCED GRAVITY UPON HUMAN BONE STRUCTURE. IT HAS IMPORTANT IMPLICATIONS TO MISSION DURATION DETERMINATIONS. WHEREVER POSSIBLE, LOAD BEARING BONES OF THE SUBJECT WILL BE EXAMINED VIA X-RAY MICRODENSITOMETRY. THIS WILL BE CORRELATED WITH CLINICAL TESTS SUCH AS BLOOD SERUM CALCIUMS AND URINARY CALCIUMS. TIME FOR EACH EXAMINATION IS 30 MINUTES. PERFORMANCE IS EVERY THIRD DAY. MONITORING EQUIPMENT CONSISTS OF X-RAY AND DENSITOMETRIC EQUIP-MENT AND CLINICAL APPARATUS.
8 2 03 30 01	**EVALUATION OF ALGAE STRAINS** THIS EXPERIMENT IS DESIGNED TO EVALUATE THE MAINTENANCE, GROWTH, AND DIVISION PHOTOSYNTHETIC RATES, AND METABLOIC PROPERTIES (INCLUDING PRODUCTS OF PHOTOSYNTHESIS) OF SELECTED ALGAE STRAINS UNDER LUNAR CONDITIONS FOR INCLUSION IN ECOLOGICAL LIFE SUPPORT SYSTEMS. PRINCIPAL EXPERIMENTAL TECHNIQUES INCLUDE GAS CHROMATOGRAPHY. DIRECT MICROSCOPIC OBSERVATION AND CELL COUNTS. THE LATTER WILL BE OBTAINED BY MEANS OF COULTER COUNTING TECHNIQUES. SAMPLES OF EACH ALGAE STRAIN WILL BE FREEZE DRIED FOR SUBSEQUENT STUDY ON EARTH.
8 2 03 30 02	**USE OF LUNAR SOIL FOR MICROORGANISMS AND HIGHER PLANTS** THIS EXPERIMENT WILL DETERMINE TO WHAT EXTENT, IF ANY, NATIVE LUNAR SOIL MAY BE USED AS A GROWTH MEDIUM FOR PLANTS AND MICROORGANISMS OF POTENTIAL ECOLOGICAL INTEREST. GROWTH OF ECONOMICALLY PROMISING PLANTS (OF POTENTIAL VALUE FOR LIFE SUPPORT) USING ENRICHED AND UNENRICHED SOIL WILL BE ATTEMPTED USING SOIL SAMPLES FROM ALL AVAIL-ABLE SOURCES. NUTRITIVE PROPERTIES OF THE SOIL WILL BE DETERMINED FROM BIOLOGICAL ASSAYS AND MEASUREMENTS OF RESPIRATION RATES, USING UNDIVIDUAL SIZE DETERMINATIONS AND GAS CHROMATOGRAPHY. THERMAL STERILIZATION OF THE LUNAR SPECIMENS WILL BE MANDATORY, THUS REQUIR-ING AN AUTOCLAVE. PLANT GROWTH CHAMBERS ALSO WILL BE REQUIRED.

EXPERIMENT NUMBER
A G S I E
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E J E V P
A T C S T

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 03 30 07 **EFFECTS OF LUNAR CONDITIONS ON PLANTS**
THE PURPOSE OF THIS EXPERIMENT IS TO DETERMINE THE EFFECTS, IF ANY, OF SUCH LUNAR CONDITIONS AS GRAVITY AND/OR IONIZING RADIATION ON GROWTH, DEVELOPMENT, REPRODUCTION, AND SURVIVAL OF SUCH PLANTS AS BARLEY, BEANS, DWARF CORN, TOMATOES, SPIDERWORT (TRADESCANTSA), THE JIMSON WEED (DATURA), AND ARABIDOPSIS SOIL FROM ALL AVAILABLE SOURCES. PLANTS WILL BE GROWN IN A GREENHOUSE USING ENRICHED LUNAR SOILS AS WELL AS THROUGH HYDROPONIC METHODS.THE PLANTS WILL BE PHOTOGRAPHED, MEASURED, AND BIOLOGICALLY FIXED, AND HISTOLOGICAL ANALYSIS PERFORMED. A PARAFFINE OVEN, MICROTOME, ESSENTIAL HISTOLOGICAL STAINS AND PHOTOMICROGRAPHIC EQUIPMENT WILL BE REQUIRED.

8 2 03 30 08 **GROWTH, DEVELOPMENT, REPRODUCTION, AND SURVIVAL OF PLANTS**
THIS EXPERIMENT WILL DETERMINE WHAT, IF ANY, ABNORMALITIES OR LESSER DEVIATIONS OF STRUCTURE AND/OR FUNCTIONING OCCUR IN INDIVIDUALS EXPOSED TO THE LUNAR CONDITIONS SPECIFIED, AND, IF ANY ARE FOUND, ATTEMPTS SHOULD BE MADE TO DETERMINE THEIR CAUSE AND TO FIND METHODS OF AMELIORATING OR CURING THEM AND OF PREVENTING THEIR OCCURRENCE. THIS STUDY IS PERFORMED IN CONJUNCTION WITH 82033007 AND UTILIZES THE SAME GREENHOUSE AND EQUIPMENT. WHERE FEASIBLE THE PLANTS SHOULD BE MAXIMALLY HOMOZYGOUS, BE RELATIVELY SMALL WITH SHORT LIFE CYCLES AND THOROUGHLY STUDIED.

8 2 03 30 09 **GENETIC EFFECTS OF LUNAR CONDITIONS AND EARTH-LUNAR TRIPS ON ANIMALS**
THE EXPERIMENT INCLUDES, AMONG OTHER SPECIFIC PROBLEMS, OBSERVATIONS OF POSSIBLE CYTOLOGICAL CHANGES OR GENE MUTATIONS INDUCED IN SOMATIC OF GERM CELLS BY CONDITIONS ENCOUNTERED ON THE MOON OR ON EARTH-LUNAR TRIPS. THE PROBLEM OF GREATEST CONCERN HERE INVOLVES THE EXTENT OF THE EFFECTS OF THE ADDITIONAL IONIZING RADIATION RECEIVED (PROVIDED THAT THEY ARE APPRECIABLE AT ALL BY AVAILABLE TECHNIQUES). SECONDLY THERE IS THE QUESTION OF THE POSSIBLE GENETIC EFFECTS OF THE VIBRATION, ACCELERATION, ETC., TO WHICH THE CELLS ARE SUBJECTED DURING THE TRIPS. REPRESENTATIVE INVERTEBRATES (FRUIT FLYS, ETC.) AND VERTEBRATES (MICE, CHICKS, ETC.) WILL BE EMPLOYED IN THE STUDY. THIS STUDY WILL MEASURE THE SAME PARAMETERS, TECHNIQUES AND EQUIPMENT (PARAFFINE OVEN, MICROTOME, HISTOLOGICAL STRAINS AND PHOTOMICROGRAPHIC EQUIPMENT) AS IN THE PLANT EXPERIMENTS.

8 2 03 30 10 **GROWTH, DEVELOPMENT, REPRODUCTION, AND SURVIVAL OF ANIMALS**
THIS EXPERIMENT WILL DETERMINE WHAT, IF ANY, ENVIRONMENTALLY INDUCED, PHYSIOLOGICAL ABNORMALITIES OR LESSER DEVIATIONS OF STRUCTURE AND/OR FUNCTIONING OCCUR IN INDIVIDUALS EXPOSED TO THE LUNAR CONDITIONS. IF ANY ARE FOUND, ATTEMPTS SHOULD BE MADE TO DETERMINE THEIR CAUSE AND TO FIND MEHTODS OF AMELIORATING OR CURING THEM AND OF PREVENTING THEIR OCCURRENCE. THIS STUDY SHOULD BE CARRIED OUT IN CONJUNCTION WITH 82033007 AND 4 USING THE SAME EQUIPMENT AND FACILITIES.

8 2 03 30 03 **EVALUATION OF HYDROGENOMONAS STRAINS**
THE PURPOSE OF THIS EXPERIMENT IS TO EVALUATE THE EFFECTS OF LUNAR CONDITIONS UPON GROWTH AND GAS EXCHANGE ABILITIES OF HYDROGENOMONAS FOR INCLUSION IN ECOLOGICAL LIFE SUPPORT SYSTEMS. PROCEDURE AND EQUIPMENT FOR THIS EXPERIMENT WILL BE ESSENTIALLY THE SAME AS THAT FOR THE EVALUATION OF ALGAE STRAINS, 82033001, EXCEPT THAT LIGHT IS NOT REQUIRED, BUT A SUPPLY OF HYDROGEN GAS IS REQUIRED.

EXPERIMENT NUMBER AREA	OBJECT	SPEC	INVST	EXPT	EXPERIMENT DESCRIPTION
					MISSION SUPPORT INVESTIGATIONS
8	2	03	30	06	EVALUATION OF HYDROCARBON-UTILIZING ORGANISMS THE PURPOSE OF THIS EXPERIMENT IS TO EVALUATE THE PERFORMANCE OF MICROORGANISMS CAPABLE OF UTILIZING HYDROCARBONS AS SUBSTRATES FOR AEROBIC METABOLISM AS POSSIBLE COMPONENTS OF LIFE SUPPORT SYSTEMS. HYDROCARBONS INITIALLY USED IN THE LUNAR EXPERIMENTS WILL BE TAKEN FROM EARTH, BUT THE ULTIMATE OBJECTIVE OF THE EXPERIMENT WILL BE TO STUDY SYNTHESIS OF EDIBLE ORGANIC COMPOUNDS FROM HYDROCARBONS PRODUCED BY THE CHEMICAL REDUCTION OF CO2 BY HYDROGEN PRODUCED THROUGH ELECTROLYSIS OF WATER OR SUPPLIED FROM OTHER SUPPORT SYSTEMS ON THE LUNAR BASE. PROCEDURES AND EQUIPMENT WILL BE ESSENTIALLY THE SAME AS THAT FOR THE EVALUATION OF ALGAE STRAINS, 82033001, EXCLUDING THE REQUIREMENT FOR LIGHT.
8	2	03	30	04	EFFECTS OF BREATHING VARIOUS GAS MIXTURES THE OBJECTIVE IS TO DETERMINE EFFECTS OF BREATHING VARIOUS GAS MIXTURES UNDER REDUCED GRAVITY CONDITIONS ON HUMAN WORK OUTPUT EFFICIENCY AND METABOLIC COST. EXPERIMENTS ARE TO BE PERFORMED INSIDE THE LUNAR SHELTER ONCE EVERY THIRD DAY PER SUBJECT. SUBJECT BREATHES MIXTURE OF GASES WHILE DOING STANDARD WORK TASKS. CONSUMPTION IS MEASURED IN LITERS PER MINUTE. EQUIPMENT USED WOULD BE THAT IDENTIFIED FOR THE WORK CAPABILITY STUDY, 82032003, IN ADDITION A GAS ANALYZER AND FACILITIES FOR STORING THE MIXED GASES WILL BE REQUIRED.
8	2	03	30	05	BIOLOGICAL MONITOR AND ECO-SYSTEM PROTOTYPE THE OBJECTIVE OF THIS STUDY IS TO DETERMINE THE EFFECTS OF LUNAR CONDITIONS UPON ANIMALS IN A CLOSED ECOLOGICAL LIFE SUPPORT SYSTEM. THE AFRICAN CLAWED TOAD (XENOPUS LAEVIS) AND EITHER RATS OR MICE ARE MORE AMENABLE TO EXPERIMENTATION TO MONITOR PROTOTYPE ECOSYSTEMS THAN MAN. GROSS PHYSIOLOGICAL RESPONSES WILL BE OBSERVED AND PHOTOGRAPHED AND HISTOLOGICAL PREPARATIONS MADE. THE REQUIRED EQUIPMENT CONSISTS OF A GROWTH CHAMBER, A PARAFFINE OVEN, MICROSCOPE, AND MICROTOME. THIS INVESTIGATION UTILIZES THE EQUIPMENT FOR 82033007, EFFECTS OF LUNAR CONDITIONS ON PLANTS.
8	2	04	31	01	SIMULATED PERSONNEL SHIELDING FROM SOLAR EVENT PROTONS AAP CANDIDATE EXPERIMENT UTILIZES LIGHT-WEIGHT DOSIMETERS PLACED IN WATER TANKS, INSIDE EQUIPMENT CONTAINERS AND AT NUMEROUS SELECT LOCATIONS WITHIN LABORATORY/SHELTER. DOSIMETERS WILL MEASURE ACCUMULATED RADIATION AT VARIOUS LOCATIONS AND FOR VARIOUS TYPES OF PROTECTION DURING FLIGHT, STANDBY AND OCCUPANCY PHASES OF MISSION. CREW OPERATIONS CONSIST OF COLLECTING DOSIMETERS PRIOR TO LABORATORY DEACTIVATION AND PACKAGING FOR RETURN TO EARTH. RESULTS WOULD BE CORRELATED WITH PARTICLES AND FIELDS FUNDAMENTAL EXPERIMENT WHICH MEASURES INCIDENT FLUX. YIELDS DATA FOR DESIGN OF WATER BAG SHIELDING AND/OR STORM SHELTER-TYPE SHIELDING FOR TRAVERSE VEHICLE AND TEMPORARY BASE ENVIRONMENTAL PROTECTION.
8	2	04	32	01	LUNAR ENVIRONMENT EFFECTS ON ANTENNA SYSTEMS MEASUREMENT OF ANTENNA PATTERN DISTORTION OF DIRECTIONAL ANTENNAS DUE TO LUNAR ENVIRONMENT FACTORS SUCH AS DUST, MECHANICAL AND THERMAL STRESSES AND MATERIAL BREAKDOWN. REQUIRES EMPLACEMENT OF RECEIVER AND COLLIMATING TARGET ON PROMINENT FEATURE AT APPROXIMATELY 5 KM FROM ANTENNA. INCLUDES PERIODIC INSPECTION OF ANTENNA SYSTEM FOR CORRELATING DATA.
8	2	02	32	02	RF FORWARD SCATTER TECHNIQUES OBJECTIVE IS TO DETERMINE THE UTILITY OF THE LUNAR SURFACE FEATURES TO REFRACT AND REFLECT RF ENERGY. AVAILABLE TRANSMITTING EQUIPMENT (VHF OR S-BAND) OR ADDITIONAL TRANSMITTERS (X-BAND OR KU-BAND) WITH DIRECTIONAL ANTENNAS SHALL BE USED FROM THE FIXED BASES. THE RF ENERGY WILL BE POINTED AT SELECTED TERRAIN FEATURES AND REFRACTED OR REFLECTED TO MOBILE RECEIVERS.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	MISSION SUPPORT INVESTIGATIONS
8 2 04 32 03	**RF GROUND WAVE PROPAGATION** MEASUREMENT OF NEAR AND FAR-FIELD STRENGTHS OF LUNAR SURFACE WAVES AT SEVERAL FREQUENCIES AND DISTANCES TO CONFIRM PROPAGATION MODEL. SELECTION OF OPTIMUM FREQUENCY AND ANTENNA IS TO BE PERFORMED AT THE SAME TIME. EFFECTS OF LUNAR SURFACE DISCONTINUITIES ARE TO BE DEFINED. INVESTIGATION IS DEPENDENT ON RESULTS OF LUNAR SURFACE AND SUBSURFACE ELECTROMAGNETIC PROPERTIES INVESTIGATION AND IS MADE UP OF SIMILAR EXPERIMENTS CONDUCTED WHERE SURFACE PROPERTIES DIFFER, E.G. MARE AND HIGHLANDS. THE INVESTIGATION IS DESIGNED TO EVALUATE GROUND WAVE PROPAGATION AND TO DEFINE THE MOST EFFECTIVE LINK. UTILIZES TRANSMITTER AND ANTENNA AT BASE AND SIMPLE RECEIVER ON TRAVERSE VEHICLE.
8 2 04 32 04	**RF SUBSURFACE PROPAGATION** INVESTIGATION OF PATH RESISTANCE AND COUPLING EFFECTS FOR LUNAR SUBSURFACE PROPAGATION AT SELECTED FREQUENCIES DETERMINATION OF OPTIMUM EXCITATION AND ANTENNA CONFIGURATIONS. DIRECTED ALSO TO IDENTIFICATION OF ATTENUATION AND ECHO EFFECTS OF STRATA DISCONTINUITIES AND IRREGULARITIES. INVESTIGATION TO BE PERFORMED AT SITES WHERE LUNAR SUBSURFACE CONDUCTION PARAMETERS INVESTIGATION HAS INDICATED FEASIBLE CONDITIONS EXIST. UTILIZES DRILL HOLES FROM FUNDAMENTAL EXPERIMENTS. SEVERAL CONFIGURATIONS OF SUBSURFACE TRANSMITTING AND RECEIVING ANTENNAS INCLUDING TRANSMITTERS AND RECEIVERS ARE REQUIRED. IN ADDITION, SURFACE ANTENNAS WILL BE USED TO TRANSMIT A SURFACE SIGNAL FOR COMPARISON WITH THE SUBSURFACE SIGNALS.
8 2 04 32 05	**LASER SCATTER PROPAGATION** USE OF LASER BEAMS AND RECEIVERS TO MEASURE SCATTER REFLECTION PROPERTIES OF ELEVATED LUNAR SURFACES SUITABLE FOR SETTING UP OVER-HORIZON LASER COMMUNICATION LINKS. INCLUDES TEST TO EVALUATE UTILIZATION OF EMPLACED DIRECTIONAL SCATTER SCREENS TO SUPPLEMENT NATURAL REFLECTORS VISIBLE FROM THE BASE.
8 2 04 32 06	**RETRODIRECTIVE OPTICAL SYSTEM TECHNIQUES** EXPERIMENT TO EVALUATE MODULATED INTERFERENCE RETRODIRECTIVE OPTICAL SYSTEM (MIROS) AS AN OPTICAL COMMUNICATIONS TECHNIQUE OFFERING NON-INTERFERENCE WITH RADIO ASTRONOMY AND COMMUNICATIONS EXPERIMENTS. INVOLVES UTILIZATION OF LASER OR OTHER OPTICAL SOURCE FROM LUNAR LABORATORY DIRECTED TO REMOTELY-LOCATED CORNER REFLECTOR, BOTH DIRECTLY AND VIA PASSIVE RELAYS. ONE FACE OF THE CORNER REFLECTOR IS DEFORMABLE, THUS MODULATING RETURN WAVE. INTEGRATION OF THIS MIROS EXPERIMENT WITH SENSORS FROM OTHER SELECTED FUNDAMENTAL EXPERIMENTS IS INDICATED.
8 2 04 33 01	**LUNAR SURFACE TRANSMISSION LINE INTERACTIONS** INVESTIGATION OF INTERACTIONS BETWEEN LUNAR SURFACE AND ELECTRICAL TRANSMISSION LINE COMPONENTS SUCH AS SUPPORTS, INSULATORS, LINES AND TERMINAL EQUIPMENT. CABLE TEST SECTIONS WOULD BE DESIGNED TO PROVIDE COMPARATIVE DATA INDICATING SHAPE, SURFACE FINISH AND MATERIALS FOR BEST HEAT REJECTION, DURABILITY, AND DEPLOYMENT. AFTER EXPOSURE AND USE, SMALL LINE SEGMENTS AND COMPONENTS SHOULD BE RETURNED TO EARTH FOR LABORATORY EVALUATION. INVESTIGATION TO BE BASED ON PREVIOUSLY COLLECTED DATA ON LUNAR SURFACE AND ENVIRONMENT - ALSO TO BE CORRELATED WITH EXPERIMENT NO. 82010104, CORROSIVE ACTION OF LUNAR MATERIALS.

EXPERIMENT NUMBER

AREA	OBJECT	SPEC	INVS	EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 04 33 02 **ELECTRICAL TRANSMISSION LINE ROUTES**
SURVEY TO ACQUIRE PHYSICAL (BEARING AND SHEAR STRENGTH), ELECTRICAL (CONDUCTIVITY), AND CHEMICAL (CORROSIVITY) DATA ALONG SPECIFIC POTENTIAL ELECTRICAL TRANSMISSION LINE ROUTES IN SUPPORT OF ROUTE ELECTION AND MODE OF DEPLOYMENT. PERFORMED ON EXTENDED EXPLORATION MISSIONS AFTER FEASIBILITY AND DESIGN REQUIREMENTS OF LUNAR ELECTRICAL TRANSMISSION LINES HAVE BEEN DETERMINED. GROUND SURVEY WILL BE BASED ON TOPOGRAPHICAL DATA FROM EARLIER AERIAL SURVEY. UTILIZES EQUIPMENT FROM EXPERIMENTS 82010108 AND 82010104 AND ON-BOARD GEOSCIENCES EQUIPMENT.

8 2 04 33 10 **ELECTRICAL SYSTEMS GROUNDING**
INVESTIGATION TO DETERMINE WHETHER, OR UNDER WHAT CONDITIONS, ELECTRICAL SYSTEMS ON THE MOON CAN BE SUCCESSFULLY GROUNDED OR WHETHER A FLOATING GROUND-TYPE SYSTEM IS NECESSARY. EXPERIMENTS WHICH APPLY TO FIXED SITE SYSTEMS UTILIZE TWO METAL SPIKES JOINED BY AN INSULATED CONDUCTOR WITH OHMMETER IN SERIES. SPIKES WOULD BE SEPARATED BY KNOWN LENGTH OF INTERCONNECTING WIRE, DRIVEN INTO SURFACE, DEPTH OF PENETRATION NOTED AND RESISTIVITY MEASURED. SHOULD BE REPEATED FOR THREE SURFACE CONDITIONS AND CORRELATED WITH GEOPHYSICS TECHNOLOGY EXPERIMENT 81021201, RELATIVE ELECTRODE ELECTRICAL COUPLING PROPERTIES OF THE LUNAR SURFACE. VEHICLE GROUNDING EXPERIMENTS INVOLVE INTERCONNECTED GROUNDING CHAINS WITH OHMMETER IN SERIES.

8 2 04 34 01 **DUST REMOVAL TECHNIQUES**
COMPARATIVE INVESTIGATION OF MEANS OF LUNAR PARTICLE (DUST) REMOVAL FROM SCIENTIFIC AND SUPPORT EQUIPMENT, AND LUNAR PERSONNEL SUITS IN THE LUNAR ENVIRONMENT. TECHNIQUES ARE TO INCLUDE MECHANICAL VIBRATION, GAS JET BLAST SWEEPING AND ELECTRICAL POTENTIAL TO REPEL CHARGED PARTICLES. IN THE CASE OF PERSONNEL SUITS, THE EXPERIMENT WOULD INCLUDE GAS JET BLAST SWEEPING WITHIN AN AIRLOCK WITH THE SUIT GROUNDED. PARAMETERS ARE REMOVAL RATE, DEGREE OF REMOVAL ATTAINABLE AND ENERGY REQUIRED. RATE AND DEGREE OBTAINED BY VISUAL INSPECTION, ENERGY BY EARTH CALCULATION. REQUIRES MECHANICAL VIBRATOR, GAS SOURCE, BRUSH AND LEADS.

8 2 04 34 02 **DAMAGE TO LUNAR EQUIPMENT**
DETERMINATION OF FUNCTIONAL DAMAGE TO EXPERIMENTAL AND MISSION SUPPORT EQUIPMENT USED ON THE MOON, TO DEFINE PROTECTIVE MEASURES AND DESIGN RULES FOR FUTURE EQUIPMENT. CONSISTS OF SERIES OF INSPECTIONS OF OPERATIONAL EQUIPMENT WITH PHOTOGRAPHIC AND QUANTITATIVE MEASURES OF DEGRADATION OR DAMAGE. INCLUDES MEASUREMENT OF DAMAGE TO UNDERSIDES OF VEHICLES, RESILIENCE AND SURFACE DEGRADATION OF SEALS FOR CORRELATION WITH KNOWN LEAKAGE RATES, AND DAMAGE TO LUNAR SUIT COMPONENTS. IN ADDITION TO PHOTO FILM, INSPECTION DATA RECORDED ON TAPE FOR TRANSMISSION TO EARTH. EMPLOYS COMMON USAGE EQUIPMENT.

8 2 04 34 03 **STATIC EXPOSURE EFFECTS ON MATERIALS**
CANDIDATE EXPERIMENT FOR AAP TO DETERMINE ALTERATION OF MATERIALS PROPERTIES RESULTING FROM EXPOSURE TO LUNAR SURFACE ENVIRONMENTS. UTILIZES EXTENSIBLE PANEL CONTAINING SAMPLES OF MATERIALS TO BE EXPOSED. AFTER LANDING OF AAP LAB, PANEL IS DEPLOYED REMOTELY FOR EXPOSURE DURING STANDBY PERIOD. AT END OF MANNED MISSION, SAMPLES ARE EXAMINED AND SELECTED ITEMS ENCAPSULATED FOR RETURN TO EARTH. SAMPLES ARE TO INCLUDE METALS (FOR STRUCTURES, ELECTRICAL COMPONENTS AND REFLECTORS), ORGANICS (FOR STRUCTURES AND SURFACE FINISHES), AND CERAMICS AND GLASSES (FOR OPTICAL AND GLAZING COMPONENTS). COMBINED EFFECTS OF PARTICULATE RADIATION, MICROMETEOROIDS, DUST, TEMPERATURE AND HIGH VACUUM TO INCLUDE DETERIORATION OF ELECTRICAL CONNECTORS AND INSULATORS, AND ALTERATION OF REFLECTIVITY OF MIRRORS AND OF OPTICAL CHARACTERISTICS OF GLASS. SUGGEST SMALL 7 INCH SQUARE PANEL WITH 49 ONE INCH SQUARE SAMPLES TO BE ENCLOSED IN VACUUM SEALED MYLAR BAG FOR RETURN TO EARTH.

EXPERIMENT NUMBER

ARBEAT SPACE INVEST EXPT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 04 34 04 **EXPOSURE EFFECTS ON RADIATOR MATERIALS**
ACQUISITION OF DATA ON THE LONG-TERM EFFECTS OF PARTICULATE RADIATION MICROMETEOROIDS, EXTREME VACUUM, AND TEMPERATURE ON THE EMISSIVITY AND REFLECTIVITY OF CANDIDATE RADIATOR MATERIALS AND COATINGS, ALSO ACQUIRE DATA ON THE RESPONSE OF THERMAL DIFFUSIVITY TO THE ABOVE ENVIRONMENT. INVOLVES EXPOSING SAMPLES OF THE MATERIALS AND COATINGS TO THE COMBINED ENVIRONEMNT AND THE RECORDING OF THEIR APPARENT AND TOTAL RADIATION TEMPERATURES. ELEVATED TEMPERATURE FROM ISOTOPIC POWER SOURCE. EXPERIMENT NO. 82043403 MAY BE ON SAME OR SEPARATE LAB. DURATION TO INCLUDE STANDBY, OCCUPANCY AND EMPLACED STATION PHASES OF AAP MISSION TO TOTAL ONE YEAR OR MORE.

8 2 04 34 09 **LONG-TERM STATIC EXPOSURE EFFECTS ON MATERIALS**
EXTENDED EXPLORATION PHASE EXPERIMENT TO BROADEN, SUPPLEMENT AND EXTEND STATIC EXPOSURE EXPERIMENT 82043403. UTILIZES SIMILAR EXTENSIBLE PANEL CONTAINING SAMPLES TO BE DEPLOYED FOR EXPOSURE AFTER REMOTE LANDING. DEGRADATION OF MATERIALS PROPERTIES TO BE MONITORED BY ASTRONAUT DURING 90-DAY OCCUPANCY. SELECTED SAMPLES TO BE ENCAPSULATED FOR RETURN TO EARTH. PARAMETERS TO BE MONITORED INCLUDE ELECTRICAL CONDUCTIVITY, REFLECTIVITY, TRANSMISSIVITY AND SURFACE ROUGHNESS.

8 2 04 34 06 EARLY MATERIALS DYNAMIC TESTS--MACHINE ELEMENTS
DYNAMIC TESTS TO MEASURE BEHAVIOR OF CONTACTING MACHINE ELEMENTS, INCLUDING UTILIZATION OF LUBRICATING COMPOUNDS, IN THE LUNAR ENVIRONMENT. (TESTS TO BE INTEGRATED WITH THIN FILM BEARINGS AND ELECTRICAL COMPONENTS.) TYPICAL MACHINE ASSEMBLIES WILL REPRESENT SLIDING, ROLLING AND STATIC CONTACT IN LUBRICATED AND UNLUBRICATED CONDITIONS. POTENTUAL SOLID LUBRICATING COMPOUNDS (DISULFIDES AND DISELENIDES OF TUNGSTEN,MOLYBDENUM, NIOBIUM AND TANTALUM) WILL BE INCORPORATED IN SINTERED POWDER COMPOSITES IN THE FORM OF MACHINE ELEMENTS. TEMPERATURE RISE TO BE MEASURED WITH THERMOCOUPLES, FRICTION FORCES WITH STRAIN GAGES AND SURFACE CONDITION WITH GAGE AND PHOTOMICROGRAPHS.

8 2 04 34 07 EARLY MATERIALS DYNAMIC TESTS--THIN FILM BEARINGS
PART OF INTEGRATED INVESTIGATION WHICH MEASURES DURABILITY OF THIN FILM DEPOSITIONS ON INSTRUMENT-TYPE BEARINGS WHICH ARE DIFFICULT TO EQUIP WITH LUBRICATING RETAINERS MADE FROM POWDER COMPOSITES BECAUSE OF SMALL SIZE. EXPERIMENT TO INCLUDE STANDBY IN LUNAR SURFACE ENVIRONMENT, CONTROLLED OPERATIONS AND EXAMINATIONS. SIMULTANEOUS ARRAY TESTING OF EQUALLY LOADED BEARINGS ON COMMON SHAFT. TEMPERATURES TO BE MONITORED, WEAR TO BE MEASURED PERIODICALLY AND SURFACE CONDITION RECORDED.

8 2 04 34 08 EARLY MATERIALS DYNAMIC TESTS--ELECTRICAL COMPONENTS
PART OF INVESTIGATION WHICH TESTS THE EFFECTIVENESS OF SOLID LUBRICATING COMPOUNDS (SUCH AS COMPOUNDS OF NIOBIUM AND TANTALUM) IN PREVENTION OF SEIZING AND/OR LUBRICATING ELECTRICAL CONTACTS AND MOTOR BRUSHES. TEST PERIOD INCLUDES UNMANNED STORAGE OR OPERATING PERIOD AND OCCUPANCY PERIOD. TEST ITEMS COULD INCLUDE OPERATIONAL EQUIPMENT EXAMINED UPON DEACTIVATION. BASIC PARAMETERS ARE TEMPERATURE, COEFFICIENT OF FRICTION, WEAR AND LIFE. PERFORMED WITH COMBINED TEST APPARATUS, REFERENCE EXPERIMENT NO. 82043406.

8 2 04 34 05 **MATERIALS DYNAMIC TEST PROGRAM**
EXTENDED TEST PROGRAM TO EVALUATE FUNCTIONAL PERFORMANCE OF SELECTED MATERIALS IN MECHANICAL SYSTEMS, UNDER THE LUNAR ENVIRONMENT. INVOLVES TESTS OF BEARINGS, DIAPHRAGMS, SEALS, TIRES, CABLES, CORDAGE, COATED FABRICS, MOLDED PARTS, SPRINGS, SLIDING AND ROTATING SHAFTS, ETC. TEST APPARATUS WOULD INCORPORATE PARALLEL TESTING OF ALTERNATE MATERIALS AND MECHANICAL DEVICES. INTEGRATES TEST FUNCTIONS IN COMPOSITE APPARATUS TO DEGREE THAT INDIVIDUAL FAILURES DO NOT COMPROMISE OTHER TEST FUNCTIONS. SHOULD BE PERFORMED IN ULTRA-HIGH VACUUM APART FROM PRESSURIZED FACILITIES. MONITORED PARAMETERS ARE TEMPERATURE, FRICTION, SURFACE DETERIORATION AND LEAKAGE RATES. SMALL TENSILE TESTER TO BE EMPLOYED FOR MECHANICAL PROPERTIES.

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 02 34 13 **SOLID-STATE MATERIALS**
IDENTIFICATION OF LONG-TERM EFFECTS OF ELECTROMAGNETIC AND PARTICULATE RADIATION, AND LUNAR VACUUM AND THERMAL ENVIRONMENT ON THERMOELECTRIC, PHOTOELECTRIC, SEMICONDUCTING, AND SUPERCONDUCTIVE MATERIALS. EXPERIMENT APPROACH IS TO INCORPORATE SOLID STATE DEVICES IN CONTROL CIRCUITS WHICH ARE SHIELDED FROM ENVIRONMENTAL CONDITIONS, EXCEPT FOR DEVICES TO BE TESTED. EXPOSED DEVICES ARE CONNECTED IN PARALLEL WITH COMPARABLE SHIELDED DEVICES. BY SWITCHING, COMPARATIVE PERFORMANCE DATA CAN BE OBTAINED. EXPOSURES OF 3 MONTHS TO 1 YEAR IN LUNAR ENVIRONMENT ARE ANTICIPATED. ASTRONAUT HAS OPTION OF RETURNING EXPOSED DEVICES TO EARTH OR OF CONTINUING EXPERIMENT IN EMPLACED STATION MODE.

8 2 04 34 14 **ELASTOMER AND POLYMER BEHAVIOR**
OBJECTIVE IS TO DETERMINE EFFECTS OF EXPOSURE OF SELECTED COMPOUNDS IN PURE STATE AND IN SEMIFABRICATED PARTS SUCH AS VACUUM-JOINED ELASTOMERS AND PLASTIC, COATED FABRICS ON DACRON, NYLON AND METAL CLOTHS, SIMULATED DIAPHRAMS, TIRES, SPACESUITS, HOSES AND BOOTS. INCLUDES DYNAMIC TESTING OF SIMPLE STRUCTURES SIMULATING USE CONDITONS OF ABOVE ITEMS. MANY OF THESE TESTS CAN BE INCORPORATED AS PARTS OF OTHER TEST EQUIPMENT STRUCTURES TO GAIN USEFUL DATA AT MINIMAL ADDED COST. LIMITED EXAMINATION OF ENVIRONMENTALLY-INDUCED AND ENVIRONMENT/DYNAMIC USE-INDUCED EFFECTS TO BE PERFORMED ON THE LUNAR SURFACE. LEAKAGE RATES TO BE MONITORED. KEY SPECIMENS TO BE ENCAPSULATED IN VACUUM FOR RETURN TO EARTH FOR DETAILED STUDY.

8 2 04 34 15 **STATIC AND DYNAMIC SEALS**
EXPERIMENT UTILIZES TEST ARTICLES, INCORPORATING VARIED SEAL GEOMETRICS AND VARIOUS SEAL MATERIALS PLACED IN STORAGE IN REQUIRED MODES I.E., DOOR SEALS UNDER FLANGE COMPRESSION, COMPARTMENT SEALS RETAINING INTERNAL PRESSURE, ROTARY SEALS AT REST WITH NO PRESSURE DIFFERENTIAL AND WITH PRESSURE DIFFERENTIAL. ALL SIMULATED CONFIGURATIONS TO BE INSTRUMENTED TO DETECT PRESSURE LOSS AT INTERVALS. TEST ARTICLES TO BE OPERATED (OPENED AND CLOSED) BY SCIENTIST AT INTERVALS TO DETECT DETERIORATION BY FUNCTIONAL INDICATORS - STICKING, CRACKING OR FLOWING OF SEAL MATERIALS,ETC. ROTARY SEALS TO BE OPERATED INTERMITTENTLY BY HAND TO CHECK DEGRADATION OF FUNCTION. INCLUDES TENSILE AND COMPRESSIVE TESTS OF SEAL SEGMENTS. SAMPLES TO BE REMOVED AND ENCAPSULATED FOR TRANSFER TO EARTH FOR ANALYSIS.

8 2 04 35 01 **DYNAMICS AND SURFACE ENVIRONMENT EFFECTS ON LONG ANTENNA STRUCTURES**
EXPERIMENT TO TEST ANTENNA EXTENSION TECHNIQUES, DESIGN CONCEPTS AND THERMAL AND DYNAMIC STABILIZATION OF LONG ANTENNA STRUCTURES IN THE LUNAR SURFACE ENVIRONMENT. ANTENNA HEIGHTS OF 30 TO 150 METERS MAY BE REQUIRED FOR LONG WAVE RADIO ASTRONOMY ARRAYS AND FOR SURFACE COMMUNICATIONS. THIS EXPERIMENT BUILDS ON ORBITAL TECHNOLOGY FOR EXTENSIBLE ANTENNAS IN ZERO G AND ADAPTS THIS TO ERECTION USING LATERAL SUPPORT STABILIZATION IN 1/6 G ENVIRONMENT. EXPERIMENT IS TO BE PERFORMED ON SMALL MODEL(S) SIMULATING SUCH LARGER OPERATIONAL ANTENNA STRUCTURES. IT MAY BE PERFORMED DURING LUNAR DAY WITH THERMAL DEFLECTION AND DURING LUNAR NIGHT WITHOUT THERMAL GRADIENTS.

8 2 04 35 02 **REPAIR TECHNIQUES FOR MAJOR STRUCTURAL DAMAGE**
THE OBJECTIVE OF THE EXPERIMENT IS TO TEST TECHNIQUES AND EFFECTIVENESS FOR REPAIR OF DAMAGED STRUCTURAL PANELS SIMULATING PENETRATION AND DISTORTION BY SURFACE EQUIPMENT OR METEOR IMPACT. THE EXPERIMENT IS TO BE PERFORMED IN LUNAR VACUUM ENVIRONMENT. THE PROCEDURE CONSISTS OF THE APPLICATION OF ALTERNATE EARTH-DEVELOPED TECHNIQUES TO THE STRAIGHTENING, COVERING OR PATCHING, AND SEALING OF THE PRE-DAMAGED PANELS. AFTER REPAIR, DIAPHRAMS ARE SECURED TO THE PANELS AND LEAKAGE MONITORED. THIS EXPERIMENT PROVIDES COMBINED ASSESSMENT OF ASTRONAUT-SUIT CAPABILITIES. EFFECTIVENESS OF HAND TOOLS, AND OF JOINING AND SEALS. (TO BE CORRELATED WITH HUMAN FACTORS INVESTGATIONS AND MATERIALS RESEARCH INVESTIGATIONS.)

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 05 36 01 **SOIL VALUE VARIATIONS IN LUNAR TERRAIN**

THIS INVESTIGATION HAS AS ITS OBJECTIVE THE MEASUREMENT OF LOCOMOTIVE STRESS-STRAIN RELATIONSHIPS IN LUNAR TERRAIN. THE LUNAR TERRAIN TO BE TRAVERSED IN EXPLORATION MISSIONS IS EXPECTED TO BE HETEROGENEOUS AND TO EXHIBIT RANDOM CHANGES IN LOCOMOTIVE CHARACTERISTICS. THE SOIL VALUES TO BE ENCOUNTEDED ARE HIGHLY IMPORTANT IN DESIGN AND IMPROVEMENT OF SURFACE VEHICLES IN THAT THEY PERMIT DETERMINATION OF THRUST AVAILABLE IN THE SOIL, MOTION RESISTANCE DUE TO SOIL COMPACTION, DRAWBAR PULL, SLOPE CLIMBING CAPABILITY, RUNNING GEAR DIMENSIONS, ETC. CORRELATION OF SOIL VALUE VARIATIONS WITH TOPOGRAPHY AND LITHOLOGY WILL SUPPORT THE PLANNING OF TRAVERSE ROUTES. THE INVESTIGATION ENVISAGES THE USE OF A FIELD BEVAMETER, SIMILAR IN OPERATION TO THE MK-100, IN WHICH INDEPENDENTLY LOADED WHEELS ARE TOWED BY A LUNAR VEHICLE. THE WHEELS ARE SUBJECTED TO VARIABLE LOADS AND ALL FORCES INCLUDING TOWBAR PULL, SLIP AND SINKAGE ARE RECORDED. THIS PERMITS CALCULATION OF THE ANGLE OF SOIL FRICTION (LETTER PHI), THE COULOMBIAN SOIL COHESION (C). THE SOIL SLIP VALUE (K), THE COHESIVE AND FRICTIONAL MODULI OF DEFORMATION (K SUB C AND K-SUB PHI), AND THE EMPIRICAL SOIL VALUE (N).

8 2 05 36 02 **DANGEROUS TERRAIN WARNING TECHNIQUES**

INVESTIGATION OF JOINT AND INDIVIDUAL APPLICATION OF GEOPHYSICAL SURVEY TECHNIQUES FOR WARNING OF DANGEROUS LUNAR TERRAIN FEATURES ENCOUNTERED ON FOOT OR VEHICLE TRAVERSES. SPECIFIC EXPERIMENTS INVESTIGATE THE CAPABILITIES OF UHF AND VHF, RADARS, DENSITOMETERS, GRAVIMETERS, MICROWAVE AND INFRARED RADIOMETERS, AND CONTINUOUS SEISMIC ECHO RANGING TO DETECT CREVASSES, SUBSURFACE VOIDS AND INCREASED DUST LAYER THICKNESSES. RECOGNIZED SUBSURFACE VOIDS WOULD BE MAPPED FOR POTENTIAL USE AS STORAGE AREAS OR SHELTERS. (AUTOMATION OF THESE TECHNIQUES TO PROVIDE TERRAIN AND CREVASSE AVOIDANCE SYSTEMS FOR POSSIBLE UNMANNED OPERATION WOULD BE PERFORMED ON EARTH.)

8 2 05 37 01 **VISUAL TECHNIQUES IN LAND NAVIGATION - ASTRONAUT VISION**

THE OBJECT OF THIS EXPERIMENT IS TO ACQUIRE DATA ON DRIVER VISUAL CAPABILITY AS RELATED TO THE PHOTOMETRIC CHARACTERISTICS OF THE LUNAR SURFACE UNDER A REPRESENTATIVE SAMPLING OF LUNAR LIGHTING CONDITIONS AND TERRAIN TO SUPPORT ADVANCEMENT OR REFINEMENT OF VISUAL AIDS TO LAND NAVIGATION. LUNAR LIGHTING CONDITIONS WILL VARY MARKEDLY WITH SOLAR ELEVATION RELATIVE TO TOPOGRAPHY AND THE OBSERVER'S LINE OF SIGHT RELATIVE TO THE SUN. THE ABSENCE OF ATMOSPHERIC SCATTER OF LIGHT WILL RESULT IN HIGH CONTRASTS BETWEEN LIGHTED AND SHADOWED AREAS. THE EXPERIMENT INVOLVES THE CONDUCT OF VISUAL CAPABILITIES TESTS THROUGH THE ACQUISITION AND INTERPRETATION OF VISUAL TEST FORMS PLACED ON REPRESENTATIVE TYPES OF TERRAIN. IT INCLUDES THE ACQUISITION AND RECORDING OF COORDINATED DATA INCLUDING PHOTOGRAPHS, RECEIVED LIGHT INTENSITY, FILTERS EMPLOYED, LIGHTING AND VIEWING GEOMETRICAL PARAMETERS, AND VEHICLE LIGHTING AIDS. IT MAY BE PERFORMED FROM THE LSSM DURING THE EARLY AAP PHASE FOR APPLICATION TO SUBSEQUENT AAP MISSIONS AND TO ROVER. PRIMARY EQUIPMENTS ARE A COMMON-USAGE CAMERA, AND CAMERA AND HELMET FILTERS. THE EXPERIMENT COMPLEMENTS 82032005 "VISION STUDIES" IN THE MOBILE ENVIRONMENT.

EXPERIMENT NUMBER
AREA / OBJECT / SPEC / INVST / EJECT

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 05 37 02 **VISUAL TECHNIQUES IN LAND NAVIGATION - LAND RECOGNITION**
THIS EXPERIMENT REPRESENTS THE CULMINATING LUNAR PHASE OF AN EARTH BASED SIMULATION PROGRAM OF LUNAR LANDMARK RECOGNITION. MANY AREAS OF THE LUNAR SURFACE WILL PRESENT REPETITIOUS TOPOGRAPHY WHICH WILL SERIOUSLY IMPAIR THE ABILITY OF THE ASTRONAUT TO MAINTAIN KNOWLEDGE OF HIS LOCATION BY VISUAL REFERENCE OR TO RE-ESTABLISH HIS LOCATION IF LOST. THE OBJECTIVE OF THE EXPERIMENT, THEREFORE, IS TO ASSESS THE EFFECTIVENESS OF LANDMARK RECOGNITION TECHNIQUES UNDER SELECTED LUNAR CONDITIONS TO PROVIDE DATA FOR THEIR IMPROVEMENT. THE EXPERIMENT WILL CONSIST OF VISUAL RECOGNITION TESTS PERFORMED BY THE SECOND, NON-DRIVING ASTRONAUT ON THE LSSM AND POSSIBLY THE ROVER. RECOGNITION REFERENCE DATA WILL HAVE BEEN PROVIDED BY PREVIOUS HIGH-RESOLUTION MAPPING OF THE AREA FROM ORBIT. (COMPLEMENTARY LOW-ELEVATION PHOTOGRAPHS OF THE TERRAIN FROM ORBIT, SIMULATING ASTRONAUT VIEW-ANGLES TO LANDMARKS, MAY BE REQUIRED). EQUIPMENT INCLUDES PHOTO-REFERENCE MATERIAL, MARKERS FOR RETURN REFERENCE TEST, AND COMMON USAGE BINOCULARS, RANGE FINDER, SEXTANT AND CAMERA. THE ON-BOARD NAVIGATION SYSTEM PROVIDES CONTROL DATA. THE EXPERIMENT SHOULD BE PERFORMED WHILE EN-ROUTE ON LUNAR EXPLORATION SORTIES.

8 2 05 39 01 **EXPLOSIVE TECHNIQUES FOR SURFACE MODIFICATION**
DEVELOPMENT OF TECHNIQUES FOR SURFACE MODIFICATION IS EXPECTED TO FOLLOW DEVELOPMENT AND USE OF EXPLOSIVE SEISMIC EXPLORATION TECHNIQUES AND IDENTIFICATION OF LUNAR SURFACE PHYSICAL CHARACTERISTICS. THE CHARGES TO BE USED WILL BE SELECTED FOR THE MATERIAL TO BE MODIFIED. EXPLOSIVE TYPES WILL RANGE FROM RDX FOR FRANGIBLE MATERIAL, LIKE GRANITE, TO BLACK POWDER FOR SPONGY MATERIAL. DEBRIS INHIBITORS SUCH AS BLASTING MATS MAY NOT BE FEASIBLE BECAUSE OF THEIR WEIGHT AND BULK. THE INVESTIGATION INCLUDES MEASUREMENT OF CRATER FORMATION, DEBRIS PATTERN, IMPACT DANGER ZONES, DETERMINATION OF EXPLOSIVE WEIGHT PER CUBIC YARD OF MATERIAL MOVED, BREAK-UP EFFECTS FOR EXCAVATION AND MINING, SHAPED CHARGE EFFECTIVENESS AND EFFECTIVENESS OF SPECIAL EXPLOSIVE DEVICES SUCH AS EXPLOSIVE FOXHOLE DIGGERS. EXPERIMENTS WOULD UTILIZE EXPLORATION DRILL HOLES WHERE AVAILABLE AND WOULD BE BASED ON EARTH CONDUCTED RESEARCH PROGRAM.

8 2 05 39 02 **DIGGING AND CUTTING TOOL ASSESSMENT**
PROGRAM OF MEASUREMENT OF FRICTION-INDUCED HEAT IN LUNAR EXCAVATION EQUIPMENT FOR USE IN IMPROVING TOOTH AND BIT DESIGNS AND HEAT TRANSFER AND REJECTION TECHNIQUES. THIS IS AN EXTENDED EXPLORATION PHASE ACTIVITY. NO ADDITIONAL SUPPORT IS INVOLVED. USE EXISTING INSTRUMENTATION AND MANHOURS INCLUDED IN THE DRILLING EXPERIMENT. THEREFORE, ONLY O CARD IS SUBMITTED.

8 2 05 40 01 **METALS JOINING TECHNIQUES IN LUNAR SURFACE CONSTRUCTION AND REPAIR**
WELDING TECHNIQUES TO BE ASSESSED INCLUDE ELECTRON BEAM WELDING. CANDIDATE BRAZING TECHNIQUES INCLUDE EXOTHERMIC AND INDUCTION BRAZING.DIFFUSION BONDING WOULD TAKE ADVANTAGE OF VERY HARD LUNAR VACUUM. INVESTIGATION WOULD BE SUPPORTED BY EXPERIMENT NO. 90010101 GENERATION OF HIGH ENERGY ELECTRON BEAMS. LACK OF GASEOUS INTERFACE PRESENTS PROBLEMS IN CONTROL OF LIQUID METALS DURING BRAZING AND WELDING. PARAMETERS INCLUDE LOSS OF WELD MATERIALS BY VAPORIZATION, PATTERN OF VAPORIZATION, AND QUANTITIES AND PRESSURES OF INERT GASES TO DIRECT LIQUID METAL FLOW.

8 3 06 41 01 **DETECTION OF HYDROGEN IN LUNAR MATERIALS USING NEUTRON ACTIVATION**
OBJECTIVE IS TO OBTAIN INDICATION OF WATER CONTENT IN LUNAR MATERIALS. SURVEY UTILIZES N-GAMMA SPECTROMETER AND TECHNIQUES EMPLOYED IN FUNDAMENTAL EXPERIMENT NO 32010101, CHEMICAL ANALYSIS USING NEUTRON ACTIVATION. INSTRUMENTS TO BE AVAIALABE FOR ALL SURFACE TRAVERSES.

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 3 06 41 06 **DETECTION OF HYDROGEN IN LUNAR MATERIALS USING INFRARED SPECTROMETER**
OBJECTIVE IS TO PROVIDE QUANTITATIVE EVALUATION OF WATER CONTENT IN LUNAR MATERIAL SAMPLES. ANALYSIS UTILIZES ATTENUATED TOTAL REFLECTION SPECTROMETER, AND TECHNIQUES EMPLOYED IN FUNDAMENTAL EXPERIMENT NO. 32010102, CHEMICAL ANALYSIS USING AN INFRARED SPECTROMETER. ANALYSIS IS PERFORMED AT LUNAR BASE.

8 3 06 41 05 **QUANTITATIVE ANALYSIS OF HYDROGEN IN LUNAR MATERIAL**
ANALYSIS PERFORMED AT THE LUNAR BASE UTILIZING NUCLEAR MAGNETIC RESONANCE SPECTROMETER TO YIELD DATA ON WATER CONTENT. THIS IS AN EXTENSION OF FUNDAMENTAL EXPERIMENT NO. 32010103, CHEMICAL ANALYSIS USING A NUCLEAR MAGNETIC RESONANCE SPECTROMETER.

8 3 06 41 04 **DETECTION OF HYDROGEN WITH A PHOSPHORUS PENTOXIDE CONDUCTANCE CELL**
ANALYSIS UTILIZES HEATER AND DISTILLATION APPARATUS PORTION OF EQUIPMENT CONTAINED IN FUNDAMENTAL EXPERIMENT NO. 32010301, DIFFERENTIAL THERMAL ANALYSIS - DISTILLATION OF VOLATILES FROM SOILS. PHOSPHORUS PENTOXODE CONDUCTANCE CELL IS PLUG-IN UNIT TO DISTILLATION APPARATUS. IT PROVIDES MEASURE OF WATER DRIVEN OFF AS A FUNCTION OF TEMPERATURE.

8 3 06 41 02 **CHEMICAL AND DIFFERENTIAL THERMAL ANALYSIS FOR OXYGEN AND CO2 SOURCES**
ANALYSIS PERFORMED AT BASE ON SAMPLES OF MATERIALS REPRESENTING POTENTIAL RESOURCES FOR THE PRODUCTION OF OXYGEN AND CARBON DIOXIDE. EMPLOYS EQUIPMENT AND TECHNIQUES FOR FUNDAMENTAL EXPERIMENTS NO. 32010105, CHEMICAL ANALYSIS, BASE LABORATORY, AND 32010301 DIFFERENTIAL THERMAL ANALYSIS - DISTILLATION OF VOLATILES FROM SOLIDS.

8 3 06 41 013 **DIFFERENTIAL THERMAL ANALYSIS OF POTENTIALLY CASTABLE MATERIALS**
DETERMINES MELTING TEMPERATURE OF LUNAR MATERIALS WHICH ARE CANDIDATES FOR USE IN CAST FORMS FOR STRUCTURES. EMPLOYS EQUIPMENT FROM FUNDAMENTAL EXPERIMENT NO. 32010301, DIFFERENTIAL THERMAL ANALYSIS - DISTILLATION OF VOLATILES FROM SOLIDS. SUPPORTS SELECTION OF EARTH-RETURN SAMPLES FOR USE IN EARTH-BASED LUNAR RESOURCES UTILIZATION PROGRAM.

8 3 06 42 01 **CHARACTERISTICS OF LUNAR ORES - SELF-WELDING**
THE OBJECTIVE OF THIS INVESTIGATION IS TO LEARN HOW TO CONTROL AND/OR COPE WITH THE COHESIVE CHARACTERISTICS OF LUNAR SUBSURFACE AND SURFACE MATERIALS IN THE LUNAR ENVIRONMENT. REDUCTION OF COHESION MAY BE DESIRED FOR PERFORMANCE OF EXTRACTION, CRUSHING AND SCREENING OPERATIONS. ENHANCEMENT OF COHESION MAY BE DESIRED TO STABILIZE FILL AND SURFACE MATERIALS, AND FOR SOME HANDLING OPERATIONS. THE SELF-WELDING EXPERIMENT SUGGESTED HERE WOULD SUPPORT THE LARGER OBJECTIVE BY EXAMINING THE TENDENCY OF FRESHLY BROKEN (BLASTED) MATERIAL TO COHERE ACROSS THE CLEAN, FRESHLY EXPOSED SURFACES. PERFORMANCE OF THE EXPERIMENT IN CONJUNCTION WITH 80390101, EXPLOSIVE TECHNIQUES FOR SURFACE MODIFICATION, IS SUGGESTED. THE EXPERIMENT PROCEDURE IS TO FILL AND COMPACT CYLINDRICAL SPECIMEN MOLDS WITH FRESHLY-BROKEN MATERIAL AND PERFORM TIME-SEQUENCED LOAD TESTS OF THE UNCONFINED SAMPLES. THE INVESTIGATION INCLUDES PHOTOGRAPHS OF SURFACE EJECTA, AND PHOTOMICROGRAPHS OF FRESHLY BROKEN SURFACES. SAMPLES WOULD BE PREPARED AND INITIAL TESTS PERFORMED IMMEDIATELY AFTER THE EXPLOSION, AND TESTS WOULD BE REPEATED AT ONE DAY AND ONE WEEK SUBSEQUENT. WHERE FEASIBLE, AN ADDITIONAL, LONGER INTERVAL REPETITION IS SUGGESTED. THE EXPERIMENT DATA WILL BE CORRELATED ON EARTH WITH RESULTS OF FUNDAMENTAL INVESTIGATIONS PERFORMED PREVIOUSLY AT THE DRILL SITE. CAMERA AND PHOTOMICROGRAPH EQUIPMENT FOR FUNDAMENTAL GEOLOGY INVESTIGATIONS WOULD BE USED HERE.

EXPERIMENT NUMBER
A G S I E
R B P N X
E J E V P
A T C S T

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 3 06 43 03 **PARTICLE ADHESION IN MECHANICAL PROCESSING**

THE PROBLEM OF PARTICLE ADHESION TO SURFACES IN THE LUNAR HIGH VACUUM AS ENCOUNTERED IN EARLY EXPLORATION IS INVESTIGATED IN 82010201 (ENVIRONMENT), 81021101 AND 81021102 (DRILLING), AND 82043401 (REMOVAL TECHNIQUES). THESE INVESTIGATIONS WILL UNDOUBTEDLY STIMULATE EARTH-BASED RESEARCH ON THE PREVENTION OR MINIMIZING OF PARTICLE ADHESION. THE PURPOSE OF THIS LATER LUNAR INVESTIGATION IS TO ASSESS THE EFFECTIVENESS OF EARTH-DEVELOPED TECHNIQUES AS APPLIED TO BASIC ELEMENTS OF MECHANICAL PROCESSING EQUIPMENT. BASIC EQUIPMENT SUGGESTED ARE BUCKETS, EXPERIMENTAL ROCK CRUSHER AND SCREENS. CANDIDATE TECHNIQUES FOR EFFECTIVENESS EVALUATION ARE, THE SELECTIVE USE OF BASIC MATERIALS, SURFACE TREATMENTS AND COATINGS FOR EXPOSED EQUIPMENT ELEMENTS, USE OF ADDITIVES IN LUNAR ORES, ELECTRICAL POTENTIAL AND MAGNETIC TECHNIQUES, ETC., AND COMBINATIONS THEREOF. PARAMETERS WOULD INCLUDE OUTPUT CAPABILITY MEASURES, RATE OF DEGRADATION AND EQUIPMENT DURABILITY.

8 3 06 45 01 LUNAR DRY CEMENT AND CONCRETE APPLICATIONS

THE POSTULATED EXISTENCE OF DIVERSE LUNAR MATERIALS OFFERS THE CHALLENGE OF DEVELOPING AN APPROACH TO COMBINING FILLERS AND BINDERS IN PHYSICAL-THERMAL-CHEMICAL PROCESSES TO FORM A LUNAR EQUIVALENT OF CONCRETE. SUCH A PROCESS HAS BROAD AND BASIC APPLICATION IN LUNAR BASING AND CONSTRUCTION PROGRAMS. PROCESS RESEARCH AND DEVELOPMENT WOULD BE PREFORMED AS PART OF THE EARTH-BASED RESEARCH AND TECHNOLOGY PROGRAM REFLECTING EXPLORATION FINDINGS AND, WHERE POSSIBLE, USING RETURNED SAMPLES FOR VERIFICATION. A CANDIDATE PROCESS UTILIZES ASH, PUMICE AND CLINKERS AS FILLER, SULFUR AS A BINDER AND EXOTHERMIC REACTANT ADDITIVES FOR SETTING. THE LUNAR INVESTIGATION SUGGESTED IS IN ESSSENCE A FIELD TEST OF THE EARTH-DEVELOPED PROCESS IN THE LUNAR SURFACE AND SUBSURFACE ENVIRONMENT. APPLICATIONS TO BE TESTED INCLUDE FOUNDATIONS, ROADWAY AND PAD SURFACES, FORM CASTING CEMENTING OF CAST OR NATURAL BLOCK MATERIALS, AND SEALING AND CALKING. EXPERIMENTS RELATED TO LUNAR SURFACE APPLICATIONS SHOULD BE DESIGNED TO HAVE OPERATIONS SUPPORT UTILITY WHERE POSSIBLE. STANDARD-TYPE SPECIMENS WOULD BE FORMED FROM SAME BATCHES FOR LATER TESTING OF MECHANIAL, THERMAL AND SEALING PROPERITIES. THIS REQUIRES USE OF EQUIPMENT IN THE LUNAR MATERIALS LABORATORY. THE INVESTIGATION SHOULD BE PERFORMED WHERE A VEHICLE EQUIPPED WITH A BACK-HOE, LOGISTICS CARRIER, GRIZZLY, CRUSHER AND SIEVES ARE AVAILABLE AS OPERATIONAL/EXPERIMENTAL SUPPORT EQUIPMENT.

8 2 04 50 01 **HEAT TRANSFER IN LIQUIDS THROUGH NATURAL CONVECTION**

THE PURPOSE OF THIS EXPERIMENT IS TO DERIVE HEAT TRANSFER COEFFICIENTS WITHIN LIQUIDS AND BETWEEN LIQUIDS AND CONTAINER WALLS, WITHOUT STIRRING, UNDER THE UNIQUE CONVECTIVE CONDITIONS OF LUNAR GRAVITY. RESULTS OF THE EXPERIMENT WILL SUPPORT THE DESIGN OF ADVANCED LUNAR THERMAL POWER PLANTS, HEAT EXCHANGERS, AND CHEMICAL PROCESSING EQUIPMENT. THE EXPERIMENT UTILIZES A CALIBRATED CYLINDRICAL CONTAINER EQUIPPED WITH ELECTRIC HEATING ELEMENTS IN SECTIONS OF THE CONTAINER WALL AND SETS OF SMALL THERMOCOUPLES FOR MONITORING LIQUID AND WALL TEMPERATURES. TRANSPARENT WINDOWS ARE PROVIDED FOR OBSERVATION AND MOTION-PICTURE PHOTOGRAPHY OF SUSPENDED PARTICLES CARRIED ALONG THE DIRECTIONS OF INTERNAL LIQUID FLOW. UP TO 50 TEMPERATURE VALUES WOULD BE SAMPLED 5 TIMES PER SECOND AND RECORDED SEQUENTIALLY, WITH TIME MARKERS INDICATING RELATED CAMERA EXPOSURES. MEASUREMENTS WILL PERMIT DEFINITION OF CHANGES IN FUNCTIONAL RELATIONSHIP BETWEEN NUSSELT NUMBER AND GRASHOF - PRANDTL NUMBERS FOR DIFFERENT LIQUIDS.

EXPERIMENT NUMBER
AGSIE
RBPNX
EJEVP
ATCST

EXPERIMENT DESCRIPTION

MISSION SUPPORT INVESTIGATIONS

8 2 04 50 03 **TEMPERATURE/DENSITY STRATIFICATION OF CRYOGENIC LIQUIDS**

THE OBJECTIVE OF THIS EXPERIMENT IS TO OBTAIN DATA ON STRATIFICATION PHENOMENA IN THE LUNAR ENVIRONMENT FOR APPLICATION TO THE DESIGN OF LONG-TERM CRYOGENIC STORAGE VESSELS, AND FOR THE DESIGN AND OPERATION OF LIQUID HYDROGEN BUBBLE CHAMBERS FOR LUNAR-BASED RESEARCH. THE EXPERIMENT ENVISAGES MEASUREMENT OF TEMPERATURE DISTRIBUTION OF LIQUID HYDROGEN AND OXYGEN BY MEANS OF ABOUT 60 SMALL ELECTRIC THERMOMETERS INSTALLED THROUGHOUT TWO OPERATIONAL CRYOGENIC TANKS. THE EXPERIMENT PROCEDURE IS AUTOMATIC AND CONSISTS OF PERIODIC SAMPLING, RECORDING AND TRANSMISSION OF THERMOMETER SIGNALS TO YIELD TEMPERATURE DISTRIBUTION WITHIN THE LIQUIDS AND CORRELATING OUTER WALL TEMPERATURES. FROM THESE, TEMPERATURE/DENSITY STRATIFICATION AND HEAT TRANSFER PHENOMENA MAY BE DERIVED.

8 2 04 50 02 **HEAT TRANSFER IN FILM-AND DROP CONDENSATION PROCESSES**

HEAT TRANSFER AND CONDENSATION RATES DEPEND ON THE INTERACTION OF LIQUID SURFACE TENSION, LIQUID-SOLID ADHESION (WETTING FACTOR), AND GRAVITATIONAL FORCES CAUSING FORMATION OF DROPLETS. THE LOW GRAVITY OF THE LUNAR SURFACE WOULD CHANGE THE BALANCE BETWEEN THESE FORCES TOWARDS INCREASED FILM CONDENSATION, WHICH IN TURN LOWERS HEAT TRANSFER AND CONDENSATION RATES. THESE EFFECTS ARE TO BE MEASURED WITH SIMPLE CONDENSER TUBES, EACH WITH A DIFFERENT WETTING FACTOR OF THE INSIDE SURFACE, AS A FUNCTION OF TEMPERATURE AND HEAT FLOW. A SMALL VESSEL WITH ELECTRIC HEATER IS TO BE FED A CAREFULLY METERED FLOW OF VAPOR WITH CONTROLLED TEMPERATURE TO THE CONDENSER TUBE, WHERE THE AMOUNT AND RATE OF CONDENSATION IS MONITORED BY WEIGHING AND/OR NUCLEAR TRACE TECHNIQUES. VAPOR AND WALL TEMPERATURES ARE TO BE MONITORED BY 20 THERMOCOUPLES, TO BE SEQUENTIALLY SAMPLED AND RECORDED ABOUT 10 TIMES PER SECOND. THE RESULTS ARE IMPORTANT TO THE EFFECTIVE DESIGN OF CLOSED-CYCLE THERMAL POWER PLANTS AND FRACTIONAL DISTILLATION EQUIPMENT FOR LATER APPLICATION ON THE MOON.

EXPERIMENT NUMBER	EXPERIMENT DESCRIPTION
	MISCELLANEOUS BASIC AND APPLIED RESEARCH
AGSIE RBPNX EJEVP ATCST 9 0 01 01 01	GENERATION OF HIGH-INTENSITY ELECTRON BEAMS THE OBJECTIVE OF THIS INVESTIGATION IS TO TEST ELECTRON BEAMS IN THE LUNAR HYPER-VACUUM, REDUCED GRAVITY AND LOW MAGNET FIELD FOR MELTING, DRILLING, SHAPING, GLAZING AND WELDING OF SOLIDS. IN THIS CAPACITY, THE INVESTIGATION SUPPORTS 82054001 - METAL JOINING TECHNIQUES IN LUNAR SURFACE CONSTRUCTION AND REPAIR. ADDITIONALLY, THE INTERACTION OF THE HIGH-INTENSITY ELECTRON BEAMS WITH LUNAR SURFACE MATERIALS WOULD BE EXPLORED WITH THE OBJECTIVE OF ASSESSING TECHNIQUE FEASIBILITY FOR SUPPORT OF MINING, MATERIALS PROCESSING, JOINING AND FOR OTHER RESOURCES APPLICATIONS. THE EXPERIMENTS WOULD BE PERFORMED WITH A TRIPOD-SUPPORTED 10 KW RATED ELECTRON-GUN WITH MECHANICAL AND ELECTRIC FOCUSSING AND BEAM INTENSITY CONTROLS, AND WITH ADJUSTABLE POWER PULSE CONTROL.
9 0 01 02 01	HIGH-INTENSITY ARC GENERATION IN LUNAR ENVIRONMENT THE OBJECTIVES OF THESE EXPERIMENTS WITH NITROGEN AND ARGON HIGH-VOLTAGE PLASMA ARCS HAVING MAGNETIC FOCUS CONTROL ARE TO EVALUATE ELECTRODE CONFIGURATIONS, OPERATING PARAMETERS AND MODES, AND TO ASSESS FEASIBILITY AS AN ULTRA-HIGH TEMPERATURE SOURCE IN THE LUNAR VACUUM. APPLICATIONS INCLUDE UTILIZATION IN MATERIALS EXTRACTION AND PROCESSING TECHNOLOGY INVESTIGATIONS. IMPLEMENTATION SUGGESTS A 10KW PLASMA ARC WITH ADJUSTABLE MECHANICAL AND ELECTRICAL CHARATERISTICS. AN ELECTRIC POWER SUPPLY AND GAS SOURCE ALSO WOULD BE REQUIRED.
9 0 02 01 01	FIELD EMISSION OPTICS THE PRINCIPAL PURPOSE OF THIS INVESTIGATION IS TO ASSESS THE UTILITY OF FIELD EMISSION TECHNIQUES FOR LUNAR BASED ANALYSIS OF MINERALS, ELEMENTS AND GASES FOUND IN LUNAR EXPLORATION. THE PORTABLE EXPERIMENTAL EQUIPMENT INCLUDED A SMALL EVAPORATOR FOR COATING THE TIPS OF 1-MICRON RADIUS NEEDLE ELECTRODES WITH THE SUBSTANCES TO BE ANALYZED, A SMALL FIELD EMISSION CAMERA WITH FILM MAGAZINE AND A BATTERY-OPERATED POWER SUPPLY. A FLUORESCENT SCREEN WOULD BE USED FOR VISUAL OBSERVATIONS AND ADJUSTMENT. PHOTOGRAPHS WOULD BE OBTAINED OF FIELD EMISSION PATTERNS OF THE ELEMENTS AND COMPOUNDS COATED ONTO THE TIPS OF NEEDLE ELECTRODES IN THE LUNAR HYPER-VACUUM, INCLUDING THE USE OF MAGNETIC AND/OR ELECTROSTATIC FIELD FLATTENING HEADS. TESTS MAY BE PERFORMED IN PROTECTIVE VACUUM VENTED ENCLOSURES SEPATAED FROM THE OUTGASSING EFFECTS OF LUNAR BASE MODULES.
9 0 03 01 01	RADIATION CRYOSTAT MEASUREMENT OF HEAT FLOW AND TEMPERATURE DISTRIBUTION PARAMETERS OF A SUPERINSULATED CAVITY WITH A HEAT SINK REFLECTOR SHADED FROM THE SUN AND FACING SPACE OF LOW STELLAR DENSITY. GEOMETERIC CONFIGURATION, MATERIALS AND NUMBER OF SUPERINSULATION LAYERS FOR CAVITY TEMPERATURES BELOW 18 DEGREES KELVIN ARE TO BE DETERMINED. EXPERIMENTAL EQUIPMENT INCLUDES A SET OF DIFFERENTLY DESIGNED RADIATION CRYOSTATS WITH MINIMAL INTER-LAYER CONTACT, ONE CRYOSTAT WITH LAYERS SEPARATED AND LEVITATED BY ELECTROSTATIC FORCES, A PARABOLIC CYLINDRIC HEAT SINK MIRROR, AND A LOW TEMPERATURE THERMOMETER. APPLICATIONS INCLUDE LONG-TERM STORAGE OF CRYOGENIC LIQUIDS, SUPER-CONDUCTIVE POWER LINES AND MAGNETS, COOLING OF SENSORS AND ANTENNAS, AND HYDROGEN BUBBLE CHAMBER.

EXPERIMENT NUMBER (AGEN BJECT SPACE INVES EXPT)	EXPERIMENT DESCRIPTION
	MISCELLANEOUS BASIC AND APPLIED RESEARCH
9 0 03 02 01	SOLAR FURNACE WITH CONTROLLABLE FOCAL ENERGY FLUX THE OBJECTIVE OF THIS INVESTIGATION IS TO EXPLORE THE APPLICATION OF ADVANCED TECHNIQUES IN THE DESIGN, CONSTRUCTION AND OPERATION OF A SOLAR FURNACE IN THE LUNAR ENVIRONMENT. THIS INCLUDES TESTING OF METHODS FOR ADJUSTING THE FOCAL ENERGY FLUX DISTRIBUTION OVER A WIDE RANGE BY CONCERTED DIRECTIONAL CONTROL OF EACH CONCAVE MIRROR IN A MULTIPLE MIRROR ARRAY OF MODERATE DIMENSIONS. THE INVESTIGATION SUPPORTS DERIVATION OF REQUIREMENTS OF OPERATIONAL FURNACE ARRAYS FOR THE EXTRACTION OF USEFUL MATERIALS, INCLUDING WATER FROM LUNAR ROCKS, FOR PHOTOLYSIS EXPERIMENT AND FOR POWER GENERATION. MAJOR EQUIPMENT COMPONENTS ARE A 100 SQUARE METER ARRAY WITH 19 CONCAVE, INFLATABLE STABILIZED MIRRORS OF 7 METER FOCAL LENGTH IN A STATIONARY FRAME, AND WITH MECHANICAL LINKAGES FOR CONCENTRIC ADJUSTMENT OF ALL MIRRORS. ONE HELIOSTAT OF CORRESPONDING DIMENSIONS WITH ELECTRIC CLOCK DRIVE, AND ONE ELEVATED STAND, ASSORTED CRUCIBLES, AND PYROMETRIC INSTRUMENTS AS NEEDED FOR MEASURING THE THERMAL CHARACTERISTICS OF THE ARRAY AND FOR PERFORMING EXPLORATORY ROCK MELTING EXPERIMENTS.
9 0 03 03 01	HEAT CONVECTION AND FLOW OF GASES IN ENCLOSED SPACES DETERMINATION OF LAMINAR AND TURBULENT FLOW AND CONVECTION PARAMETERS OF HEATED GASES AT 1/6G FROM SYNCHRONIZED MOTION PICTURES OF INCANDESCENT ZONES (FLAMES) TAKEN IN X-Y-Z DIRECTIONS IN A PRE-CALIBRATED CONTAINER. PROVIDES EMPIRICAL DATA FOR COMPARISON WITH PARAMETERS AT 1G FOR DEVELOPMENT OF LUNAR COMBUSTION TECHNIQUES OR CONTROL.
9 0 04 01 01	LIFETIMES OF ATOMIC SPECIES PRODUCE VERY WELL COLLIMATED (0.1 DEG) BEAM OF UNSTABLE ATOMIC OR MOLECULAR SPECIES, IONS, FREE RADICALS, ETC., AT ENERGY OF A FEW EV. BEAM DIRECTION IS PARALLEL TO LUNAR SURFACE. PRODUCE IONIZATION AND EXCITATION STATES IN COLLIMATED BEAM BY INTRODUCING CROSS ELECTRON BEAM. MEASURE DECAY RATE BY OBSERVING BEAM INTENSITY AT DISTANCES FROM 1 M TO 1 KM OR MORE FROM SOURCE.
9 0 05 01 01	LORENTZIAN PLASMA ENVIRONMENTAL PHYSICS THE OBJECTIVE OF THE INVESTIGATION IS TO DETERMINE LOW FREQUENCY MHD WAVE SOURCE AND PROPAGATION MECHANISMS. LORENTZIAN PLASMAS (THOSE WHICH ARE COLLISIONLESS EXCEPT FOR LORENTZ FORCES) CAN BE PRODUCED IN THE LABORATORY ONLY ON A SCALE MUCH SMALLER THAN THE DEBYE LENGTH (ABOUT 20 METERS) EXPECTED NEAR THE MOON. THE EXPERIMENTS INVOLVE THE GENERATING OF PLASMAS BY EXPLODING WIRES OR CHEMICAL EXPLOSIONS ABOVE THE SURFACE, AND MEASUREMENT OF PLASMA PARTICLE DENSITY AND VELOCITY VS. POSITION AND TIME. IN ADDITION A MAGNETOMETER IS USED TO MEASURE MAGNETIC FIELDS IN THE HYDROMAGNETIC SHOCK WAVES WHICH MAY ACCOMPANY SUDDEN PLASMA EXPANSION. THE SIMPLEST EXPERIMENTAL EQUIPMENT WOULD INVOLVE AN ELECTRON GUN AND TRI-AXIS MAGNETIC VARIOMETER TO RECORD SIGNAL WAVEFORM AND POLARIZATIONS. AN EXTENSION OF THIS INVESTIGATION COULD UTILIZE A MAGNETIC MIRROR ARRANGEMENT. IONIZED PLASMAS COULD BE PRODUCED WITHIN THE MAGNETIC FEILD OR INJECTED INTO IT. PLASMAS CONTAINED BY THE MAGNETIC FIELD WOULD BE FULLY IONIZED. PLASMA PARTICLES LOST FROM THE MAGNETIC FIELD WOULD NOT BE REFLECTED BACK INTO THE FIELD BY VACUUM CHAMBER WALLS, AND FEW EXTRANEOUS PARTICLES WOULD GET BACK INTO THE FIELD.

EXPERIMENT NUMBER

AGSIE
RBPNX
EJEVP
ATCST
90 05 02 01

EXPERIMENT DESCRIPTION

MISCELLANEOUS BASIC AND APPLIED RESEARCH

CORNER REFLECTORS FOR LASER BEAMS

THIS EARTH-BASED INVESTIGATION UTILIZES THREE CORNER-CUBE REFLECTORS INSTALLED AT ACCURATELY SURVEYED LOCATIONS ON THE MOON. LASER RANGING IS PERFORMED FROM EARTH TO MEASURE (1) SECULAR CHANGES IN THE GRAVITATIONAL CONSTANT, G, (2) SECULAR AND TIDAL PERTURBATIONS OF MOON'S ORBIT (3) EARTH-MOON DISTANCE, AND (4) ALTERATION OF THE PLANE OF THE REFLECTORS BY LIBRATION AND SEISMIC ACTIVITY. A SECULAR CHANGE IN GRAVITATIONAL CONSTANT, SHOULD IT EXIST, WOULD BE DEDUCED FROM COMPARISON OF ATOMIC AND EPHEMERIS TIME SCALES, NEW VALUES FOR THE LATTER BEING DERIVED FROM THE CORNER REFLECTOR MEASUEMENTS OVER A PERIOD OF TIME. A RELATIVISTIC PHENOMENON OF GREAT IMPORTANCE THAT MIGHT SHOW UP IN ACCURATE RANGING MEASUREMENTS WOULD BE THE PRESENCE OF GRAVITATIONAL WAVES. LUNAR MISSION ACTIVITIES IN SUPPORT OF THIS INVESTIGATION CENTER ABOUT THE EMPLACEMENT OF THE CORNER REFLECTORS IN WIDELY-SEPARATED LOCATIONS WHERE COORDINATES ARE ACCURATELY ESTABLISHED.

4.0 EXPERIMENT DATA MANAGEMENT SYSTEM

4.1 OBJECTIVE

One task of the Scientific Mission Support for Extended Lunar Exploration Study is to develop a flexible data processing and retrieval technique for compiling and displaying experiment data, equipment data, and mission support requirements. The objective of this data management system is to provide lunar exploration mission planners with a tool for evaluating system/mission tradeoffs and for compiling vehicle and system requirements and design criteria. An extension of this objective is to provide NASA with organized information for analyzing lunar exploration programs in terms of cost, schedules, and scientific accomplishment.

4.2 BACKGROUND

As lunar studies evolve toward defining extended exploration systems and programs, the problem of cataloging the many and diverse experiment requirements for system support increases in complexity. The point is soon reached where simple compilation tables become unwieldy from sheer weight of numbers. An added complexity factor is the need to quickly retrieve information as well as to change certain values as an experiment becomes better defined and information can be updated. The electronic computer is a natural tool for this task.

It was initially visualized that the simple computerization of information tables similar to those assembled by hand in the original LESA Scientific Mission Study would suffice for this program. However, the current status of studies of extended lunar exploration made it desirable at this time to establish a computer data retrieval program. It was recognized that such a program could be used for a more comprehensive data management system as the need arose. The following requirements were established for the data retrieval program:

1) it must be flexible to accommodate future known and unknown requirements.

2) it must have a large potential capacity to accommodate large numbers of experiments as the investigations and experiments

become better defined and can be divided into manageable discrete units of accomplishment

3) it must easily lend itself to constraint analysis in support of trade-off analysis to aid in determining the effectiveness of future lunar exploration candidate systems

4) it must be simple to be useful to the uninitiated and to allow maximum use of human judgment

4.3 DESCRIPTION

The subject data management system consists of the entry of numerical and text data relative to a given scientific experiment in a format suitable for processing and sorting of the data on a digital computer system. Preliminary analysis of the operations involved and the extended lunar exploration summaries desired indicated that the program would resemble business-type computer operations, where bookkeeping is a major factor, rather than scientific computer capabilities, where mathematical equation solutions are the objective. Consequently, the COBOL computer language and IBM 7010 computer were selected as the basic working tools of the experiment data management system.

Implementation of the data management system included: (1) a review of the types of scientific experiments to be included in the study, (2) selection of the experiment detail information categories that would be a requirement for providing desired information about each experiment and that would be suitable for summary data of selected experiment groupings, (3) selection of suitable input formats for computer handling of the data, (4) design of computer output formats for display of individual experiment and combined experiment summary information, (5) design of a computer program that would process the data inputs into the desired outputs, (6) compilation into the chosen format of the selected scientific experiment information for approximately 340 experiments, (7) operation of the computer program, and (8) review of the results and utilization of the various summation capabilities of the computer to aid in major analysis of the scientific mission support requirements of basic groupings for the proposed extended lunar exploration experiments.

Details of the procedures and an illustration of the computer master report are shown in Volume 4, "Experiment Sequences," Volume 5, "Master Data Report," and Volume 6, "Computer Program." A condensed version of data descriptions for each experiment package was obtained by using coded entries where significant groups of common descriptions could be identified. None of the information presented in the card data field should be considered final; it is the best estimate based on the information available.

4.4 EXPERIMENT CODING

Suitable codes were selected to allow scientific and engineering reviewers to describe experiments in terms of mission/system constraints, subsystem support, and equipment performance requirements. These data have been stored on a series of standard IBM cards summarizing the essential characteristics of each experiment.

An 11-digit number has been adopted to facilitate sorting of the data and identification of the experiments (Figure 9). The first three digits define the card type and card number (for multiple cards that must be sorted and printed in sequence). The data have been organized so that either complete experiment descriptions or selected outputs can be retrieved at the discretion of the user. Seven types of data cards are being used. An important feature of the system is the ability to reproduce complete typewritten descriptions of the experiment and equipment, thereby providing documentation of important information that could not otherwise be encoded. The remaining eight digits represent the basic experiment number by which all data cards can be correlated. As shown in the chart, all experiments have been organnized into eight discipline areas of fundamental investigations, a single area of Mission Support Investigations, and an area of Miscellaneous Basic and Applied Research investigations. Scientific objectives and major specialties have also been defined for each area to correlate related scientific investigations on an interdisciplinary basis. The last two two-digit groups designate, respectively, investigations, and the experiments that comprise the investigations.

4.5 CARD DESCRIPTION

The basic data entry cards were designated as Type-0 cards (Experiment Description), Type-1 cards (Experiment Summary), Type-2 cards (Experiment Operations), Type-3 cards (Experiment Man-hour Categories), Type-4 cards (Experiment Equipment Parameters), Type-5 cards (Equipment Description), and Type-6 cards (Experiment Telemetry Requirements). The cards are shown in Figure 10.

The Type-0 card (Figure 10a) is a written summary of an experiment. It presents the objectives of the experiment, the phenomena to be measured, the equipment, and the parametric range of measurement. Unique requirements or relationships that cannot be tabularized are also provided.

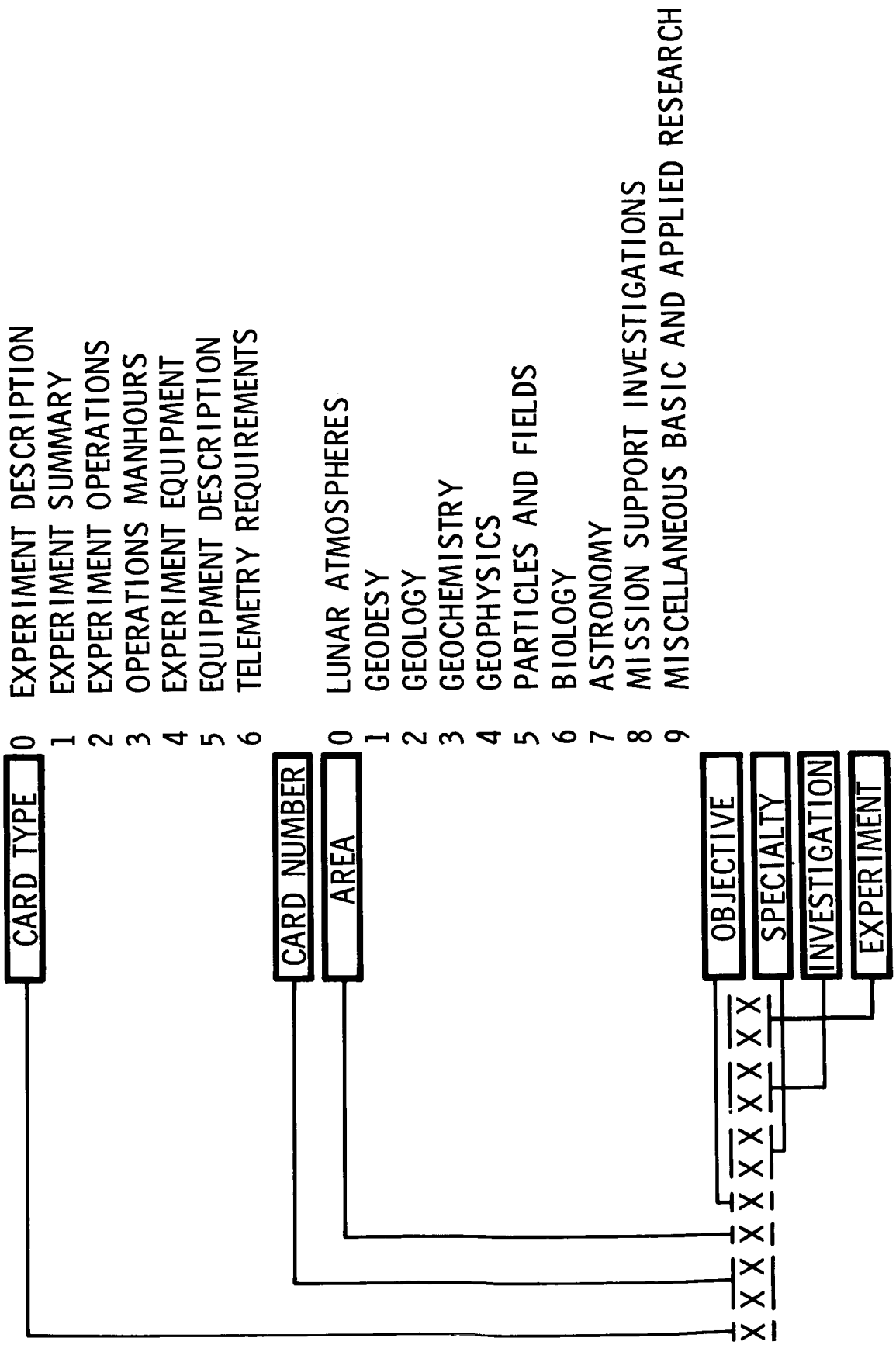

Figure 9. Experiment Identification and Data Organization

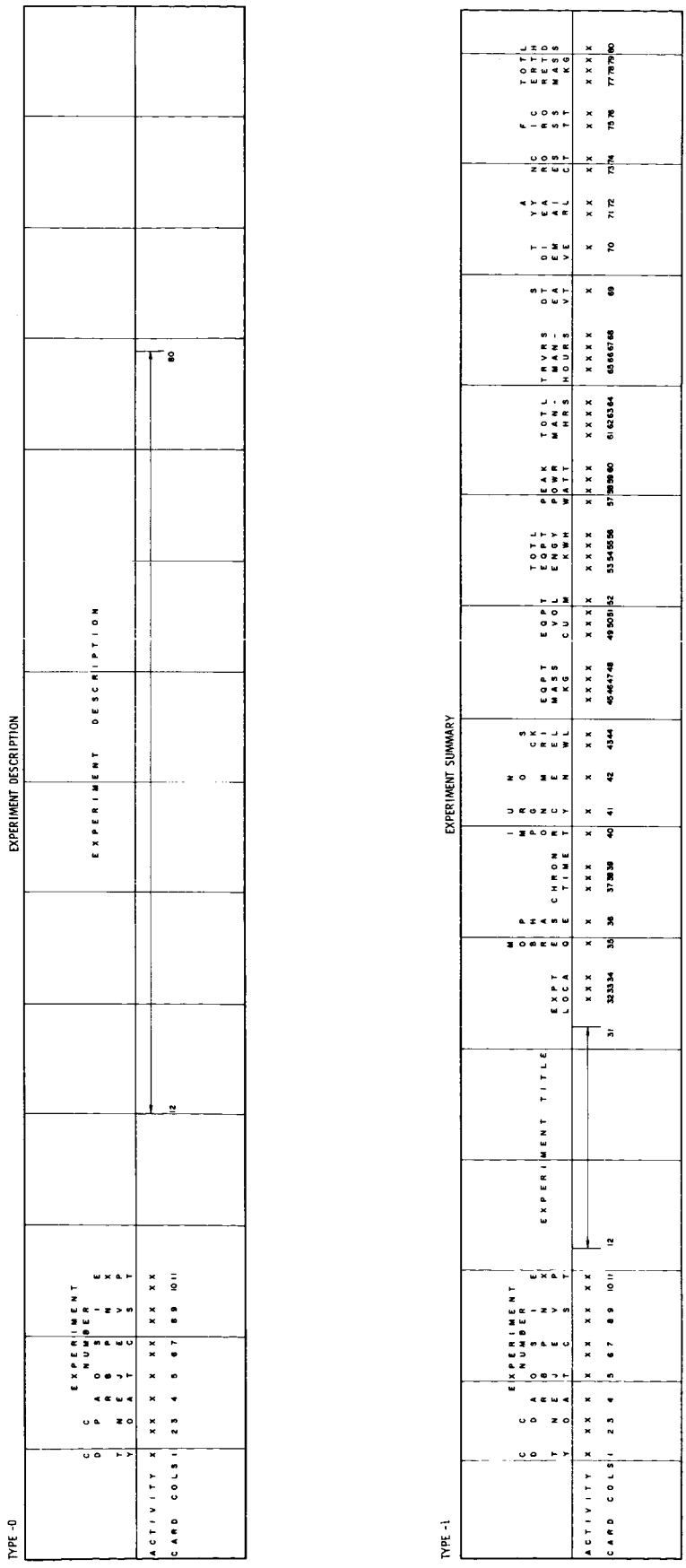

Figure 10a. Data Printout Format,

TYPE -2 EXPERIMENT OPERATIONS

	CODE TYPE	CODE NO	AREA	EXPERIMENT NUMBER OBJECT	SPECIFIC	NEXT	EXPERIMENT TITLE	EXPT LOCA	MOBREQ	PHASE	CHRON TIME	EXP REF	FLTSTA	IMPORT	UNSCNCY	NOMEN	STRICKEL WL	TRAVERSE MAN-HOURS SHLRETV	SPACESUIT OPERATION SHLPUCT	BASE SHLRETV	SPACEPUCT	REPTN	FRQNCY	ESRESS	PARTSWC	TOTAL DATBITS	MAX DATA RATE B/S	DLINK	EXPT COST	NOMS	ITEMS
ACTIVITY	X	XX	X	X	XX	XX	XX	XXX	X	X	XXX	XX	X	X	X	X	XX	X	XXX	XXX	XXX	XX	X	X	X	XXX	XXXX	X	XXXX	X	X
CARD COLS	1	2 3	4	5	6 7	8 9	10 11	12 31 32 33 34	35	36	37 38 39	40 41	42	43	44	45	46 47	48 49 50	51 52 53	54 55 56	57 58 59	60 61	62	63	64	65 66 67 68	69 70 71 72	73	74 75 76 77 78	79	80

TYPE -3 OPERATIONS MAN-HOURS

	CODE TYPE	CODE NO	AREA	EXPERIMENT NUMBER OBJECT	SPECIFIC	NEXT	SET-UP	SHIRTSLEEVE OPERATION	SHIRTSLEEVE ANALYSIS	TRAVERSE TEAR DOWN	TRAVERSE SET-UP	SPACESUIT OPERATION	SPACESUIT ANALYSIS	TEAR DOWN	SET-UP	SHIRTSLEEVE OPERATION	SHIRTSLEEVE ANALYSIS	BASE TEAR DOWN	BASE SET-UP	SPACESUIT OPERATION	SPACESUIT ANALYSIS	TEAR DOWN
ACTIVITY	X	XX	X	X	XX	XX	XX	XXXX	X	XXX	XXXX	X	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
CARD COLS	1	2 3	4	5	6 7	8 9	10 11	12 13 14 15	16	17 18 19	20 21 22 23	24	25 26 27	28 29 30 31	32 33 34 35	36 37 38 39	40 41 42 43	44 45 46 47	48 49 50 51	52 53 54 55	56 57 58 59	60 61 62 63

Figure 10b. Data Printout Format (Cont)

TYPE -4

EXPERIMENT EQUIPMENT

	CD TY	CD NO	AREA	EXPERIMENT NUMBER OBJT	SPEC	INVS	EXPT	EQUIPT NUMBER	EQUIPMENT NAME	EQUIPT LOCA	PARMTR	PARAMTR RANGE	EQPT MASS KG	EQPT VOL CUM	AVE POWR WATT	PEAK POWR WATT	EQPT OPER HRS	AVE DATA RATE B/S	TYPE	MAX DATA RATE B/S	REAL TIME DATA B/S	LEA	ERTH RETD MASS KG	PARCE KG	STREQ	ENRVRQ	DEVT	TIME	AVAIL	NCROST	FIRST COST
ACTIVITY	X	XX	X	X	XX	XX	XX	XXXXXX		XX	X	XXXXXXX	X	XXX	XXXX	XXXX	XXXX	XXX		XXXX	XX	X	XXX	XX	XX	XX	X	X	XX	XX	XX
CARD COLS	1	2 3	4	5	6 7	8 9	10 11	12 13 14 15 16 17	18	29	29 30	31	32 33 34 35 36 37 38	39	40 41 42	43 44 45 46	47 48 49 50	51 52 53 54	55 56 57 58	59 60 61	62	63 64 65 66	67 68	69	70 71 72	73 74	75 76	77 78	73	74	75 76	77 78	79 80

TYPE -5

EQUIPMENT DESCRIPTION

	CD TY	CD NO	AREA	EXPERIMENT NUMBER OBJT	SPEC	INVS	EXPT	EQUIPT NUMBER	NO. ITEMS	FULL EQUIPMENT NAME
ACTIVITY	X	XX	X	X	XX	XX	XX	XXXXXX	XXX	
CARD COLS	1	2 3	4	5	6 7	8 9	10 11	12 13 14 15 16 17	18 19 20 21	72

TYPE - 6

EQUIPMENT TELEMETRY REQUIREMENTS

	CD TY	CD NO	AREA	EXPERIMENT NUMBER OBJT	SPEC	INVS	EXPT	EQUIPT NUMBER	PARMTR	PARAMETER NAME	PARAM RANGE	EDUPRMTN	LINK	STORG	PERIOD READT	EVENT	TYDTA	SIGCD	OUTPTN	AFREQY	ANALGY	BRISLN	DIGOT	NOBITS	BRATE	NOCOMS	INPTS
ACTIVITY	X	XX	X	X	XX	XX	XX	XXXXXX	X	XXXXXXX	XXXXX	XXX	XXXX	XX	XXXX	XX	X	X	XXX	XXX	XX	XX	X	XX	XXX	X	X
CARD COLS	1	2 3	4	5	6 7	8 9	10 11	12 13 14 15 16 17	18	19 30	31 32 33	34 35 36 37	38 39 40	41	42	43 48	49	50	51	52 53 54	55 56 57	58 59	60 61	62	63 64	65 66 67	68	69

Figure 10c. Data Printout Format (Cont)

The Type-1 card (Figure 10a) is an experiment summary produced by the computer from information stored in the remaining data cards. Primary emphasis for this card is placed on data which affects mission/system trade-offs; therefore, data are included for experiment location, mobility requirements, exploration phasing, and chronological time. In addition, codes for defining scientific importance and urgency for priority sequencing have been provided. Mission support requirements have been defined in terms of number of men, crew skill, man-hours, and equipment support parameters. Equipment lead-time data for the pacing item in the equipment set are presented in terms of data for development status, development time, and earliest year available. Cumulative cost estimates for development and first item(s) are also presented.

The Type-2 card (Figure 10b) provides major information relative to experiment operations and mission support requirements. The major portion of this information is abstracted on the summary card. In addition, data are provided on this card for defining experiment replication requirements and gross communication requirements in terms of the total bits of information, bit rate, and the type of data link. Provisions for compiling a "relative experiment cost factor," based on the conversion of mass, volume, power, and man-hours into equivalent equipment dollars, have also been included on the operations card. These data will provide mission planners with guidelines for comparison of scientific investigations on an equivalent basis.

The Type-3 card (Figure 10b), provides detailed estimates of astronaut man-hours to set up, operate, analyze, and tear down the instrumentation or equipment necessary to support an experiment. The man-hour estimates are differentiated for shirtsleeve and spacesuit conditions while the astronaut is operating from a traverse vehicle or from a lunar base. These time estimates can be used by mission planners to evaluate logistic requirements for astronaut support systems. All of the times are given in terms of normal Earth environment; as more information concerning the effectiveness of operations at reduced gravity and with specific spacesuit designs is obtained, a multiplication factor, "K", can be introduced to convert these times to actual lunar operation times.

The Type-4 card (Figure 10c) is used to define the equipment requirements directly related to an experiment. In addition to the basic experiment number, all instruments or equipment (scientific) have been identified by a six-digit numerical code based on the "Guide to Scientific Instruments" as developed by Science Magazine, and shown in Section 4.3 of Volume 5 (Appendix B). This feature allows machine-sorting to identify commonality and time-sharing of equipment that can be used to optimize mission logistics. The output format will display multiple cards for each item of different equipment or multiple cards for a multiparameter single item of equipment. Data concerning equipment location, parameter range and precision, and

support requirements parameters (mass, volume, power, data, sample return, and environmental constraints) are provided. These data cards are compiled cumulatively by the computer to produce the experiment summary. The last five data fields shown on the Type-4 card data printout format (development status, development time, year available, non-recurring cost, and first cost) are the result of data code entries in columns 73 - 80 of the associated Type-5 card. The desired equipment data information exceeded the capacity of the Type-4 card. The computer program U615-01 transfers this information to the Type-4 card output printout for convenience in comparison of the experiment equipment data.

The Type-5 card (Figure 10c) is essentially a supplement which provides a written description of the equipment, with up to 99 cards available to define the requirements for "new" equipment or data not otherwise encodable. The first card in the series contains development status and cost data for the particular instrument or item of equipment.

The Type-6 card (Figure 10c) has been incorporated in the program to present more detailed information concerning telemetry requirements. This card is typical of a series of cards that could be utilized to expand the experiment data management system to provide more detailed information for preliminary concepts and mission systems design. As a further example, an eighth card might be added to provide more detailed information for life support systems.

The division of the experiment data into these basic card types provides a convenient system for obtaining numeric and textual information relative to each of the experiments to be considered for a lunar mission. Incorporation of the information on the standard punched cards of a computer system provides the capability of sorting the experiments in a variety of ways and of automatically extracting particular details of information from a large mass of experiment data. Types -2, -3, -4, -5, and -6 cards, as presently designed, provide approximately 75 information fields of numeric or coded information about experiment operations, man-hour requirements, and equipment requirements. Since more than one equipment and related card can be used for each experiment, many additional information items can be gathered for a given experiment. Also, pertinent information that does not fit into the defined fields or codes can be described verbally in the Type-0 experiment description cards (69 characters and spaces per card) and in the Type-5 equipment description cards (52 characters and spaces per card). The present computer program and identification system allows up to 99 experiment description or equipment description cards per individual experiment. If required, this total could be expanded.

The Type-1 experiment summary card provides 20 information fields, some of which involve computer operations in the generation of the data. For

example, the computer adds equipment weights and volumes from all individual pieces of equipment specified for the experiment. The longest estimated equipment development time is selected for the summary. The total energy requirement for a given experiment is obtained by multiplying equipment average power by operating hours on each of the Type-4 cards containing this information, summing the resultant products for all equipment items, and entering this value on the Type-1 summary card.

Further experience with the present program and application to other projects may suggest that other card and data format arrangements are better suited to specific study needs. The present program experience can provide a basis for the evolving improvements in the data system.

4.6 COMPUTER PROGRAMS

Three computer programs were formulated for the processing of data cards into the desired computer system output, consisting of a master list of experiments, summary card listings, equipment listings, and other special listings. Program U 615-01 produces the master report and summary cards from the main data inputs. Program U 615-02 produces summary card listings from the summary card inputs. Program U 615-03 provides equipment listing outputs from the Master Report tape. Simplified block diagrams of these operations are shown in Figures 11, 12, and 13. Additional information concerning these programs is shown in Volume 6, which includes detailed block diagrams, descriptions of special NAA subroutines used in connection with the COBOL computer language, input-output format illustrations, program control card descriptions, and examples of the program source listings.

Figure 11 shows the summary diagram of the SMS-ELE Master Report computer operations and identifies the major peripheral equipment used. The "SMS-ELE INPUT" symbol indicates the basic punched cards that provide the descriptions and data for all the scientific experiments originally entered into the program. After an original run of the program has been made, the SMS-ELE input function can be utilized to incorporate additional experiments, additional descriptive matter or instrumentation cards to an existing experiment, or changes of data values within an existing data card of a given experiment. Thus, changes or additions to an experiment description and/or data can be accomplished by processing a minimum number of new and simplified data cards. The punched card information is transferred to a program activity tape by using the IBM 1460 computer and a standard NAA program (BLOTC). The activity tape, plus the current SMS-ELE master tape (if it has been previously generated), provide the inputs to the IBM 7010 computer and the U 615-01 program run. Running of the 7010 program provides an updated master data tape, a computer program output file tape, and a Card-Type-1 punch output tape. The updated master

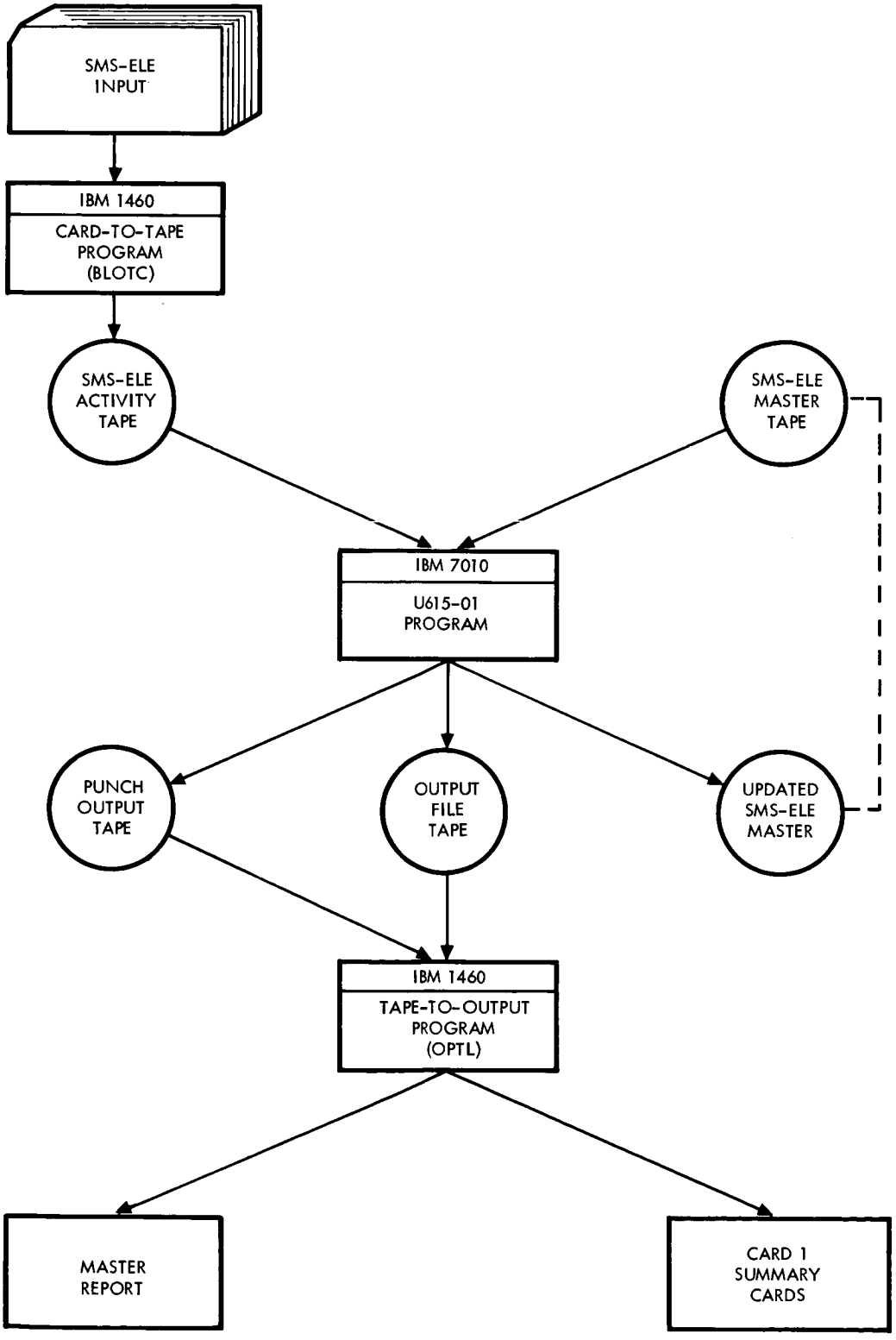

Figure 11. SMS-ELE Master Computer Program U615-01 Block Diagram

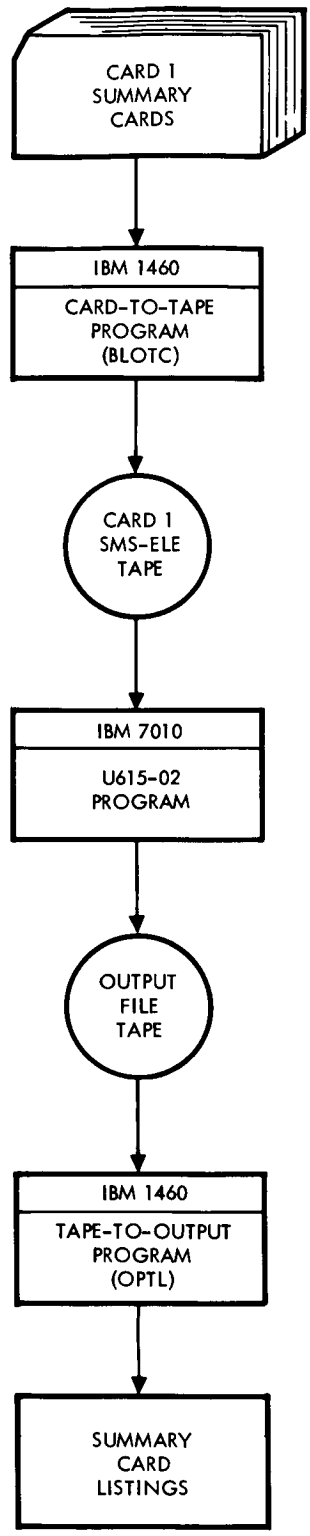

Figure 12. SMS-ELE Summary Card Listing Computer Program

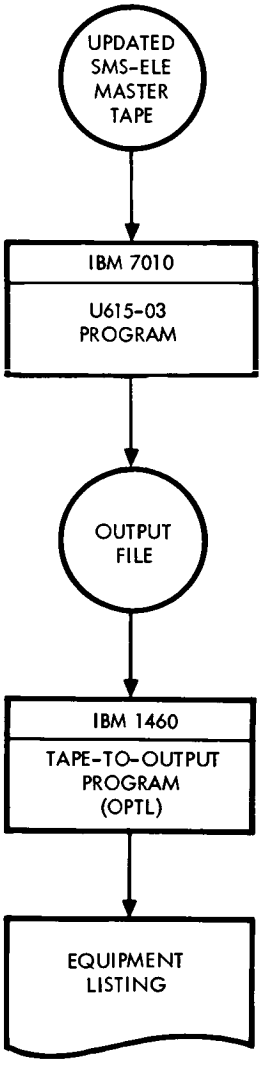

Figure 13. Equipment Listing Computer Program

data tape goes to storage for use in fugure program runs (when data additions or revisions are required), and the output file tapes are processed on the 1460 computer to provide the master report printout and the desired deck of Type-1 cards punched with the computer-assembled and generated data. This report printout routine also utilizes a standard NAA computer program (OPTL) to transfer from the 7010 output file tapes to the desired report printout and punched cards.

The U 615-02 summary program and the U 615-03 equipment listing program (Figures 12 and 13 respectively) also utilize the OPTL programs in the processing of the desired outputs. More detailed descriptions of the computer operations are given in Volume 6 (Appendix C).

4.7 CAPABILITY OF DATA MANAGEMENT SYSTEM

The SMS-ELE data management system can be used in various ways after the required experiment information is available for a variety of proposed space mission experiments. In line with the present study, it is possible to establish a master file of lunar experiments and associated data. These master files, under the present system, have extensive expansion capabilities.

4.7.1 DATA MANAGEMENT SYSTEM UPDATING

The revision or updating procedure is a feature of the data management system which already has been employed in the study. This feature allows changes of data on the computer program master tape without the necessity of rerunning the entire punched card input file. Corrected card files can be generated directly from the updated tape when the punched card file revision is desirable. A relatively up-to-date punched card backup file is a recommended operating procedure in case the tapes are accidentally changed or destroyed. In the present study, this data file is on the order of 8000 punched cards to describe the 340 experiments compiled in this study effort.

The updating feature allows additions of complete experiments by selection of a new experiment identification number with a simple check of the up-to-date run or experiment title run to avoid duplication of numbers. Additional descriptive data, within an existing experiment, such as on the Type-0 or Type-5 cards, can most easily be input by adding material at the end of the existing text. Revision of material within the body of existing text may require rewriting of the punched cards that follow the revised material.

Revising data within an existing data card is accomplished very simply by identifying the experiment and card number and then entering the revised data on only the data field of the card being changed. All of the updating procedures will require the processing of a new punched card for each addition or change to be accomplished, but the amount of data coding and processing is kept to a minimum by the developed procedures. The correction cards are simply added to the next run of additions to the master data tape; the computer searches the tape for the card identification number and transfers the desired corrections to the tape which is then ready for use on the next program run.

An experiment may be deleted from the data management system by extracting the applicable cards from the input card deck and reconstituting the computer program master tape.

4.7.2 ADDING NEW EXPERIMENTS

The preparation and organization of the material for experiments to be added later must be handled carefully because of the amount of data to be encoded and the correlation which must be accomplished with other experiments for the data to be of maximum use. For purposes of discussion, the steps required to add a new experiment to the SMS-ELE Experiment Master List will be divided into two general areas: (1) the selection of an experiment identification number, and (2) the preparation of the experiment description and data cards.

To initiate the selection of an experiment identification number, the area, the first digit of the experiment number, is determined by appropriate discipline (see Figure 9, Page 168). The basic list of scientific objectives of the specific scientific discipline is reviewed to select that objective which is enhanced by the accomplishment of the experiment. This review establishes the second digit of the experiment number. The list of scientific specialties of the discipline is used for selection of the most appropriate specialty and establishment of third and fourth digits of the experiment number. The fifth and sixth digits of the experiment number define the scientific investigation involved. Most experiments fit into existing scientific investigations, but some may require establishment of a new investigation area. The seventh and eighth digits of the experiment number are the next sequence numbers of the series having the same proceding six digits. Thus, the experiment number for a new experiment is defined.

The preparation of the experiment description and the information for encoding on the Type-0 data cards includes an experiment summary description, major objectives, equipment required, and experiment information parameters to be measured. This information is entered directly on a FORTRAN-type code sheet, reviewed by the appropriate scientific review team, and encoded for Data Processing.

The data card forms (Card types-2, -3, -4, -5, and -6) will then be completed, to the extent possible, from the subject data source. The encoding of this data and text material will require the use of Volume 6, for direct entry of the experiment data on code sheets. It will usually be preferable to use an intermediate data form on which all of the data field entries are made in a direct reading form and which can be reviewed by cognizant personnel and then encoded. These data forms can be similar to Figure 7 through 13 in Section 6.1 of Volume 2.

An organized procedure of data card preparation, after the "zero" card experiment description has been made, will be important in the efficient preparation of the complete data package. A suggested order would be to (1) prepare the equipment data cards and equipment description cards (Type-4 and Type-5 cards), (2) prepare the equipment related telemetry requirements card (Type-6), (3) prepare the estimation of the man-hour requirements in the breakdowns of the Type-3 card, and then (4) prepare the Type-2 experiment operations card. This operational summary card requires information from the equipment cards, such as data rates and total bits and a man-hour summary from the Type-3 card. The Type-1 card (experiment summary) is prepared by the computer program and will not require any direct entries by the scientific coordinator.

Most new extended lunar exploration experiment sources will not have all the required data readily available for completing all the data fields developed for the master file in the current study. The cognizant experiment coordinator for the given new experiment must, in such instances, provide any missing data by calculation, interpolation, and estimation based on the available information.

Specialists in various areas (e.g., telemetry, equipment development) should be consulted for assistance in preparing realistic estimates; similar experiments, in which the details have been developed, should be reviewed and, on the basis of this coordination, all data fields should be completed.

After completion and review of all data entries, the data cards for the new experiment are keypunched. This data can then be added to the existing master data tape by a simple run through the computer program. Details are described in the Volume 6 (Appendix C) computer documentation. The new experiment will then be properly sorted into the master data tape and will appear in the next printout made of the complete master tape, or it will be available for printout and analysis with a selected group of experiments from the master list.

4.8 MISCELLANEOUS USES OF DATA MANAGEMENT SYSTEM

In addition to those programs directly employed in this study, auxiliary programs can be written to search, select, and compile data in a variety of ways. A number of these operations and their results are illustrated in Section 5.0 where experiment sequencing is discussed. In addition, any of the data fields can be made the basis for special listings. For example, the mobility requirement column of either the Type-1 summary card or the Type-2 operations card could be made the basis for a search and listing which could identify all of the proposed lunar experiments for which the use of a small roving vehicle was recommended (i.e., code number 4 appears in column 35 of the Type-2 card). With the data management system ability to search, select, and compile data the mission planner is provided with the implements necessary to relate experiment support requirement to specific system capability for purposes of planning scientific missions. Specifically, he may apply a constraint for every data field represented in the data management system. There are 30 experiment-oriented data sorting fields among the Type-1, Type-2, and Type-3 data cards, and 12 equipment parameters sorting fields in the Type-4 and -5 equipment cards. By applying sequential card sorting, the planner may utilize any combination of constraints. In this manner, he can rapidly define the scientific mission capability of a given system, providing he can define the system constraints associated with the specific system or concept.

4.9 POTENTIAL GROWTH

The potential applications of the system can best be illustrated by citing the growth of the computer data retrieval program to its present configuration. As originally conceived, the program was primarily intended for use in developing system and operation tradeoffs for lunar exploration. This need was satisfied initially by the Type-1 card information; however, when more information was needed concerning the activities of the lunar base crew, Cards 2 and 3 were added. Information Cards 4 and 5, and later a telemetry card, Type-6, which provide more detailed experiment equipment information were added to provide sufficient information so that the compiled data would be one generation of study activity ahead of the system studies. The near-future expansion requirements would appear to be detailed subsystem information regarding life support subsystems, lunar spacesuit, power, mobility, etc. These can be satisfied by the addition of Cards 7, 8, etc.

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4.10 CONCLUSION

The most significant result of the computer data retrieval program is the establishment of a flexible and expandable information storage and retrieval system which can be used as a management tool for use in lunar-exploration-mission and mission-support planning. This system is dynamic in nature; it has the ability to grow and change and, thereby, adapt to the future requirements relating to the scientific exploration of the Moon.

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5.0 EXPERIMENT EQUIPMENT AND OPERATIONS

5.1 INTRODUCTION

A major objective of this study as stated in previous sections is to estimate the basic support requirements of lunar scientific operations sufficiently early so that the resulting requirements can serve as significant factors in the definition of future lunar exploration systems. The basic experiment support requirements data that contribute in a major way to the fulfillment of this objective are included in Volume 5 - Appendix B. In Volume 5 data in the Type-2 and -3 cards quantify the operations support requirements; data in the Type-4 and -5 cards quantify the scientific equipment requirements; and data in the Type-6 cards quantify the telemetry support requirements. This section enhances the support requirements objective by facilitating the interpretation of data and offering guidance for utilizing the mission-support data in experiment integration and mission planning.

Description and interrelation of scientific equipment requirements is vital to future integration of the basic data into mission formats. To facilitate such application, the following section presents a summary of scientific-equipment commonality for major items of equipment. The discussion on telemetry (Section 5.3) illustrates how the basic data deck can be expanded to define subsystem support requirements. The Operations and Man-Hours subsections provide ground rules important to interpretation and utilization of the experiment support data. Special attention is given to a description of astronaut time, expressed in man-hours, which is generally a mission-variant parameter depending on system capability. Because the formulations of specific missions were not a part of the study effort, specific numbers of detailed tasks, such as the number of samples analyzed during an experiment were arbitrarily defined and noted (see Section 5.5).

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5.2 SCIENTIFIC EQUIPMENT

5.2.1 APPROACH

The principal objective of the scientific equipment analysis was to compile the equipment characteristics, data requirement, and environment consideration to support definition of the scientific equipment portions of the experiments compilation. This objective was accomplished by supporting the scientific staff and by follow-up acquisition, verification, and encoding of equipment data in the Type-4 card, Experimental Equipment, and the Type-5 card, Equipment Description.

Data entered in the Type-4 card provide the basic description of the performance of significant equipment in terms of information characteristics and the equipment operating and support requirements which constitute implementation characteristics. The following listing reviews Type 4-card information.

IDENTIFICATION

Experiment I. D. Number
Equipment Number
Equipment Name (Abbreviated)

INFORMATION (PERFORMANCE) CHARACTERISTICS

Parameter
Parameter Range
Average Data Rate (bits/sec)
Type Data
Max. Data Rate (bits/sec)
Real Time Data Rate (bits/sec)
Earth-Returned Mass (kg)

IMPLEMENTATION CHARACTERISTICS

Equipment Location
Equipment Mass (kg)
Equipment Volume (cu meters)
Average Power (watts)
Peak Power (watts)
Equipment Operating Time for Experiment (hours)

Packaging Requirements
Storage Requirements
Environmental Requirements

Data entered in the Equipment Description card (Type-5) supplement the Experimental Equipment card data by including a detailed description of all significant equipment employed in the experiment under consideration. (Equipment support requirements include estimates for secondary items such as test tubes, hoses, clamps, etc.)

Type-5 card information content is as follows:

IDENTIFICATION

Experiment I. D. Number
Equipment Number
Number of Same Equipment Items Employed in Experiment
Full Equipment Name

DEVELOPMENTAL CHARACTERISTICS *

Development Status
Development Time (yr)
Year Available
Nonrecurring Cost Estimate (Dollars)
First Item Cost Estimate (Dollars)

Cost estimates are based on information supplied by NASA MSFC and were reviewed by MSFC personnel. Equipment information not included in the card but important to equipment definition and integration in the scientific mission is described in later sections.

The methodology employed for collection, analysis, and encoding of this information consisted primarily of the following steps.

1. Collection of data from available sources
2. Screening for pertinent equipment data
3. Preparation of preliminary equipment data bank
4. Dissemination to scientific staff
5. Selection and definition of equipment for given experiments
6. Acquisition of new source data

* Data is input on a Type-5 card due to lack of space on the Type-4 card. It is printed out under the Type-4 card format by the machine program (see Table 8, Page 42 of Volume 6).

7. Incorporation into revised equipment bank

8. Review and updating of encoded data in cards 4 and 5 to match best available equipment data to experiment requirements

9. Generation of equipment estimates where available equipment data is incomplete

10. Correlation of equipment requirements for related experiments

11. Identification of equipment used in more than one experiment; and, in conjunction, identification of equipment that approaches common usage but for which parameter range or other requirements are unique

The first step in implementing this methodology was to review the information contained in the data sources supplied by NASA to identify scientific equipment requirements and characteristics. (Sources are listed in the Bibliography, Section 10.2.)

For steps 6 through 11, the encoded information describing the total set of scientific equipment was verified to the extent possible against instrument data contained in Brown Engr. TN R-160 and Bendix TM-Bx-023. Conflicting multiple values of data on identical parameters of apparently similar instruments were averaged. Information voids were resolved by estimation. The encoded information regarding the total set of scientific equipment appears in Volume 5.

5.2.2 INSTRUMENT DEVELOPMENT CONSIDERATIONS

Review of developmental data and generation of preliminary schedule and cost estimates where data deficiencies existed was an important part of the Phase II activity. The general developmental status of the instrumentation may be classified as: (1) commercially available instruments, (2) existing space-flight rated instruments, and (3) new instrument concepts. Availability, modification, and integration are the more usual considerations for application of commercially available and existing flight-rated instruments. The developmental lead times are reasonable, usually no longer than two years. New instrument concepts, expected to evolve from lunar scientific exploration requirements, would normally affect smaller numbers of instruments. Requirement studies, design, and development programs would require longer lead times. Timely application of new equipment can be assisted by utilizing a continuous monitoring system to support planning and decision making. Provision for phasing in, along parallel paths if necessary, of worthy new concepts should be considered in scheduling lunar exploration experiments.

In addition, several scientific areas provide experiments that permit evolutionary development of the scientific instruments/equipment involved. These areas are: Particles and Fields, Astronomy, Geophysics, and Geology. The earlier versions of equipment provide the necessary operational experience that is prerequisite to the design of more complex advanced systems. The geological drilling rig involves an estimated scientific development period of three years, while estimates in the remaining scientific areas entail periods to about nine years.

5.2.3 EQUIPMENT INTERRELATION

Several means for correlating instrument requirements to reduce both the instrument types and numbers are inherent in the computerized program approach. The assignment of a number to each distinct instrument type enables the computer to sort out similar types. The lunar scientific experiments and, therefore, the instrumentation needs may be sorted to guide the grouping of experiments according to Mission Support, Exploration Phase, and Composite sequences. Consolidation of instrumentation can be accomplished by adaptation for common use in multiple experiments. Determining the common usage of instrumentation and experiment sequencing are dependent operations, and further tradeoff studies would be desirable. As an initial step, potential experiments making common usage of instruments were established by means of a computer program printout. The results, along with some general remarks with respect to environmental requirements, operation, etc., are shown in Table 10 for major items of scientific equipment. The equipment is listed in alphabetical order.

Correlation of the related instruments, if the reviewer has a thorough knowledge of the basic operation principles of the instruments, can be made in some cases within the generic groups shown in the same table. Descriptions of the basic principles of operation of a large group of instruments are available in the documents listed in the Bibliography. Such descriptions are difficult to quantify for programming, and further consolidation must be founded on design judgment and familiarity with the basic operating principles and experimental objectives.

The current encoded data for instrument requirements provide considerable capability for evaluating the effects of changes in proposed lunar exploration experiments. By updating the information at reasonable intervals, a current status of potential experiments and instrument/equipment needs can be maintained. Such information, categorized and phased according to specific sequences, is essential for determining an orderly development plan, for projection of instrumentation requirements, and for estimating lead times and costs.

Further development of the data management approach can produce methods to assist in the correlation of measurements between experiments. In addition, by using suitable input data and interrogation programs, areas in which simultaneous measurement, redundancy, or backup observations are needed can be pinpointed. Sorted card printouts from an expanded deck can be devised to uncover potential incompatibilities with other instrumentation, mission support equipment, or lunar environment (e.g., radiation interferences due to radioactive, electromagnetic, radio frequency, local environmental of space sources, peak power demands and bandwidth and data storage problems). Examination of such relatively complete displays of information can uncover special instrumentation requirements that can be used to support research and development specifications.

(Text Continued on Page 211)

Table 10. Scientific Equipment Commonality Summary

Equipment Name and Number	Common Usage Experiment No.	Remarks
Amplifier (0063.5)	40130771	See similar equipment in experiments 40080353, 40080352, 40080354, 40060628, 40060629, 40060630, 40060631, 44070843, 40130772
Amplifier, Electro-Magnetic Pulse Receiver (6404.01)	41060540, 41050541	Equipment receives and amplifies transmitted pulse reflected from subsurface.
Amplifier, Seismic (0063.1)	40010101, 40010102, 40010103, 40010104, 41010205, 41020208	
Amplifier, Thermocouple (4946.0)	44070842, 44070845, 44070846, 44070847, 44070848, 44070849, 44070850, 44070882	
Analyzer, Electrostatic (6705.00)	79070103	Instrument requires protection against vacuum conditions, severe thermal cycling and radiation.
Analyzer - 100 Channel, Pulse-Height (2930.5)	40130771, 40120780, 40120779, 40120778, 40130772, 40130775, 40130776, 40080370, 40070883	Equipment No. 2930.3 (32-channel PHA) appears in experiment numbers 52020201, 52020202, 52020203, equipment number 2930.4 (64-channel PHA) appears in experiment numbers 52030101, 52030102, 52030103, 52030201, 52030202, 52030203.
Antenna, Central Dipole Array (6702.00)	75050102	
Antenna, Electro-Magnetic Subsurface Probe (6403.01)	41060540	This equipment is mounted on the lunar roving vehicle. Similar item in experiment number 41050541.
Antenna, Remote Dipole Array (6711.00)	75050102	Used in conjunction with Ryle-Vonberg radiometer.
Autoclave, Biological (0205.0)	61040102	
Balance, Analytic Recording (0245.0)	61010201	
Blanket, Surface Thermal (4950.1)	44070846	
Bolometer (0501.2)	44070844, 44070843	Instrument is sensitive to temperature changes less than 0.0001 C and is especially useful in the infrared portion of the spectrum.
Bolometer (0501.1)	47021202, 47011101, 47031303, 47041404, 47051505, 48112311	
Bridge, Capacitor (0565.1)	40050537, 40050538, 40050539	

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Bridge, Inductance (2185.0)	40060535, 40060532, 40060534, 40060533	The bridges are used in measurements of the changes in q of the resistivity probe. Magnetic susceptibility bridges are used in experiments 40050524, 40050325, 40050326 and 40050527 to measure changes in inductance. Should be isolated from strong electromagnetic fields at operational frequencies of instrument; also should be induced external electric and magnetic field of instrument must be compatible with other systems. Shielding and temperature limits unknown.
Bridge, Magnetic Susceptibility (2185.1)	40050524, 40050525, 40050526	Instrument is used to measure changes in inductance. A similar instrument specified on experiment 40050527.
Bubble Chamber, Liquid Hydrogen, 25-cm with Cameras (2956.1)	54080101	
Bubble Chamber, Liquid Hydrogen, 50-cm with Cameras (2956.2)	54080102	
Bubble Chamber, Liquid Hydrogen, 250-cm with Camera (2956.3)	54080103	
Camera, Frame 70 mm (6201.3)	21040102	Similar camera required in this experiment is located in Manned Orbiting Vehicle. Cameras designed for use in the lunar environment may be subject to environmental hazards such as the following: 1) Extreme temperature variation from sunny to shady side could cause differential expansion resulting in defocusing. 2) High vacuum requires exposed moving or removable parts to be coated with materials that prevent vacuum welding. 3) High vacuum and low temperatures dictate use of solid-state lubricants on all moving parts. 4) Film must have low expansivity and maintain its flexibility if exposed to the cold temperature of the Moon. 5) Film must withstand vacuum and lack of moisture if camera is not pressurized. 6) Film must be shielded against cosmic and solar flare radiation. 7) If film is stored for more than several hours at temperature of 120 F and above, a latent image will be formed by the IR radiation. 8) Low temperatures reduce the sensitivity of film and color balance is lost. Zero to 25 C is the probable specification for the temperature at which film must operate.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Camera, Framing (9 x 9 Format) (6201.1)	21040102	
Camera, Lyman Alpha (with Tuneable Filter) (0189.00)	72010521	Design should be included for -30 C to +30 C temperature control; temperature control or correction required; operation in vacuum; launch and acceleration vibration and shock. Protect reflecting mirror surface from particle radiation.
Camera, Photomicrographic (3790.0)	61040102	Camera includes microscope.
Camera, Spectrazonal (0535.0)	40070869	Camera takes ultraviolet, infrared and various color images simultaneously.
Camera, Television (4840.0)	11010101, 11010505, 12010202, 13030303	This instrument is a vidicon camera, a fuller description is given in the Master List of Experiments.
Camera, 35 mm (0530.12)	61010201, 61020202	
Camera, 4.5-inch (6201.4)	21040102	
Chromatograph, Gas (0745.0)	61040101	The chromatograph is a flame ionization detecting type. The Surveyor Gas Chromatograph Prototype, Model P-2, should be considered.
Chromatograph, Gas (0755.0)	01030464	The Surveyor instrument, with provision that completely automatic operation is unnecessary, appears satisfactory Should be isolated from contaminating gas sources. Can tolerate -185 C to 125 C and operate at -50 C to +125 C; passive control to give maximum isothermal temperature below column operating temperature of 105 C.
Chronometer, Astronomical (4985.0)	47021202, 47011101, 47031303, 47041404, 47051505, 47051512, 47081808, 48092109, 48102210, 48112311	
Container, Core (6200.6)	21020307, 21020308	
Counter, Geiger-Muller (3025.0)	40130774, 40130773	Two G-M tubes are used with different shielding to differentiate betas and gammas. Gamma ray detector should be from RIG or similar power sources. Fixed mounting should assure 2-π steradians access to radiation without obstruction.
Counter, Module, Geiger (6707.00)	73020622	Coupled with X-ray telescope assembly, Mylar gas filled filter placed over telescope.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Counter, Particle, Telescope System Solid State (3060.1)	52020201, 52020202, 52020203	The system consists of 3 to 10 totally depleted silicon particle detectors. Parametric requirements for instrument in common usage experiments are identical.
Counter, Scintillation (3052.4)	40130775	
Detector, Cerenkov Telescope System (3059.0)	52020201, 52020202, 52020203	
Detector, Gamma Ray Telescope, Solid State (3130.00)	73030725	Gamma ray spectrometers are used on traverse and in orbit in experiments 33010101 and 33010102 respectively. A gamma source and detector is used in experiment 32010113.
Detector, Meteorite (6407.01)	40080352, 40080353	Instrument is a capacitor type detector. Similar instrument in experiment 40084354 is mounted on MOLAB and operates as an acoustic detector.
Detector, Millimeter Wave (6409.03)	47081808	Similar to instrument No. 6409.01 (experiment 48102210). May need modification.
Detector, Neutron Phoswich (3035.0)	40110777	Similar instruments have been flown in balloons. Avoid proximity to isotopic power supply. Solid state electronic devices in circuit must be thermally protected; capable of enduring launch and landing vibrations and shocks.
Detector, Phase (6710.00)	75040101	
Detector, Solid State (3061.0)	40130773, 40130774, 40130771, 40130772	The detectors are surface barrier types. The alpha detector rejects betas up to 0.1 MEV and protons up to 2 MEV; the beta detector responds to betas up to 5 MEV.
Detector, Submillimeter Wave (6409.01)	48102210	Similar to requirements in experiment 47081808.
Diffractometer and Accessories, X-Ray (5405.0)	32010107, 32010114	Consideration should be given for using fast back-reflection (Lane) diffraction with the Flourex-Axtracon image intensification system for TV presentation or motion picture photography. No special caging requirements; instrument to be enclosed for protection against dust and contaminants; radiation shielding for protection of astronauts; photographic film must be X-ray radiation protected. Operating temperature, -40 C to 11 C; nonoperating, -148 C to 127 C.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Diffractometer and Accessories, X-Ray (5405.0) (Cont)		Particles larger than 2 mm size will require powdering. This may prove difficult due to powder aggregation caused by potential cohesion of powders in vacuum. X radiation from diffractometer may be hazard to astronaut and photographic emulsions. Mineral phase or phase of lunar particles may be changed by excessive temperature during drilling or pulverization.
Dosimeter, Total Radiation (3085.1)	52020401	Instrument ionization, tissue equivalent type. Dosimeter system recently flight qualified, range 0-1000 rads, maximum pulse rate corresponding to a dose rate of 108 rads/hr. (weight 0.363 kg; vol., 0.00005 m^3). Mounting should assure 2-π steradians unobstructed access to radiation. Exposure to radiation from power sources should be avoided.
Drill, 30-Meter (6201.6)	21010412	Drill is mounted on vehicle. Drill must be designed for operation in all natural and induced environments encountered during missions. Also see "Rig, Drilling."
Florescence Activated by Gamma Rays, X-Ray (5425.0)	32010104, 32010112	
Gauge, Pressure, Redhead (1945.0)	01030159, 01030260	Instrument also known as inverted magnetron pressure gauge; partial pressure measurements required for interpretation of data collected. Care must be taken to minimize detection of gas evolution from unnatural outgassing sources. Exposure to lunar atmosphere is required. Thermal control for solid state electronics required. Small magnetic fields can be tolerated. Designed for vacuum operation. Must withstand launch and landing accelerations. Local shielding against ionizing radiation required. Ionization gauges have disadvantages: requiring auxiliary equipment, varying sensitivity for different gases and vapors, the presence of certain gases may "poison" the filament, the filament is susceptible to burnout if heated in air, ion bombardment destroys filament with continued use, electrode must be thoroughly outgassed for maximum reliability at extremely low pressures, and the hot filament decomposes certain gases.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Generator, Time Base (4985.1)	40010101, 40010102, 40010103, 40010104	Instrument No. 4985.1 is an oscillator whose output is real time; instrument No. 4985.2 (experiment 41010205) gives a real time standard in milliseconds; instrument number 4985.3 (experiments 43080252 and 43080153) is an interval timer.
Geophone (4405.1)	40010101, 40010102, 40010103, 40010104	Possible advances in design, such as digital output, radio signal transmission (elimination of cables) and efficient geophone coupling to ground are estimated to require two years and $300,000 for development. Vibrating equipment, electric magnets and rf generating equipment must be inactivated during period from detonation to five seconds following detonation. Static electricity and poor ground connections may deteriorate signal-to-noise ratio. Operating temperature -40 C to +50 C storage -200 C to +65 C.
Gravimeter, (La Coste-Romberg Type) (2021.0)	45030913, 45030912, 45030914, 45030915	Parametric values for last two instruments, shown in common usage, differ from those listed. Requires rigid support and automatic leveling. Must be protected from micrometeoroid bombardment. Internal temperature must be controlled, range 100 C to -166 C. Pressure range, vacuum to 1 atmosphere. Instrument must withstand launch and landing accelerations and should be caged until deployed.
Gravimeter, Orbital (2021.5)	45030985, 45030968	
Greenhouse (46.5 Sq Meters) (0384.01)	61010201	
Incubator, General Purpose (2175.0)	61040102	
Lens-Two Degree Aberration Free, Field Correcting (3560.0)	47051512	Used with 40-inch reflecting telescope.
Magnetometer (2370.0)	46040616, 46040617, 46040620, 46040621, 46040618	General remarks concerning magnetometers: Instrument requires leveling. It also requires careful site selection with respect to ferromagnetic materials (meteoroids, other magnets, etc.) to reduce problem of magnetic saturation. Zero drift calibration on earth will be a problem due to much lower lunar magnetic field. Helium magnetometer is generally preferable to the rubidium magnetometer for lunar applications because of the temperature sensitivity of the vapor cell and the lamp and the lamp life of the rubidium magnetometer.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Magnetometer (2370.0) (Cont)		Instrument may be either a nuclear type proton precession, rubidium vapor, or a triaxial vector similar to IMP magnetometer. Instrument number 2375.0 in experiment 41040219 is a 3-component fluxgate or variometer type. See also experiment 53050101.
Magnetometer, Fluxgate (6200.9)	24030413	The instrument is a three-component fluxgate magnetometer with a sensitivity of 0.1 gamma. The heat must fit into a 1-inch borehole.
Magnetometer, Metastable Helium (2371.3)	53050102, 53050103, 53050104	Similar instrument equipment numbers 2371.4 and 2371.5 are used in experiments 53050103, 770720101 and 79090101. A metastable helium magnetometer has been developed for Mars probe. Sensing element should be isolated 100 meters from other magnetic and electric equipment (strong magnetic fields >0.5 gamma). Requires -85 C to +110 C upper limit of 150 C feasible (transistors).
Magnetometer, Metastable Helium (2371.50)	77070101, 79070101	No calibration is required for this instrument.
Magnetometer, Rubidium Vapor (2371.2)	53050101	
Magnetometer, Total Field, Airborne (2370.2)	46040667	Use assumed restricted to orbital experiments.
Magnetometer, Triaxial Fluxgage, with Data Encoder (2371.1)	53050101, 53050102, 53050103, 53050104, 53050201, 53050202, 53050203	Parametric requirements for instrument, equipment numbers 2371.2 and 2371.3 in common usage experiments 53050201, 53050202 and 53050203 are different from those given for this instrument.
Meter, Drill Rate (1820.2)	40090456	
Meter, Electric Field (6408.01)	020303/61, 02030362	General remarks concerning electric field meters: Rotating vane and divergent beam meters may be marginal in sensitivity for Moon. They may also disturb lunar E-field. Linear beam E-meter will require high beam energy (100 KEV). Planned measurement at single elevation will give incomplete information about plasma sheath. An alternate type meter, using modified electron emission in a diode resulting from an external superposed electric field, is under development. Data to be correlated with results from experiment 02030263. Note experiment 53070101, instrument number 1791.0 for possible common usage.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Meter, Electric Field (6408.01) (Cont)		Should be isolated from equipment generated electric or magnetic fields. Instrument should not be operated in shielded compartment. Thermal control for electronics only; magnetic field must be corrected; operates in vacuum.
Meter, Electric Field (6704.00)	79070101	Instrument requires protection against vacuum, severe thermal cycling and radiation exposure. Similar to instrument 6704.00 to experiment number 77020201.
Meter, Electrostatic Field, Triaxial (5327.0)	53070101, 53070102	Instrument 5327.11 in experiment 53070102 differs from 5327.0 in parametric requirements.
Meter, Electrostatic Field, Uniaxial (5327.12)	53070102	
Meter, Electrostatic Field, Very Low Frequency (1791.0)	53070101	
Meter, Field Strength (6706.00)	76070102	For additional data see the Master List of Experiments. The following instruments can be used to support this experiment: atmospheric mass spectrometer, total gas-pressure gauge and hydrogen Lyman-Alpha detector.
Microscope (2651.1)	71010101	Instrument is small hand held magnifier for inspection of pitting of telescope lens.
Microscope, Petrographic (2665.0)	32010108	Consider for common usage instrument number 2651.1 in experiment 71010101. Consider adapting unit for multiple uses in biology and biomedicine. Mounted for observations from seated position located inside shelter. Crushing or sectioning of mineral samples inside the shelter may be a health hazard due to dust or poisonous fumes emanating from rock or soil specimens. Precautionary measures need study. Individual minerals may be difficult or impossible to identify. Supplemental observations by X-ray diffractometer may be helpful.
Neutron Activation Analysis Equipment (2906.0)	32010101, 32010111	Should be operated and stored at locations remote from equipment sensitive to radiation. Internal shielding required during experimentation. Shielding requirements for storage and transportation unknown.
Oscillator (4065.1)	40060535, 40060630, 40060631, 40050537, 40050538, 40050539	One megacycle oscillators in experiments 40050538, 40050537 and 40050539, and low frequency oscillators in experiments 40060330 and 40060431 are separately grouped as common usage items. The oscillator in this experiment (4 KHz, 5 V) is used in a subsurface coil and is part of the borehole logging tool.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Pendulum, Electrostatic Ballistic (6401.00)	40080352, 40080353	Pendulum must be calibrated over range from 3 to 3000 dynes/sec.
Periscope (6200.7)	21020307, 21040411	
Photometer, Photoelectric (12-inch Telescope) (3760.10)	72010103	In function similar to 72010310 (40-inch telescope) and 72010419 (100-inch telescope).
Photometer, Photoelectric (3760.15)	72010310	In function similar to 72010103 (12-inch telescope).
Photometer, Photoelectric (3760.20)	72010419	Instrument includes interchangeable detectors attached to focus of 100-inch telescope. In function similar to 72010103.
Photometer, Ultraviolet Scanning (2865.1)	55220101	
Photomultiplier (2865)	47021202. For 6-inch telescope: 47011101, 47031303, 47041404, 47051505. For 40-inch telescope: 47061606, 47071707, 48112311	
Preamplifier, Bolometer (0063.2)	44070844, 44070843	
Probe, Subsurface Resistivity (4370.1)	40060534	Instrument consists of coil which is placed in a borehole.
Probe, Surface Resistivity (4370.0)	40060533, 40060532	Consists of coil placed on lunar surface. Should be isolated from magnetometer, vertical electric field equipment, radio transmitter and from lunar staff. Requires heat dissipation capacity of 35 watts.
Probe, Temperature (4950.2)	44070886	Probe is emplaced from lunar orbit. Pressurization not required. Temperature limits: platinum resistance thermometer, -129 C to 871 C; thermistor thermometer, -101 C to 288 C; quartz crystal, limited only by ability to prepare suitable crystal. For lunar surface measurements sensors must be buried three centimeters deep for protection from direct exposure to sun.
Pyrometer, Total Radiation (3565.1)	44070847, 44070850	
Radar, Mapping, High Resolution Orbital (6406.00)	40060565	At this time design specifications of instrument are not defined.
Radar, Mapping Orbital (6202.3)	21040101	Similar to radar used in aerial surveying.

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Radiometer (4203.0)	44070851	
Radiometer, Microwave (6202.4)	21040101	Similar to those used for each surveying (see experiment 44070866, equipment number 4203.10). Microwave radiometers and detectors will be exposed to the environmental hazards present in space. The following precautions for the microwave detector should be considered: 1) Must be shielded from cosmic and solar flare radiation. 2) Operating temperatures must be kept constant and around 25 C to avoid background noise and drifting baseline. 3) The antenna must be cooled to avoid a high background from its blackbody emission. 4) The silicon wafer and tungsten whisker must be able to withstand the g forces of launch. 5) If the antenna is rotatable, a solid-state lubricant must be used.
Radiometer, Multi-Channel Stop-Frequency Ryle-Vonberg (4203.50)	75040101, 75050102	For fuller description of this equipment, see Master List of Experiments.
Radiometer, Orbital Microwave (4203.10)	44070866; presently unknown—see experiments 47081808, 48102210, 44070851	Instrument will measure apparent black body temperature of lunar surface from orbit.
Radiometer, Rapid Burst (6714.00)	75040101	
Radiometric System Submillimeter (6715.07)	75060101	
Rangefinder, Laser or Equivalent Device for Determining Range (2272.51)	4903301	Parallel effort on development of laser type and modification of existing military service units should be maintained.
Receiver, RF (6712.00)	75050102	
Recorder, Pressure (4105.1)	40090456	
Recorder, Tape (4241.0)	41010205, 40010102, 40010103, 40010104, 40010101	
Reflectance Attachment Attenuated Total (4630.0)	32010102	Used in conjunction with equipment number 4640 in the same experiment.
Refractor, 5-Inch Photographic (0189.05)	74010520	
Refractor, 36-Inch Grazing Incidence (6708.00)	73020623, 73020624	

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Rig, Deep Drill (300-Meter) (6208.5)	21020308	Deep drill rig includes all necessary tools and accessories.
Rig, Drilling (3-Meter) (6201.4)	21020307	Drilling rig includes coring equipment and core splitter.
Scaler (3281.0)	40130773, 40110777, 40130774, 40080370, 02030263	
Scanner, IR Orbital (6202.2)	21040101	Similar to Nimbus IR Scanner.
Scanner, Photoelectric Field (3767.01)	72010207	Instrument used with 12-inch telescope.
Scanner, Spectral (40-Inch Telescope) (0186.9)	72010313	Related instruments in experiments 55220301 and 55220401.
Sectioning Equipment (2665.1)	32010108	Microtome type of sectioning equipment may not be necessary, consider substitution.
Seismometer, Lamont Four Component (4405.5)	41010206, 41020207, 41020208, 41020211	
Seismometer, Vertical Axis Short Period (4405.6)	41020208, 42020284	Remote location from vibrating equipment. Instrument must be solidly mounted on rigid structure in direct contact with the lunar surface. Self-leveling capability is required. Must operate in vacuum and withstand launch and landing accelerations. Also, must be caged until emplacement and shielded from thermal radiation and meteorite impacts.
Shield, Heat Source (2055.1)	44070847	
Source and Detector, Gamma (3150.0)	32010113	Remote location from sensitive equipment and shielding of sensor from direct exposure to source radiation is required. Radiation sensor probe must be unpressurized and in good contact with lunar surface.
Source Curium - 242, Alpha Particle (3321.0)	40130771, 40130772	A neturon generator (equipment number 3215.0) producing a source of deuterons is used on experiments 40250375, 40250476. A gamma source and detector (equipment number 3150.0) is included in experiment 32010113.
Spectrograph, Astronomical (0186.81)	47021202, For 6-inch telescope: 47011101, 47031303, 47041404, 47051505, For 8-inch telescope: For 40-inch telescope: 47061606, 47071707, 480102210, 48112311, 72010311	

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Spectrograph, Astronomical Coude, High Dispersion (0186.82)	72010312	This instrument is for a 40-inch telescope. Similar instruments in experiments 55220302, 55230101, 55230102, 55230201.
Spectrograph, High Dispersion (0186.83)	72010415	Similar to instrument in 72010312 except instrument is for the 100-inch telescope.
Spectrograph, Stellar (0186.8)	72010104	Used to obtain medium and low dispersion spectra (attached to 12-inch telescope).
Spectrograph, Ultraviolet (1868.1)	55220201	See Master List of Experiments for fuller description.
Spectrometer, Charged Dust (6800.0)	02030263	A Neugebauer-type electrostatic velocity selector modified to perform as a charged dust spectrometer, has been developed for Ranger; further development is necessary. A major problem is that the number of dust particles is expected to be very small, and charge per dust particle is expected to be small. The potential of the analyzer against lunar surface also is uncertain.
Spectrometer, Charged Particle (Bendix Channeltron) (2931.1)	52020101, 52020102, 52020103	A Neugebauer solar plasma spectrometer has been developed for space use by JPL. Proximity to RTG power source should be avoided. Unobstructed exposure to radiation from upper hemisphere is required.
Spectrometer, Charged Particle, Triaxial Array (3060.3)	52020301	
Spectrometer, Cosmic Ray Charged Particle Solid State (3060.5)	52020401	
Spectrometer, Curved-Plate Electrostatic Plasma (3093.1) and (3093.2)	53010101, 53010102, 53010103, 53010104, 53010201, 53010202	Parametric requirements for instrument (equipment number 3093.2) in common usage experiments are different from those of this instrument. Proximity to isotopic power supply should be avoided. Operating temperature, 0 C to 70 C except for transistors; magnetic flux density at sensors less than 100 nanotesla; requires vacuum environment; must withstand launch and landing accelerations; store in vacuum to avoid outgassing and contamination; velocity selector plates should be shielded from sunlight.
Spectrometer, Electron, Cerenkov (3059.0)	52020401, 52020402, 52020403	

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Spectrometer, Electron, Solid State (3060.2)	52020402, 52020403, 53040101, 53040102	Parametric requirements for instrument in first two common usage experiments differ. See Master List of Experiments for details. Space rated instrument developed by Lawrence Radiation Laboratory for use on Discoverer '29 space probe.
Spectrometer, Faraday Cup Plasma (3092.1)(3092.2) (3092.3)(3092.4)	53010101, 53010102, 53010103, 53010104, 53040101, 53040102, 79070101	Parametric requirements differ for common usage experiments (see Master List of Experiments for details).
Spectrometer, Infrared Recording (4650.0)	61040102	Instrument may be interchangeable with 4640.0 in experiment 32010102.
Spectrometer, Interferometer (4597.0)	40070883	Instrument is sensitive to spectral radiation.
Spectrometer, Mass, for Solids (2442.0)	32010110	
Spectrometer, Meson, System for Neutrino Detection (3059.5)	52090101	
Spectrometer, Nuclear Magnetic Resonance (2895.0)	32010103	Instrument to be developed for late missions
Spectrometer, Quadrupole Mass (2443.8)	34010401, 34010402, 34010403	Instrument is equipped with a pressure intensifier, possibly a "snorkel" aimed in the direction of travel.
Spectrometer, Reflection Grating (4665.0)	40070883	Photomultiplier tube is used as detector for visible and ultraviolet; P6S sensor for infrared. Should be emplaced to avoid outgassing from spacesuit and mobile or static shelters. Must be thermally controlled to protect solid state electronic components, vacuum conditioned (outgassed) and transported to Moon under vacuum seal. Constructed to endure launch and landing vibrations and shock.
Spectrometer, Scintillation Particle, 15-cm Na-I-Tl Crystal, Telescope (3052.4)	52030101, 52030102, 52030103, 52030201, 52030202, 52030203	
Spectrophotometer, Infrared (4640.0)	32010102, 32010117, 32010118	
Spectrophotometer, Ultraviolet and Visible, Recording (4675.0)	32010115	Similar instrument (number 4675.1) is used in orbit in experiment 32010116.
Surveying Staff, Astronaut (6200.2)	21010203, 21010204, 21040205, 24030310	

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Survey Kit, Mapping (6200.3)	21010203, 21010204, 24030310	Requirements for initial landings and extended exploration differ, see specific data sheets in master list. Kit consists of telescope sighting device, range finding device, data tables for establishing position on lunar surface and related items.
Telescope Cassegrainian Focus, Six-Inch Reflecting (0187.6)	47021202, 47011101, 47031303, 47041404, 47051505, 49013101, 49013102, 49023201	
Telescope, Radio, 20-Foot Dish with Mounting Drive and Guide (6411.0)	47081808, 48102210	Must be isolated from any equipment radiating at the frequencies over which the antenna tunes. Protection against extreme temperature fluctuations of electronics, instrumentation packages and structural seals and against radiation from wind, solar flares and cosmic rays is necessary. Antenna design problem posed by meteoroid and secondary ejecta flux.
Telescope, Reflecting 100-Inch (0187.64)	72010414, 48102210, 49023102, 72010415, 72010416, 72010417, 72010418, 72010419	Diffraction limited, wavelength interval 3000-1000 angstroms. For additional requirements for the common usage experiments see Master List of Experiments.
Telescope, 8-Inch (1882.8)	55220201, 55220101	Telescope is a Cassegrainian or Hershellian off-axis paraboloid, diffraction limited, F/10.
Telescope, 12-Inch, High Resolution Reflecting (0187.62)	71010101, 72010102, 72010103, 72010104	Equipped to perform in photographic, photoelectric and spectrographic modes.
Telescope, 12-Inch Wide-Field Reflecting, 5 Degree Field (0187.65)	72010205, 72010206, 72010207	Should be isolated from primary sources of artificial light; emplace on firm foundation. Provide passive thermal protection of electronic equipment. Main apparatus should be shaded from direct solar and lunar surface radiation during day. Optical surfaces protected from lunar dust, particle bombardment, and meteoroid effects. Select materials with regard to potential sublimation.
Telescope, 40-Inch Reflecting, Prime Cassegrainian and Coude Foci (0187.63) and (1882.4)	72010308, 55220301, 55220302, 55220401, 55220501, 55220601, 55230101, 55230102, 55230201, 47071707, 47051512, 47061606, 48112311, 48102310, 49023202, 49033301, 49013102, 72010309, 72010310, 72010311, 72010312, 72010313	See parametric requirements listed in common usage experiments for particular variations.
Television, Borehold Logging (6200.8)	21040411, 21010412	

Table 10. Scientific Equipment Commonality Summary (Cont)

Equipment Name and Number	Common Usage Experiment No.	Remarks
Television Monitor, LEM (6200.4)	21040205	
Television, Orbital (6202.1)	21040101	A Ranger or weather type TV could be used.
Thermobalance (0330.0)	32010301	Instrument is a thermogravimetric type balance.
Thermocouple (4905.0)	44070842	Contact type instrument calibrated for operation from 225 to 400 K.
Timer, Interval (4985.3)	40080352, 40080353	
Tool Box, Lunar Geological (6200.1)	21010203, 21010204, 21010309, 24030310	The lunar geological tool box is currently being developed by USGS, Flagstaff, Arizona. A prototype for earth testing has been used and modifications suggested.
Transducer, Acoustic (5135.0)	40080370	
Transmitter and Matched Antennas (6722.01)	76070102	The transmitter is a frequency and amplitude stabilized master oscillator and power amplifier (frequency range 1 KHz to 30 MHz).
Transmitter, Electro-Magnetic Pulse (6414.01)	41060540, 41050541	
Transmitter, RF (6713.00)	75050102	
Transponder, Three Frequency (6718.02) (6718.03) (6718.04)	78070101, 78070102, 78070103	Instrument includes antennas and is assumed to differ slightly in parametric requirements for the common usage experiments.
Variometer, Magnetic (2370.3)	41040681	

5.3 TELEMETRY

5.3.1 INTRODUCTION

The telemetry data Type-6 card in the Experiment Data Management System indicates the first expansion of the data management system toward a more comprehensive description of subsystem support requirements. Initially, telemetry data were included only on the Type-2 card. Then, the principal telemetry parameters were defined and encoded for each distinct piece of scientific equipment interfacing with the telemetry system. The data can be used for a preliminary definition of the requirements for telemetry systems to support scientific experiments in lunar exploration missions. However, this capability was introduced late in the program and the presently encoded data are preliminary in nature.

5.3.2 CARD FORMAT AND CONTENT

The final format for the telemetry Type-6 card was developed by NAA engineers based on initial format suggestions by NASA.

In the adopted form, the first 35 spaces on the card are used for experiment ID number, equipment number, parameter and parameter range. Telemetry data require 32 spaces and, therefore, utilize spaces 36 through 67. The data card has a total capacity of 80 spaces. Therefore, there are 13 presently unused spaces on the card. These spaces can be used for future information growth such as indication of the number of additional telemetry links.

The 32 columns containing telemetry data on a card represent 15 basic parameters selected to define the telemetry requirements. These parameters are as follows:

1. Duration of Experiment: denotes the total time in hours required to implement the experiment from activation to conclusion. (Capacity 9.9×10^9 hours.)

2. Data Link: denotes the first telemetry transmission link by type from point of transmission to point of reception (i.e., lunar orbit to lunar surface). Additional transmission links that may be required for an experiment are not defined.

3. Storage Applicability: denotes the applicability of storing sensor output data for transmission at a later time.

4. Periodic Readout: denotes the amount of time anticipated to read in and read out stored data. (Range in: 99 hrs/99 min.; out: 0-99 sec.)

5. Type of Event: denotes whether event is discrete or varying and the type of varying data (i.e., continuous, periodic, or random).

6. Type of Data: denotes whether data is analog, digital, or time-sharing; and if time-sharing, whether single or multiple routine.*

7. Signal Conditioning: denotes the need for signal conditioning, the signal output of the instrument, and the type signal conditioning required.

8. Duration of Output: denotes the amount of time output that may be anticipated from the instrument to the telemetry system.

9. Maximum Analog Frequency: denotes in Hertz (cps) the maximum analog frequency output of the instrument.

10. Analog Accuracy: denotes the accuracy required for analog signals defined in Item 9. (Range: 0.1 percent to 9.9 percent error.)

11. Bits Resolution: denotes the number of bits needed to define the signal to the accuracy established in Item 10. (Range: 01-99.)

12. Type of Digital Output: denotes whether the signal output of the instrument is serial or parallel.

13. Number of Bits: denotes the word length for serial outputs or number of output lines for parallel output.

14. Bit Rate: denotes the maximum data rate in bits per second for serial or parallel outputs.

15. Number of Commutated Inputs: denotes the number of commutated channels of data required by the instrument (0 to 99) for analog signals.

All of the preceding data are relevant for a particular input with one exception. Where Items 9, 10, and 15 are used, Items 11, 12, 13, and 14

*A single routine reflects a fixed pattern of communication and a multiple routine reflects a variable pattern of commutation.

are not applicable, and vice versa. Since one set of parameters applies to analog signals and the other set applies to digital signals, they are mutually exclusive.

It should be noted that, due to its preliminary nature, the quality of telemetry information prepared for the Type-6 card ranges from "reasonably certain" to "best guess." The latter type data were included to allow a preliminary sizing of the telemetry system. The exception is the maximum analog frequency entry which was left blank because reasonable entries could not be generated within the time available.

For future effort, it is suggested that the Type-6 card definition be expanded so that the telemetry outputs can be treated on a per experiment basis rather than an equipment basis. A level 6 card could be furnished for each telemetry output for each experiment on a per equipment basis. In addition, the scope of further work could be increased to include not only the first telemetry link, as presently shown on Type-6 cards, but also subsequent transmission links required as well.

It is recommended that future efforts be made on a step-by-step basis starting with an experiment instrument package configuration and allowing for analysis of output parameters from each package based on the manufacturers data for presently designed equipment or a comparative analysis of similar functions for new equipment to be designed. A closely coordinated effort between the scientist designing the experiments and engineers developing the telemetry data is required for a better evaluation of telemetry requirements for each experiment.

The Type-6 card, when completed for all pertinent experiments on the recommended basis, will describe the telemetry data to be transferred from any point to another during the course of lunar experimental activity. It will be possible to use the completed card deck to size the various telemetry systems required, including the transmission links required and recording necessary to handle all data transmission from point of origin to final destination.

Table 11 presents the method of coding used on the Type-6 card. Two types of codes are used: those that denote numerical values and those that represent discrete descriptions. Those items represented by the letters "d" and "e" are numerical values, and those represented by "c" indicate the use of an arbitrary code. The letter "d" in the data column indicates a digit and the letter "e" indicates the exponent to the base 10. The codes used for items requiring coding are given in Table 12.

Table 11. Telemetry Entries for Type-6 Card

Item No.	Parameter	Data Type	No. Spaces
1	Duration of experiment (hours)	d.de	3
2	Data link	c	1
3	Storage applicability	c	1
4	Periodic readout	dd dd dd	6
5	Type of event	c	1
6	Type of data	c	1
7	Signal conditioning	c	1
8	Duration of output (hours)	d.de	3
9	Maximum analog frequency (Hertz)	dd.e	3
10	Analog accuracy (percent)	d.d	2
11	Bits resolution	dd.	2
12	Type of digital output	c	1
13	Number of bits	dd.	2
14	Bit rate	dd.e	3
15	Number of commutated inputs	dd.	2

Table 12. Type-6 Card FORTRAN Codes

Item	Identification	Codes	
2	Data link	1	Lunar surface to surface
		2	Lunar surface to orbit
		3	Lunar orbit to Earth
		4	Lunar orbit to surface
		5	Earth orbit to Earth and return
		6	Lunar surface to lunar orbit to Earth
		7	Earth to lunar orbit to lunar surface
		8	Lunar surface to Earth
3	Storage applicability	0	No
		1	Yes
5	Type of event	0	Discrete
		1	Varying - continuous
		2	Varying - periodic
		3	Varying - random
6	Type of data	0	Analog
		1	Digital
		2	Time-sharing; single routine
		3	Time-sharing; multiple routine
7	Signal conditioning	0	None
		1	Amplification
		2	Amplification + conversion
		3	Conversion - ac/dc
		4	Conversion a/d
12	Type of digital output	0	Serial
		1	Parallel

Examples of the numerical values using the digit and exponent method are:

dd:	32 = 32	d. d:	32 = 3.2
dde:	322 = 32 x 10^2	d. de:	322 = 3.2 x 10^2

The "dde" code, for which the two digits are whole numbers, is used only in the Type-6 card, and only for analog frequency and bit rate entries. Other two-digit and exponent codes are in tenths units, i. e., "d. de."

5.3.3 TELEMETRY DATA

The information supplied at this time represents an input to the telemetry system for each distinct piece of scientific equipment that has a unique telemetry output. If a given transducer is associated with a signal conditioner and amplifier in the same experimental package, it is the output of the final unit in the chain (the amplifier) which is treated as a telemetry input for the purpose of the material presented. In this case, the transducer and the signal conditioner in the experiment package would list "No Telemetry Required" for the Type-6 card for these items.

It should be noted that the same equipment may be used in several experiments; however, only one entry appears in the present system for each piece of equipment. For approximate total telemetry volume, common equipment usage must be accounted for by integrating the telemetry requirement across the applicable experiments using common equipment. The data rates for like equipment in the different experiments may vary somewhat and will require consideration.

The following ground rules were established prior to deriving the information presented on the Type-6 cards:

1. Each card represents the data that enters the telemetry system from an experimental package and reflects its characteristics at that time. The data form and rate may differ from those of the transducer used as prior signal conditioning if the experiment instrument package is not shown.

2. Only the first telemetry transmission for a given input is listed. For example, an information stream which is transmitted from a remote lunar site to the fixed lunar base, stored, and retransmitted to earth will be entered as a lunar surface-to-lunar surface transmission. Subsequent transmission links which may be required are not included.

3. Data storage capability has been related to that required at the instrument package prior to entering the telemetry system for transmission. Processing of telemetry information, including storage at the receiving site, is not reflected in the Type-6 card information.

5.4 OPERATIONAL PARAMETERS

Experiment operational parameters have been quantified in this study to describe experiment support requirements.

The experiment data management system described in Section 4.0 includes a number of data fields for encoding lunar operations data related to each of the experiments. These data fields occur primarily in the Type-2 and Type-3 cards with summary data in the Type-1 card. The types of operational data summarized are: experiment location, mobility requirements, number of men required to perform the experiment, crew skill requirements, and scientific man-hours required for experiment performance - both total and on traverse. Special experiment requirements may be defined further in the experiment "zero" card descriptive material.

The operational support portion of this study is primarily concerned with manned operations on the lunar surface. Because of the high cost of providing scientific man-hours on the lunar surface, provision was made for adequate description of this area in the design of the experiment data management system.

The type of lunar crew activities and the location of these activities relative to a lunar base or landing site are important in the analysis of scientific man-hours. For example, whether the required activities are planned to be accomplished inside a fixed lunar installation or in a spacesuit on a traverse at a considerable distance from the installation will be of significance to the mission planner. Consequently, these two basic activity locations (on traverse and at the lunar base) are identified on the Type-3 card. Two astronaut activity environments (shirtsleeve and spacesuit) and four classes of astronaut activity (experiment setup, operation, analysis, and takedown) are also incorporated. Thus, 16 data fields are provided to estimate crew activities associated with a given scientific investigation.

On the Type-2 operations card, the experiment man-hour requirements are summarized into four categories (traverse shirtsleeve, traverse spacesuit, base shirtsleeve, and base spacesuit). Other operations data on the Type-2 card and not in the Type-1 card are: repetitions, frequency of performance, egresses, and crew participation.

Man-hour estimates are carried to increments as small as 0.1 hours. The standard four-digit code entry is used for man-hour data on the Type-1 and Type-3 cards, while a three-digit code was used on the Type-2 card. Man-hour estimates for the experiments included in the study are shown in the computer printout of volume 5. Man-hour requirements are reviewed in the following section.

5.5 MAN-HOUR REQUIREMENTS

The establishment of man-hour requirements for the experiments is an important consideration in mission planning for extended lunar exploration. Each experiment must be defined so that man-hours and equipment operating hours are definable and complete packages in order that "per-replication" values may be used in mission planning. Thus, experiments can be most readily fitted to missions and to mission constraints such as mass, man-hours, and other operations parameters. The objectives of a given mission may require multiple repetitions of a given experiment (e.g., lunar material sampling on a traverse). Therefore, keeping the operating information on a "per-replication" basis allows flexibility in the assembly of an efficient scientific program for a given lunar mission.

Application of this "per-replication" base to all of the experiments considered during the study required definition of replication as a function of the experiment. The principal objective of some experiments was the simultaneous accomplishment of given measurements at several widely separated points on the lunar surface or the daily measurements of a given parameter every few hours throughout a lunar month. In other experiments, for example, certain optical astronomy studies, the performance of the experiment could require dozens, hundreds, or even thousands of readings or photographs in order to accomplish the scientific objective of the experiment. For reasons such as these, the term "experiment replication" required a different connotation with different applications. The following paragraphs and the Experiment Man-hour Summary (Table 13) define the usage in the SMS-ELE study.

The general concept of man-hour estimating for the experiments described in the SMS-ELE data management system was to provide the total requirements of the lunar surface astronaut participation to complete one performance of the experiment as described in the Type-0 card description. The Type-3 card provided a format for segmenting this total participation into several categories and locations of performance. These categories are identified in the data encoding descriptions of Volume 5 (see Section 3.0 Table 7) as man-hours for experiment setup, for experiment operation, for experiment analysis, and for experiment teardown (takedown) as required. In addition, the location of performance (traverse, base, or combination) and whether the estimated man-hours are expended in a spacesuit or shirtsleeve environment can be indicated. Thus, a total of 16 fields for man-hour estimates are provided in the Type-3 card.

The experiment totals for these 16 man-hour fields are summarized into four items on the Type-2 card. These are traverse spacesuit man-hours, traverse shirtsleeve man-hours, base spacesuit man-hours, and base shirtsleeve man-hours. These four items are, in turn, summarized (by the computer) into the two categories: total man-hours and traverse man-hours for a given experiment, shown on the Type-1 card summary. Where all of the experiment man-hours are on traverse, the two Type-1 card summaries contain the same values.

The man-hour estimates are reasonable minimum requirements for equipment setup and data gathering (or sampling) to provide an acceptable body of information for analysis of the scientific question the specific experiment is designed to answer. It was anticipated that the experiment design would provide for (1) a reasonable compromise of automatic data gathering and recording, and (2) the flexibility of the data gathering system to allow the exercise of scientific judgment by the participating astronaut in the application of the instrumentation and on-the-spot review of the experiment results. For those experiments where completely automatic experimental measurements and data transmission are deemed practical, the man-hours indicated in the data management system experiment descriptions are only for equipment setup.

Because of the quantity, variety, and complexity of the 340 experiments described in the data management system, it was impractical to provide a detailed task analysis for each of the listed experiments. Where the source document for a given experiment provided estimates of the man-hours required for performance in the lunar environment, these values were used. Where man-hour estimates were not available in the source documentation, they were provided by the NAA scientist responsible for the particular discipline area.

The estimates for spacesuit man-hours shown in the SMS-ELE study are based on performance in the Earth environment. Thus, the actual spacesuit man-hours necessary on the lunar surface will require that the listed values be multiplied by a suitable "K" factor for lunar suit usage. (See Volume 3, Section 6.1.) An average "K" factor of 3 is presently recommended.

A summary is shown in Table 13 for each of the 340 SMS-ELE experiments. The third column of the table shows the total man-hours for each experiment as obtained from the Type-1 card summary. The fourth, fifth, and sixth columns show a breakdown of the type of man-hour activities into three groups: (a) setup and takedown, (b) data gathering or sampling, and (c) analysis. The seventh and eighth columns show the number of replications of activities in the man-hour totals for (a) the data gathering or sampling activity and (b) the setup and takedown activity where this detail was available in the estimating procedures.

The man-hour estimates summarized in the fourth, fifth and sixth columns were obtained from the Type-3 cards of the data management system. The number of replications are those indicated in the Type-2 card and zero card descriptions. It should be noted that the summation of the estimates in the Type-3 card fields and the experiment man-hour totals do not always agree because of "rounding" to two significant figures during the two-step summarizing process from the Type-3 card breakdown (16 fields) to the Type-2 card summary (4 fields) to the Type-1 card total.

Where blank times for setup and takedown are indicated in the summary table (e.g., Experiment 01030159), the nature of the experiment is such that the time involved in instrument preparation is considered trivial in the normal performance of the experiment. Where a blank is shown for the data gathering or sampling (operation) portion of the experiment (e.g., Experiment 02030263), the nature of the experiment is such that the only requirement for astronaut participation is for setting up the experiment in the appropriate lunar surface location.

Orbital experiments are shown with blanks for all man-hour estimate columns and replication columns since no lunar surface man-hours are involved. Certain other experiments show blanks in all fields. These are related to measurements that can be obtained during the performance of other referenced experiments and involve no additional man-hours (e.g., see Experiment 40130776) provided, of course, that they are planned prior to the lunar mission. Other experiments in which data gathering and recording or transmission are planned for automatic operation also are indicated (e.g., Experiment 40080354) in the comments column of the table.

The seventh and eighth columns of the table indicate that the performance of some experiments will require multiple operations of data gathering or setup and takedown activities for completion of the indicated experiment. The following examples will indicate the meanings attached to these entries.

In Geodesy Experiment 11010101, "Selenodetic Astronomy," 12 replications are indicated in the data gathering and setup columns. In this case, the 12 setups are required because the observations were visualized to be required from 12 widely separated points on the lunar surface. All of the readings are required in order that the experiment can provide geodetic accuracy improvements over that available from other systems.

Experiment 21020307, "Shallow Drilling," shows that normal operation of this experiment would anticipate the selection of five samples to be taken at a particular traverse stop.

In Geochemistry Experiment 32010101, 98 data gathering/sampling replications are shown with one setup. This indicates that for a routine laboratory-type geochemical analysis performed at a fixed site, the designed approach would be to set up the required apparatus for processing a relatively large group of samples in one operation. Therefore, the man-hour estimates given are for processing this group of 98 samples.

The remarks column of the table also is used to indicate two special types of experiments in which relatively long-term operations are involved. These are designated as "Observatory Programs" and "Laboratory Programs." These two terms as utilized in the man-hours summary table are defined in the following paragraphs.

Observatory Programs: Covers astronomical observatory-type experiments which can involve a large number of repetitions of, for example, photographic and related tasks over an extended time period as particular viewing opportunities related to the experiment become available. The minimum number of scientist viewing hours deemed appropriate for the exploration phase and equipment designated were estimated in order to provide an adequate data base for analysis of the experiment problem. Only one replication for operation and one replication for setup and takedown are shown for this class of experiment.

Laboratory Programs: A laboratory program implies one in which a varied group of scientific observations or measurements are repeated periodically over a period of time, usually spread out over the duration of the mission phase to which the experiment is assigned. The experiment usually applies to living subjects. The setup and data gathering replications are indicated only once each for this type of experiment.

Table 13. Experiment Man-Hour Summary

Experiment Number	Experiment Title	Total Man-Hours for Experiment	Activities Included in Total Man-Hours: Setup and Takedown	Activities Included in Total Man-Hours: Data Gathering or Sampling	Activities Included in Total Man-Hours: Analysis	Replications of Activities in Totals: Data Gathering or Sampling	Replications of Activities in Totals: Setup and Takedown	Remarks
	LUNAR ATMOSPHERES							
01030159	ATMOSPHERIC PRESSURE	0.1	-	0.1	-	1	-	
01030260	ATMOSPHERIC PRESSURE	0.1	0.1	-	-	-	1	
01030464	GAS CHROMATOGRAPH	20.0	-	10.0	10.0	10	-	
02030263	CHARGED DUST	1.0	1.0	-	-	-	1	
02030361	ELECTRIC FIELD	1.0	1.0	-	-	-	1	
02030362	ELECTRIC FIELD	0.1	0.1	-	-	-	1	
	GEODESY							
11010101	SELENODETIC ASTRON	73.0	9.4	39.0	24	12	12	
11010505	EARTH-MOON DISTANCE	73.0	9.4	39.0	24	12	12	
12010202	SELENODETIC SURVEY	55.0	4.6	26.0	24	12	12	
12020606	SELENODETIC MAPPING	-	-	-	-	-	-	Orbital experiment
13030303	SURFACE GRAVITY	17.0	6.0	6.0	4.8	12	12	
13030707	ORBITING GRAVITY	-	-	-	-	-	-	
13040404	SEISMIC OBSERVATIONS	14.0	5.9	6.0	2.4	12	12	
	GEOLOGY							
21010203	FINE STRUCTURE DEF	5.0	-	5.0	-	1	-	
21010204	GEOLOGIC MAPPING	8.0	-	8.0	-	1	-	
21010309	SURFACE SAMPLING	5.0	-	5.0	-	1	-	
23010320	SAMPLE COLLECTION	0.1	-	0.1	-	1	-	
21010230	SUBSURFACE SAMPLING	0.2	-	0.2	-	1	-	
22010412	SUBSURFACE MAPPING	14.0	3.0	6.0	5.0	1	1	
21020307	SHALLOW DRILLING	2.4	0.3	2.1	0.5	5	1	
21020308	DEEP DRILL - 300 M	500	153.0	350.0	50.0	1	1	
21040101	GEOLOGIC BASE MAP	-	-	-	-	-	-	Orbital experiment
21040102	SURFACE MAPPING	-	-	-	-	-	-	Orbital experiment
21040205	SURFACE PHOTOGEOLOGY	3.0	-	3	-	1	-	
21040411	VISUAL LOGGING	10.0	-	10.0	-	1	-	
24030310	AGE DETERMINATION	2.0	-	1.0	1.0	1	-	
24030413	PALEO MAGNETISM	0.2	-	0.2	-	1	-	
	GEOCHEMISTRY							
32010101	CHEM ANAL BY N ACTIV	22.0	2.0	10.0	10.0	98	1	
32010102	CHEM ANAL BY IR	22.0	2.0	10.0	10.0	98	1	
32010103	NMR SPECTROMETRY	21.0	1.0	10.0	10.0	98	1	
32010104	X-RAY FLUOR ANALYSIS	22.0	2.0	10.0	10.0	98	1	
32010105	CHEM ANAL W REAGENTS	200.0	-	200.0	-	98	-	
32010106	DENS BY FLOTATION	20.0	-	20.0	-	40	-	
32010107	MIN BY X-RAY DIFF	81.0	1.0	50.0	30.0	98	1	
31010108	MICR MIN A PET STUDY	100.0	-	100.0	-	98	-	
32010111	CHEM ANAL BY N ACTIV	24.0	2.0	2.0	20.0	98	1	
32010112	X-RAY FLUOR ANALYSIS	22.0	2.0	20.0	-	98	1	
32010113	GAMMA SCATTERING	10.0	-	10.0	-	98	-	
32010114	IN SITU X-RAY DIFF	10.0	-	5.0	5.0	98	-	
32010115	UV-VISIBLE SPECTRA	7.0	-	5.0	2.0	98	-	
32010116	ORBITAL UV-VIS SPEC	-	-	-	-	-	-	Orbital experiment
32010117	ORBITAL IR SPECTRA	-	-	-	-	-	-	Orbital experiment
32010118	IN SITU IR SPECTRA	7.0	-	5.0	2.0	98	-	
32010301	VOLATILE DETN/COLLN	19.0	4.0	10.0	5.0	50	1	
33010101	GAMMA RAY SPECTROM	20.0	-	15.0	5.0	98	-	
33010102	GAMMA RAY SPECTROM	-	-	-	-	-	-	Orbital experiment
34010401	ORB GAS MASS SPEC	-	-	-	-	-	-	Orbital experiment
34010402	SURF M SPEC GAS ANAL	4.5	4.0	-	0.5	-	1	
34010403	M SPEC GAS ANAL	-	-	-	-	-	-	Emplaced from orbit
35010110	SOLIDS M SPEC ANAL	40.0	-	40.0	-	10	-	
	GEOPHYSICS							
40010101	SEISMIC VELOCITY	0.2	0.1	0.1	-	1	1	
40010102	SEISMIC VELOCITY	0.3	0.1	0.2	-	5	1	
40010103	REFLECTION PROFILE	0.3	0.3	-	-	-	1	
40010104	REFRACTION PROFILE	0.6	0.4	0.2	-	1	1	
40050524	MAG. SUSCEPTIBILITY	1.0	0.5	0.5	-	1	1	
40050525	MAG. SUSCEPTIBILITY	2.0	-	2.0	-	1	-	
40050526	MAG. SUSCEPTIBILITY	1.0	0.5	0.5	-	1	1	
40050527	MAG. SUSCEPTIBILITY	2.0	0.5	1.5	-	1	1	
40050536	ELECTRICAL SURVEY	1.0	1.0	-	-	-	1	
40050537	DIELECTRIC CONSTANT	0.1	-	0.1	-	1	-	
40050538	DIELECTRIC CONSTANT	0.1	-	-	0.1	1	-	
40050539	DIELECTRIC CONSTANT	0.1	-	0.1	-	1	-	
40060532	SURFACE RESISTIVITY	0.2	0.1	0.1	-	1	1	
40060533	SURFACE RESISTIVITY	0.1	-	0.1	-	1	-	

Table 13. Experiment Man-Hour Summary (Cont)

Experiment Number	Experiment Title	Total Man-Hours for Experiment	Activities Included in Total Man-Hours			Replications of Activities in Totals		Remarks
			Setup and Takedown	Data Gathering or Sampling	Analysis	Data Gathering or Sampling	Setup and Takedown	
40060534	SUBSURFACE RESIST	0.2	0.1	0.1	-	1	1	
40060535	RESISTIVITY SUBSUR	1.0	0.5	0.5	-	1	1	
40060565	RADAR MAPPING	-	-		-	-	-	Orbital experiment
40060628	SELF POTENTIAL	2.0	0.5	1.5	-	1	1	
40060629	SELF POTENTIAL	3.0	1.0	2.0	-	1	1	
40060630	ELECTRICAL SURVEYING	1.0	0.5	0.5	-	1	1	
40060631	ELECTRICAL SURVEYING	0.5	0.3	0.2	-	1	1	
40070869	PHOTOGRAPHY	-	-	-	-	-	-	Orbital experiment
40070883	SPECTRAL REFLECTANCE	1.0	1.0	-	-	-	1	
40080352	METEORITE DETECTION	0.4	0.4	-	-	-	1	
40080353	METEOROID DETECTION	0.3	0.3	-	-	-	1	
40080354	METEOROID DETECTION	-	-	-	-	-	-	Automatic data recording, externally mounted on Rover'
40080370	METEORITE DETECTION	-	-	-	-	-	-	Orbital experiment
40090456	SURFACE HARDNESS	-	-	-	-	-	-	Related to drilling experiments
40110777	NEUTRON SPECTRA	0.2	0.2	-	-	-	1	
40120778	GAMMA RAY SPECTRA	0.5	0.5	-	-	-	1	
40120779	GAMMA RAY SPECTRA	1.0	1.0	-	-	-	1	
40120780	GAMMA RAY SPECTRA	-	-	-	-	-	-	Orbital experiment
40130771	ALPHA MASS SPEC	0.1	0.1	-	-	-	1	
40130772	ALPHA MASS SPEC	-	-	-	-	-	-	Automatic data recording, externally mounted on ROVER
40130773	RADIOACTIVITY	1.0	1.0	-	-	-	1	
40130774	RADIOACTIVITY	1.0	0.5	0.5	-	1	1	
40130775	NEUTRON ACTIVATION	2.0	2.0	-	-	-	1	
40130776	NEUT ACTIV TRVRS	-	-	-	-	-	-	Combined with radioactivity probe, Expt 40130774
41010205	SEISMIC REFLECTION	2.1	2.0	0.1	-	1	1	
41010206	SEISMIC PROFILING	-	-	-	-	-	-	Related to Expt 41010205
41020207	SEISMIC, PASSIVE	1.0	1.0	-	-	-	1	
41020208	SEISMIC, PASSIVE	6.0	6.0	-	-	-	1	
41020211	SEISMIC ARRAY	2.0	2.0	-	-	-	1	
41040681	MAGNETO-TELLURIC	3.0	3.0	-	-	-	1	
41050541	E-M PULSE	-	-	-	-	-	-	Automatic data recording mounted on roving vehicle
41050622	MAGNETISM	2.0	-	2.0	-	1	-	
41050623	MAGNETISM	3.0	-	3.0	-	1	-	
41060540	E-M PULSE	-	-	-	-	-	-	Automatic data recording, mounted on ROVER
41090487	SUBSURFACE HARDNESS	0.2	0.2	-	-	-	1	
42020284	REMOTE SEISMIC	-	-	-	-	-	-	Emplaced from orbit
44070842	NEAR SURFACE TEMP	0.1	0.1	-	-	-	1	
44070843	SUBSURFACE TEMP	0.2	-	0.2	-	1	-	
44070844	SUBSURFACE TEMP LOG	0.3	0.1	0.2	-	1	1	
44070845	TEMPERATURE GRADIENT	0.5	0.5	-	-	-	1	
44070846	THERMAL BLANKET	0.2	0.2	-	-	-	1	
44070847	SUR TEMP DIFFUSIVITY	0.3	0.1	0.2	-	1	1	
44070848	SUB SUR DIFFISUVITY	1.0	1.0	-	-	-	1	
44070849	TEMP DIFFUSIVITY	0.2	0.2	-	-	-	1	
44070850	SURFACE EMISSIVITY	0.4	0.2	0.2	-	1	1	
44070851	SURF TEMP PROFILE	-	-	-	-	-	-	Automatic data recording, mounted on ROVER
44070866	MICROWAVE RADIOMETRY	-	-	-	-	-	-	Orbital experiment
44070882	TEMPERATURE GRADIENT	0.5	0.5	-	-	-	1	
44070886	REMOTE TEMPERATURE	-	-	-	-	-	-	Emplaced from orbit
45030912	GRAVITY - ABSOLUTE	0.5	0.5	-	-	-	1	
45030913	GRAVITY - ABSOLUTE	1.2	1.0	0.2	-	1	1	
45030914	GRAVITY SURVEY	2.5	0.5	2.0	-	20	1	
45030915	GRAVITY SURVEY	11.0	0.8	10.2	-	98	1	
45030968	GRAVITY GRADIENT	-	-	-	-	-	-	Orbital experiment
43030985	GRAVITY GRADIENT	-	-	-	-	-	-	Orbital experiment
45100601	PLASMA POTENTIAL	11.0	3.0	4.0	4.0	4	4	
46040616	MAGNETIC FIELD	0.3	0.3	-	-	-	1	
46040617	MAGNETIC FIELD	0.5	0.5	-	-	-	1	
46040618	MAGNETIC FIELD	1.0	1.0	-	-	-	1	
46040619	MAGNETIC FIELD	1.0	1.0	-	-	-	1	
46040620	MAGNETIC SURVEY	2.5	0.5	2.0	-	20	1	
46040621	MAGNETIC SURVEY	11.0	1.0	10.0	-	98	1	
46040667	TOTAL MAGNETIC FIELD	-	-	-	-	-	-	Orbital experiment
47011101	EARTH HEAT BUDGET	27.0	2.2	20.0	5.0	1	1	Observatory program
47021202	EARTH ALBEDO AND REFLEC	25.0	0.6	20.0	4.5	1	1	Observatory program
47031303	AURORAL AIR GLOW PHO	20.0	0.6	20.0	-	1	1	Observatory program
47041404	UV SCATTER EARTH ATMOS	20.0	0.6	20.0	-	1	1	Observatory program
47051505	EARTH ATMOS IR SCAN	20.0	0.5	20.0	-	1	1	Observatory program
47051512	EARTH LRGE SCALE PHN	52.0	2.0	50.0	-	1	1	Observatory program
47061606	ATM DENSITY STAR REFR	120.0	41.2	40.0	40.0	1	1	Observatory program
47071707	UP ATMOS ECLIPS SPECTR	2.3	1.1	0.4	0.8	1	1	
47081808	MICROWAVE SCAN PASSIVE	14.0	4.0	5.0	5.0	1	1	Observatory program

Table 13. Experiment Man-Hour Summary (Cont)

Experiment Number	Experiment Title	Total Man-Hours for Experiment	Activities Included in Total Man-Hours: Setup and Takedown	Activities Included in Total Man-Hours: Data Gathering or Sampling	Activities Included in Total Man-Hours: Analysis	Replications of Activities in Totals: Data Gathering or Sampling	Replications of Activities in Totals: Setup and Takedown	Remarks
48092109	PLANET ATMOS CIRCULATION	33.0	3.0	20.0	10.0	1	1	Observatory program
48102210	PLANET ATMOS TEMP AND COMP	43.0	3.0	30.0	10.0	1	1	Observatory program
48112311	PLANET ALBEDO - REFLECT	180.0	8.0	120.0	50.0	1	1	Observatory program
49013101	OCEAN HEAT BALANCE	33.0	5.0	28.0	-	14	1	
49013102	OCEAN HEAT BALANCE - PH 2	1,000.0	32.0	800.0	200.0	1	1	Observatory program
49023201	SEQUENT MULTIBAND PHO	31.0	3.0	28.0	-	14	1	
49023202	SEQUENT MULTIBAND PHO	820.0	116.0	500.0	200.0	1	1	Observatory program
49033301	SEA SURF HEIGHT MEAS	940.0	41.0	705.0	180.0	1	1	Observatory program
	PARTICLES AND FIELDS							
52020101	SOLAR CHG PAR, LOW E	100.0	24.0	40.0	40.0	1	1	
52020102	SOLAR CHG PAR, LOW E	150.0	24.0	60.0	60.0	1	1	
52020103	SOLAR CHG PAR, LOW E	270.0	24.0	120.0	120.0	1	1	
52020201	SOLAR CHG PAR, HIGH E	54.0	14.0	10.0	30.0	1	1	
52020202	SOLAR CHG PAR, HIGH E	160.0	15.0	20.0	120.0	1	1	
52020203	SOLAR CHG PAR, HIGH E	310.0	30.0	40.0	240.0	1	1	
52020301	CHARGED PAR ANISOTPY	3.3	0.3	2.0	1.0	2	1	
52020401	NUCL RADIATION ENVRN	39.0	3.5	5.0	30.0	1	1	
52020402	SOLAR HIGH E ELECTRON	91.0	3.5	12.0	75.0	1	1	
52020403	SOLAR HIGH E ELECTRON	91.0	3.5	12.0	75.0	1	1	
52030101	GALACTIC NUCLEI	55.0	16.0	10.0	30.0	1	1	
52030102	GALACTIC NUCLEI	210.0	20.5	30.0	160.0	1	1	
52030103	GALACTIC NUCLEI	400.0	40.5	60.0	300.0	1	1	
52030201	GALACTIC ELECTRONS	21.0	4.5	8.0	8.0	1	1	
52030202	GALACTIC ELECTRONS	77.0	44.5	16.0	16.0	1	1	
52030203	GALACTIC ELECTRONS	77.0	44.5	16.0	16.0	1	1	
52090101	NEUTRINO SOURCE FLUX	520.0	117.0	100.0	300.0	1	1	
53010101	SOLAR WIND SPECTRUM	20.0	9.1	5.0	6.0	3	3	
53010102	SOLAR WIND SPECTRUM	39.0	17.1	10.0	12.0	6	6	
53010103	SOLAR WIND SPECTRUM	61.0	17.3	20.0	24.0	12	12	
53010104	SOLAR WIND MHD FLOW	140.0	28.3	17.6	60.0	16	16	
53010201	SOLAR WIND, SURFACE	0.2	0.2	-	-	-	1	
53010202	SOLAR WIND, SHOCK	-	-	-	-	-	-	Orbital experiment
53040101	AURORAL ELECTRONS	220.0	40.0	80.0	100.0	4	1	
53040102	AURORAL ELECTRONS	420.0	40.0	140.0	240.0	8	1	
53050101	SOLAR GEOMAG FIELD	21.0	4.1	7.0	10.0	4	1	
53050102	SOLAR GEOMAG FIELD	37.0	7.6	18.0	11.0	10	10	
53050103	SOLAR GEOMAG FIELD	65.0	9.7	33.0	22.0	16	16	
53050104	SOLAR GEOMAG FIELD	110.0	12.7	60.0	34.0	24	24	
53050201	MAGNET FIELD MONITOR	2.5	1.5	1.0	-	1	1	
53050202	MAGNET FIELD, SHOCK	-	-	-	-	-	-	Orbital experiment
53050203	MAGNETIC FIELD VS T	0.3	0.3	-	-	-	1	
53070101	ELECTROSTATIC FIELD	3.5	2.0	1.5	-	1	1	
53070102	ELECTRIC FIELD	9.7	0.7	5.0	4.0	2	2	
54080101	GALAC PAR SCAT REAC	59.0	31.0	12.0	16.0	1	1	
54080102	GALAC PAR SCAT REAC	97.0	47.0	24.0	24.0	1	1	
54080103	GALAC PAR SCAT REAC	88.0	44.0	20.0	24.0	1	1	
55220101	OUTER CORONA SPECTRA	12.0	5.5	2.0	4.0	1	1	Observatory program
55220201	FLARE UV SPECTRA - I	7.0	3.0	3.0	1.0	2	2	
55220301	GRANUL FINE STRUCTURE	54.0	47.0	6.0	1.0	1	1	Observatory program
55220302	GRANUL VELOC FIELDS	31.0	11.0	10.0	10.0	1	1	Observatory program
55220401	SUNSPOT FORMATION	16.0	9.0	6.0	1.0	3	3	
55220501	PROMINENCE STRUCTURE	220.0	9.0	204.0	4.0	3	3	
55220601	FLARE EJECTA, ACCEL	17.0	8.0	5.0	4.0	2	2	
55230101	UV LOW DISPERSION	8.0	5.0	2.0	1.0	1	1	
55230102	UV HIGH DISPERSION	11.0	5.0	4.0	2.0	1	1	
55230201	FLARE UV SPECTRA - II	21.0	5.0	10.0	5.0	1	1	
	BIOLOGY							
61010201	BIORHYTHMS, PLANT	800.0	100.0	300.0	400.0	1	1	Laboratory program
61010301	GEN EFFECTS, PLANT	170.0	16.0	100.0	50.0	1	1	Laboratory program
61020202	BIORHYTHMS, ANIMAL	2,400.0	20.0	1,600.0	800.0	1	1	Laboratory program
61030303	GEN EFFECTS, MICRO	20.0	2.0	16.0	2.0	1	1	
61040101	IND PREBIOT CHEM	240.0	20.0	120.0	100.0	1	1	Laboratory program
61040102	EVID EXIST LIFE	270.0	16.0	200.0	50.0	1	1	Laboratory program
62030401	SOIL BANK	-	-	-	-	-	-	Related to geoscience expts
	ASTRONOMY							
71010101	LUN ENVIR TEST	310.0	70.0	120.0	124.0	3	3	
72010102	HIGH RES PHOTG (12)	320.0	28.0	250.0	41.0	1	1	Observatory program
72010103	PHOTOELECT PHOTG (12)	250.0	24.0	202.0	21.0	1	1	Observatory program
72010104	LOW DISP SPEC (12)	310.0	5.0	240.0	61.0	1	1	Observatory program
72010205	SKY SURVEY (12)	920.0	104.0	800.0	21.0	1	1	Observatory program
72010206	VAR BRIGHT OBS (12)	500.0	24.0	400.0	81.0	1	1	Observatory program

Table 13. Experiment Man-Hour Summary (Cont)

Experiment Number	Experiment Title	Total Man-Hours for Experiment	Activities Included in Total Man-Hours: Setup and Takedown	Activities Included in Total Man-Hours: Data Gathering or Sampling	Activities Included in Total Man-Hours: Analysis	Replications of Activities in Totals: Data Gathering or Sampling	Replications of Activities in Totals: Setup and Takedown	Remarks
72010307	SCAN PHOTG (12)	280.0	52.0	210.0	21.0	1	1	Observatory program
72010308	PHOTG OBS (40)	540.0	203.0	320.0	21.0	1	1	Observatory program
72010309	PHOTG PHOTOM (40)	240.0	12.0	220.0	11.0	1	1	Observatory program
72010310	PHOTOEL PHOTG (40)	480.0	41.0	420.0	21.0	1	1	Observatory program
72010311	SPECTROSCOPY (40)	910.0	31.0	820.0	61.0	1	1	Observatory program
72010312	HIGH DISP SPEC (40)	940.0	31.0	820.0	91.0	1	1	Observatory program
72010313	SPECTR SCAN (40)	910.0	71.0	820.0	21.0	1	1	Observatory program
72010414	HIGH RES PHOTG (100)	1,100.0	201.0	920.0	41.0	1	1	Observatory program
72010415	HIGH DISP SPEC (100)	1,100.0	81.0	920.0	91.0	1	1	Observatory program
72010416	HIGH ENERGY (100)	690.0	21.0	620.0	51.0	1	1	Observatory program
72010417	OUTER ENVEL (100)	730.0	21.0	620.0	91.0	1	1	Observatory program
72010418	PLANET LIKE (100)	430.0	21.0	320.0	91.0	1	1	Observatory program
72010419	MAG AND COLOR (100)	1,000.0	111.0	920.0	31.0	1	1	Observatory program
72010521	LYMAN ALP SURVEY	610.0	22.0	510.0	91.0	1	1	Observatory program
73020622	SPECTR CHAC X-RAYS	980.0	42.0	900.0	41.0	1	1	Observatory program
73020623	ANGULAR POS X-RAYS	590.0	42.0	520.0	31.0	1	1	Observatory program
73020624	DIST INTERMED X-RAY	390.0	42.0	320.0	31.0	1	1	Observatory program
73030725	DETECTION GAM RAD	610.0	52.0	520.0	42.0	1	1	Observatory program
74010520	EINSTEIN PROB	62.0	21.0	31.0	11.0	3	3	
75040101	NON DIR RADIO ASTR	6.0	4.0	2.0	-	1	1	
75050102	DIR RADIO ASTRONOMY	23.0	18.0	5.0	-	1	1	
75060101	SUBMILLIMETER RA	1,000.0	168.0	470.0	400.0	1	1	Observatory program
76070102	LUN WAVE PROPAGATION	19.0	12.5	6.5	-	1	1	
77070101	AMB MAG FIELD MEAS	57.0	6.5	50.5		1	1	Observation program
78070101	CISLUNAR MEDIUM EXP	8.0	6.0	2.0	-	1	1	
78070102	RANGING STA CENTRAL	8.0	6.0	2.0	-	1	1	
78070103	RANGING STA REMOTE A	8.0	6.0	2.0	-	1	1	
78070104	RANGING STA REMOTE B	8.0	6.0	2.0	-	1	1	
79070101	ELECTRIC FIELD	-	-	-	-	-	-	Orbital experiment
79070102	MAGNETIC FIELD	-	-	-	-	-	-	Orbital experiment
79070103	PARTICLE FLUX	-	-	-	-	-	-	Orbital experiment
	MISSION SUPPORT INVESTIGATIONS							
81021101	GAS REQTS FOR DRILL	1.0	0.3	0.7	-	1	1	
81021102	LUNAR DRILL BIT TECH	-	-	-	-	-	-	Related to geoscience expts
81021103	CAL RMT SENSNG TECHS	1.0	0.4	0.3	0.3	1	1	
81021104	GEOLOG-CHEM SAMP CAS	4.0	0.8	2.6	0.6	1	1	
81021105	SAMPL SURV TECHS	-	-	-	-	-	-	Related to geoscience expts
81021201	ELECTRODE CPLNG PROP	4.0	2.0	1.3	0.7	1	1	
81021203	EXPLOSV ENERGY COUPL	8.0	6.0	1.0	1.0	1	1	
81021205	STEREO PHOTO GRAMMETRY	8.0	1.5	5.3	1.2	1	1	
81021207	EARTH REF GRAVIMTR	16.0	8.0	6.0	2.0	1	1	
81021301	BIO CONTAM LUNR SOIL	2.2	.7	1.2	.3	1	1	
81021503	LUNAR PLAS PROP SURF	-	-	-	-	-	-	Times are included with expt 82010109
81021701	EARTH RFI/BKGND NOISE	-	-	-	-	-	-	Orbital experiment
81021702	DIELECTRIC PROPERTIES	-	-	-	-	-	-	Orbital experiment
81021703	CRITICAL PLASMA FREQ	5.0	4.0	1.0	-	1	1	
81021801	ASTRONOMY FEASIBILITY	20.0	8.0	8.0	4.0	1	1	
81021802	REMOTE CORONAGRAPH	6.7	3.7	1.5	1.5	1	1	
82010101	TOPGHY AAP-LEM SITE	-	-	-	-	1	1	Orbital experiment
82010102	ENG PROP LUNAR SURFC	2.0	-	2.0	-	1	-	
82010103	SOIL SURF BEAR STREN	1.0	0.4	0.2	0.4	1	1	
82010104	CORROSION TEST	1.0	0.1	0.7	0.2	1	1	
82010105	LUNAR SOIL SHIELDING	13.0	7.5	3.0	2.5	1	1	
82010106	NUCLR REACT EMPL ASSMT	10.0	1.0	6.0	3.0	1	1	
82010107	SEISMIC ENVIRONMENT	1.0	1.0	-	-	-	1	
82010108	SUPT PROP LUN SOILS	5.0	3.0	1.0	1.0	1	1	
82010109	ELEC PARMTR SURF + SUB	14.0	11.5	2.0	0.5	1	1	
82010122	LUNAR STRATA E/M PRO	7.5	4.0	2.5	1.0	1	1	
82010201	DUST ENVRMT/SURFACE	2.0	1.5	0.5	-	1	1	
82010202	LUNAR RF NOISE PT 1	10.0	5.0	3.0	2.0	1	1	
82010203	LUNAR RF NOISE PT 2	6.5	5.0	1.0	0.5	1	1	
82010204	ANTENNA DUST ACCUMLN	2.0	1.4	0.2	0.4	1	1	
82010205	LUN ATM CONTAM-ROCKT	0.8	0.4	0.2	0.2	1	1	
82010206	THRML RAD FLUX + GRAD	2.0	1.1	0.2	0.7	1	1	
82010207	LUNAR IMPACT SPHERICS	2.4	1.9	0.5	-	1	1	
82010208	LEAKAGE MEASUREMENTS	0.8	0.4	0.2	0.2	1	1	
82023202	RF FRWD SCATTER TECH	5.0	2.0	2.0	1.0	1	1	
82023413	ENV EFFECTS/SOL CKTS	0.2	0.2	-	-	-	1	
82032001	CLINICAL MONITORING	14.0	1.0	6.0	7.0	1	1	Laboratory program
82032002	MECH EFF MAN RED GRV	4.0	1.0	2.0	1.0	1	1	
82032003	WORK CAPABILITY	2.0	0.3	1.0	0.7	1	1	
82032004	BIOASSAYS-BODY FLUID	21.0	12.7	8.3	-	1	1	Laboratory program
82032005	VISION STUDIES	0.5	-	0.5	-	1	1	
82032006	PSYCHOLOGICAL STUDY	20.0	3.0	14.0	3.0	1	1	Laboratory program
82032010	CARDIOVASCULAR PHENO	55.0	-	45.0	10.0	1	1	Laboratory program

Table 13. Experiment Man-Hour Summary (Cont)

Experiment Number	Experiment Title	Total Man-Hours for Experiment	Activities Included in Total Man-Hours			Replications of Activities in Totals		Remarks
			Setup and Takedown	Data Gathering or Sampling	Analysis	Data Gathering or Sampling	Setup and Takedown	
82032011	BONE DEMINERALIZATION	55.0	-	50.0	5.0	1	1	Laboratory program
82033001	EVALUATION ALGAE STR	210.0	8.0	130.0	72.0	1	1	Laboratory program
82033002	SOIL USE/HIGHER PLNT	140.0	20.0	100.0	20.0	1	1	Laboratory program
82033003	EVAL HYDROGENOMONAS	210.0	15.0	120.0	75.0	1	1	Laboratory program
82033004	EFF BREATH MIX GAS	23.0	-	18.0	5.0	1	1	Laboratory program
82033005	BIO MON ECO SYSTEM	10.0	3.0	5.0	2.0	1	1	Laboratory program
82033006	EVAL H-C USING ORGNM	110.0	12.0	83.0	15.0	1	1	Laboratory program
82033007	EFF LUNR COND ON PLT	85.0	18.0	61.0	6.0	1	1	Laboratory program
82033008	PLANT GRTH DEV REPRO	500.0	20.0	330.0	150.0	1	1	Laboratory program
82033009	GENETIC EFF/ANIMALS	100.0	12.0	60.0	28.0	1	1	Laboratory program
82033010	ANIML GRTH DEV REPRO	500.0	20.0	330.0	150.0	1	1	Laboratory program
82043101	SIM PERS SHLD/SOLAR	0.2	-	0.2	-	1	1	
82043201	LUNAR ENV ON ANT SYS	3.0	1.5	1.2	0.3	1	1	
82043203	RF GRD WAVE PRPGTION	8.0	1.9	5.0	1.1	1	1	
82043204	RF SUBSURF PROPGTION	11.0	3.5	4.5	3.0	1	1	
82043205	LASER SCATTER PROP	4.0	2.0	1.5	0.5	1	1	
82043206	RETRODIR OPT SYS TEC	1.0	-	1.0	-	1	1	
82043301	ELEC TRANS LINE TEST	2.0	1.0	0.5	0.5	1	1	
82043302	ELEC TRANS ROUTE	6.0	2.0	2.5	1.5	1	1	
82043310	ELEC SYST GROUNDING	2.0	1.2	0.5	0.3	1	1	
82043401	DUST REMOVAL TECHCQS	1.0	-	1.0	-	1	1	
82043402	DAMAGE LUNAR EQUIPMT	3.0	-	2.5	0.5	1	1	
82043403	STAT XPOS EFF ON MAT	0.5	0.5	-	-	1	1	
82043404	XPOS EFF ON RAD MAT	1.5	0.5	-	1.0	1	1	
82043405	MATER DYN TEST	20.0	6.5	10.5	3.0	1	1	
82043406	DYNAMIC TEST MACHN ELEC	2.0	0.5	0.5	1.0	1	1	
82043407	DYNAMIC TEST THIN FLM	2.0	0.5	0.5	1.0	1	1	
82043408	DYNAMIC TEST ELE CMPT	1.0	0.4	0.3	0.3	1	1	
82043409	LNG STAT XPOS ON MAT	3.0	0.5	0.5	2.0	1	1	
82043414	ELSTME POLYMR DEGRD	2.0	0.5	0.5	1.0	1	1	
82043415	STATIC/DYNAMIC SEALS	1.5	0.4	0.4	0.7	1	1	
82043501	EFCTS LONG BOOM STRU	2.0	0.5	1.0	0.5	1	1	
82043502	REPR TECH MAJR STRUC	3.0	1.0	1.0	1.0	1	1	
82045001	CONV HT TRANS IN LIQ	10.0	1.5	6.0	2.5	1	1	
82045002	HT XFR FILM/DRP COND	10.0	1.5	6.0	2.5	1	1	
82045003	STRATIF CRYOGEN LIQ	-	-	-	-	-	-	Automatic data recording
82053601	SOIL VAL VARI LUNAR	6.2	2.1	2.5	1.6	1	1	
82053602	DANG TERRAIN WARNING	2.0	-	2.0	-	1	-	
82053701	VIS TECH ASTRO VIS	4.3	0.5	2.5	1.3	1	1	
82053702	VIS TECH LAND RECOG	3.3	0.3	2.2	0.8	1	1	
82053901	XPLOS TECH SURF MOD	10.0	4.0	4.5	1.5	1	1	
82053902	DIG AND CUT TOOL ASSESS	-	-	-	-	-	-	Automatic data recording
82054001	METL JOIN LUNA CONST	18.0	9.3	5.5	3.2	1	1	
83064101	H DETECT BY NEUT ACT	5.0	1.0	3.0	1.0	1	1	
83064102	CHEM AND DTA ANALS-O AND CO2	10.0	1.0	8.0	1.0	1	1	
83064103	DTA ANAL CASTABLE MAT	10.0	1.0	8.0	1.0	1	1	
83064104	H WITH PHO 5 COND	4.0	0.6	3.0	0.4	1	1	
83064105	QUANT ANAL OF HYDROG	4.0	0.6	3.0	0.4	1	1	
83064106	H DETECT BY IR SPECT	40.0	6.0	30.0	4.0	1	1	
83064107	H DETECT AND ANALYSIS	-	-	-	-	-	-	Related to experiment 83064101
83064201	CHARAC LUNAR SLF WLDG	4.5	1.2	2.6	0.7	1	1	
83064303	PART ADHESN MECH FRC	24.0	9.0	11.0	4.0	1	1	
83064501	DRY CEMNT-CONCRT APP	51.0	20.0	25.0	6.0	1	1	
	MISCELLANEOUS BASIC AND APPLIED RESEARCH							
90010101	HI INT ELEC BEAM GEN	20.0	8.0	9.0	3.0	1	1	
90010201	HI INT ARC GENERATN	15.0	6.0	7.0	2.0	1	1	
90020101	FIELD EMISSION OPTCS	15.0	4.7	8.0	2.3	1	1	
90030101	RADIATION CRYOSTAT	20.0	10.0	7.0	3.0	1	1	
90030201	SLR FRNC/FCL ENG FLX	15.0	8.0	6.0	1.0	1	1	
90030301	HT XFR/CONVECN GASES	3.0	1.5	1.0	0.5	1	1	
90040101	ATOMIC SPECIES LIFE	70.0	31.0	27.0	12.0	1	1	
90050101	LORENTZ PLSMA MEAS	4.0	1.0	2.0	1.0	1	1	
90050201	CRNR RFLR LASER BEAM	0.4	0.4	-	-	-	1	

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5.6 EXPERIMENT OPERATIONS INTEGRATION

The integration of scientific experiment and support operations is an important aspect of lunar exploration mission planning. To facilitate this application, each experiment description in the experiment data management system includes man-hours, equipment location, mass, power, operating time, required egresses from the shelter, and other operational and support parameters required to perform the experiment independently of other experiments. No allowance is made for common use of equipment items or support that could be shared among several experiments (except for "key items" - see Section 7.5).

Certain of the operational support requirements were assumed to be provided by the lunar shelter, surface vehicle, or the landing vehicle and, therefore, are not included in experiment summaries. These support requirements are: a source of electrical power for the shelter or surface vehicle-located equipment, environmental control equipment, and communications equipment for communications between the surface vehicle or shelter and the next station of the communication chain.

Experiment operations integration is most sensitive to time and weight, particularly during the early exploration phases where scientific manpower and equipment weight are most restricted. The type of operations that require the greatest depth of planning will probably be those connected with spacesuit activities, egresses from the lunar shelter, and vehicle traverses away from the lunar shelter.

Other subjects to be considered in the experiment operations integration include scheduling of experiments for maximum use of the equipment on the lunar surface, scheduling of experiments to prevent simultaneous operation of high power consumption experiments, phasing of experiments with high real-time data transmission requirements, and phasing equipment operations and locating the equipment to avoid electromagnetic or other interferences. Techniques of integration involving linear programming, simulation modeling, and scheduling are available for use in experiment integration and mission planning.

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6.0 SYSTEMS AND SUBSYSTEMS

6.1 ASTRONAUT LUNAR CAPABILITIES

6.1.1 INTRODUCTION

The use of humans in the performance of scientific investigations and experiments and in mission support activities is a prime requirement in the planning of lunar missions. Man's unique capabilities more than justify his inclusion in the program. Concomitantly, his capabilities and limitations will be a major factor in the definition of experiments, the design and sizing of equipment, and the development of operational procedures as well as in mission formulation and systems support.

Major considerations governing the development of work programs for astronauts performing scientific missions arise from interactions among task requirements, reduced traction, suited performance decrements, and their combined effect on astronaut performance capabilities and characteristics. During lunar operations, the astronaut will be required to perform in environments which previous experimentation has demonstrated produce significant decrements in the productivity, capability, and efficiency of operators. Experimental evidence is available which indicates that human performance may be adversely affected in reduced traction and/or pressurized, suited environments.

6.1.2 ASTRONAUT SURFACE MOBILITY

Generally, it may be assumed that the major portion of astronaut energy expenditures may be assigned to two categories: (1) those expenditures attendant to the transport of the astronaut and ancillary equipment to and from various work areas and (2) those attendant to the execution of required work tasks. (Also, in the event of emergency operations, to those tasks directly related to walk-back capability.) For AAP missions, walk-back capability is required for LSSM-supported operations, nominally identified for a radius of 8 kilometers. Reference 6 identifies the presently estimated walk-back capability as 3.2 kilometers. Reference 6 also relates the percentage of a MOLAB mission that can be safely accomplished to astronaut walk-back capability (Figure 14).

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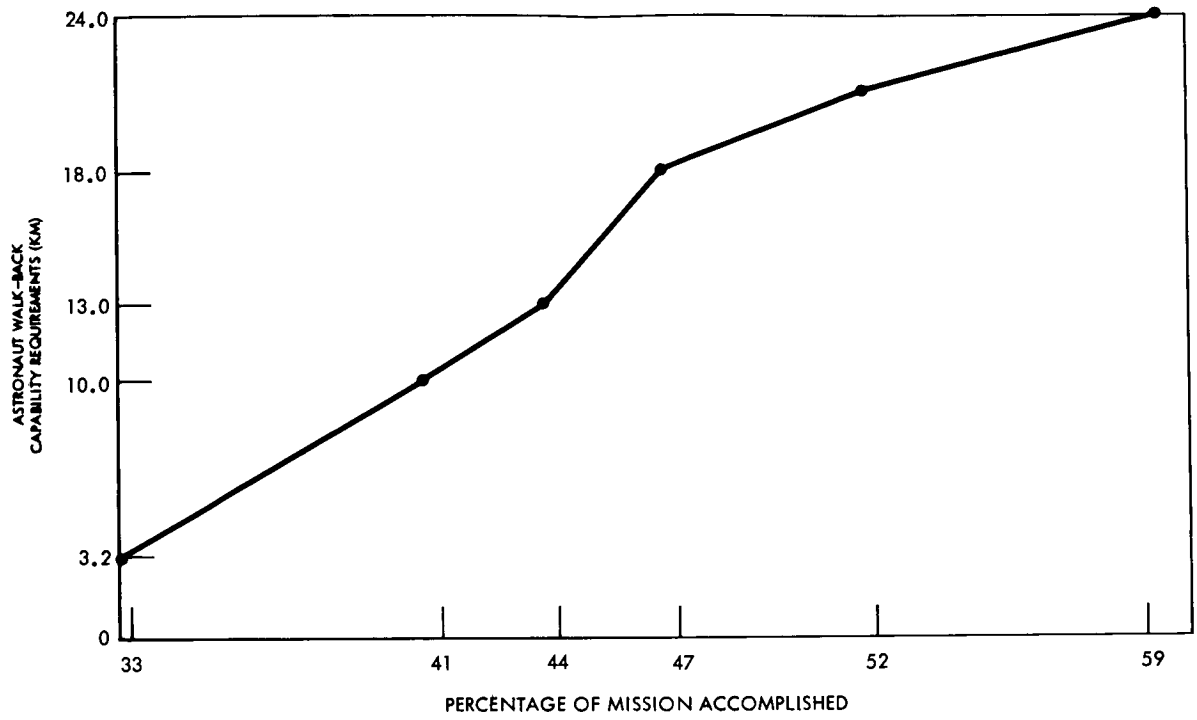

Figure 14. Required Astronaut Walk-Back Capability Versus Percentage of Mission Accomplished for MOLAB (Reference 6)

Although the literature is replete with studies that involve investigations relating to the output characteristics of walking men on a variety of surfaces under normal terrestrial conditions, the results of only two studies are available which have investigated walking characteristics in reduced traction environments. The results from these two studies are almost diametrically opposed, with one investigator reporting significant increases (Reference 7) and the other investigator reporting significant decreases (Reference 8) in the energy costs of walking in reduced traction environments. It should be noted, however, that in the experiment that reports increased walking efficiency in reduced traction environments, impairments were observed in walker directional stability. These impairments seemed directly related to the traction provided the subject, and alterations of normal walker gait and characteristics appeared. Biomechanical studies (Reference 9) in the prosthetics area have long indicated that alterations in natural characteristics of human movements inevitably reduce the efficiency with which the movements are effected. Therefore, at this time, experimental results simultaneously indicating increased walking efficiency in reduced traction environment and decreased directional stability, coupled with gait alterations, may be accepted with reservations until future clarification of these anomalies.

The earliest investigations of operator capability in pressure suits have been confined, for the most part, to examinations of operator output

characteristics during walking. The experimental evidence available indicates that pressure suits may be expected to increase energy expenditure by a minimal factor of three (References 10, 11, 12, 13, and 14). This increase has implications to system designers and mission planners that cannot be overlooked, as will be discussed later. The foregoing data do not include the latest results from evaluations of the Latex high mobility soft suit or the Litton hard suit; therefore, they may be somewhat pessimistic.

Table 14 and Figure 15 show an increase in average consumption of oxygen from 0.63 to 0.85 to 2.35 for shirtsleeve, unpressurized suit, and pressurized conditions, respectively.

Table 14. Treadmill Walking - 1 Mile Per Hour and Zero-Degree Incline, Oxygen Consumption (Liter/Min) for Four Subjects (References 6 and 11)

Oxygen Consumption (Liter/Min)								
Shirt Sleeve Environment	Unpressurized Suits				Pressurized Suits (3.5 psig)			
	Suit A	Suit B	Suit C	Average	Suit A	Suit B	Suit C	Average
0.63	0.74	0.79	1.03	0.85	1.75	2.36	2.94	2.35

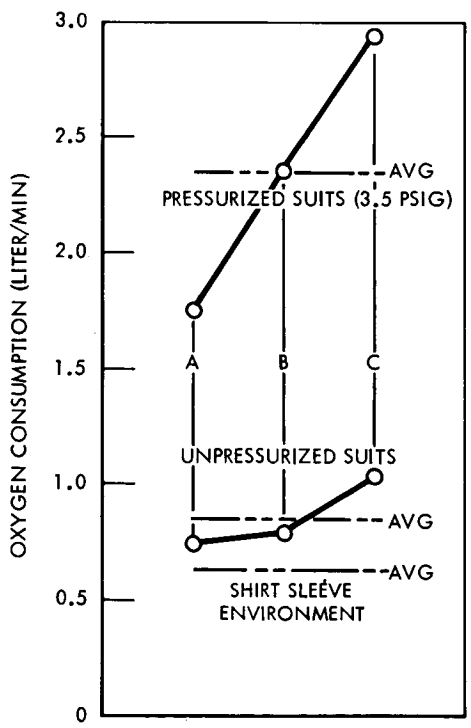

Figure 15. Treadmill Walking - 1 Mile Per Hour and Zero-Degree Incline, Average Oxygen Consumption Values for Four Subjects (References 6 and 11)

It becomes apparent that with respect to activities attendant to the transport of the operator and ancillary equipment to and from various work areas, many questions concerning astronaut fatigue and subsequent work capabilities and, concomitantly, walk-back capability remain unanswered. Some of the implications of these unanswered questions are discussed in Section 6.2.

6.1.3 WORK CAPABILITY

In studying work task effort, consideration must be given to the effects of reduced gravity and pressure suits on the work output characteristics of the human operator performing manual work. Experimental data relating to man's capabilities during the performance of manual work in such environments are more abundant and consistent with each other. Several investigators utilizing a variety of simulation systems have investigated the efficiency, productivity, and capabilities of operators during the performance of manual tasks in reduced traction or nontractive environments. Available evidence demonstrates that the progressive removal of traction produces progressively larger decrements in operator force and work producing capabilities (References 12, 13, and 15 through 21) resulting in capability degradations which are sufficiently large to require reevaluation of present concepts of system sizing and mission task requirement planning.

Decrements have been manifested, singly or in combination, as reductions in force (References 12, 15, 16, and 22) and work producing capabilities (References 10, 12, and 22); as increases in the physiological costs of work (References 10, 11, 12, 13, 14, and 23); and as increases in total task accomplishment times (References 11, 12, and 24). In one series of experiments, increases in energy needs of 30 to 70 percent were found which were correlative with decreasing levels of traction and stability provided the worker during the performance of relatively simple, normally low-energy expenditure tasks (References 11, 12 and 19).

Metabolic work costs for raising and lowering weights on a pulley via flexion/extension cycling of the arm while in normal reduced traction environments are given in Table 15.

Figure 16 presents horsepower output of work produced manually under conditions of varying traction. Figure 17 presents the relationship of energy expenditure to horsepower output during the performance of manual work in varying reduced traction environments. Figure 18 presents the percentage increases in energy expenditure per horsepower develped as a function of decreasing traction.

Table 16 presents a comparison of mean values of worker output and requirements versus reduced traction expressed as 0, 1, 2, 3A, 3B, and 4 degrees of freedom. For these purposes, 0 indicates normal traction; 1 degree of freedom is associated with the action of a horizontal reciprocating platform; 2 degrees of freedom denote bi-directional translation with no rotation; 3A degrees of freedom denote bi-directional translation plus rotational yaw; 3B degrees of freedom denote bi-directional translation plus rotational roll; 4 degrees of freedom denote bi-directional translation plus yaw and roll.

Table 15. Metabolic Work Costs (Reference 18)

METABOLIC COST FOR 7-POUND LOAD (10-MINUTE WORK PERIOD) (Subject Population Equals 14)			
	Mean (liters O_2/min/hp)	Standard Deviation	Range (liters O_2/min/hp)
Tractive	36.7	6.5	28-49
Nontractive	41.2*	5.1	33-50
*12 percent mean difference significant at 0.01 level of confidence			
METABOLIC COST FOR 15-1/2-POUND LOAD (10-MINUTE WORK PERIOD) (Subject Population Equals 10)			
Tractive	29.8	3.9	25-37
Nontractive	38.6*	5.9	32-50
*29 percent mean difference significant at 0.001 level of confidence			

Forces produced by operators during manual tasks in the NAA six-degree-of-freedom simulator are given in Table 16. These performance degradations have been attributed previously (References 25 and 26) to worker energy investments into activities required to produce forces necessary for satisfaction of the conditions of equilibrium, i.e., forces normally produced by gravity when work is performed in normal traction on Earth.

The preceding data indicate the following: if lunar-worker output requirements include the development of meaningful amounts of manual force

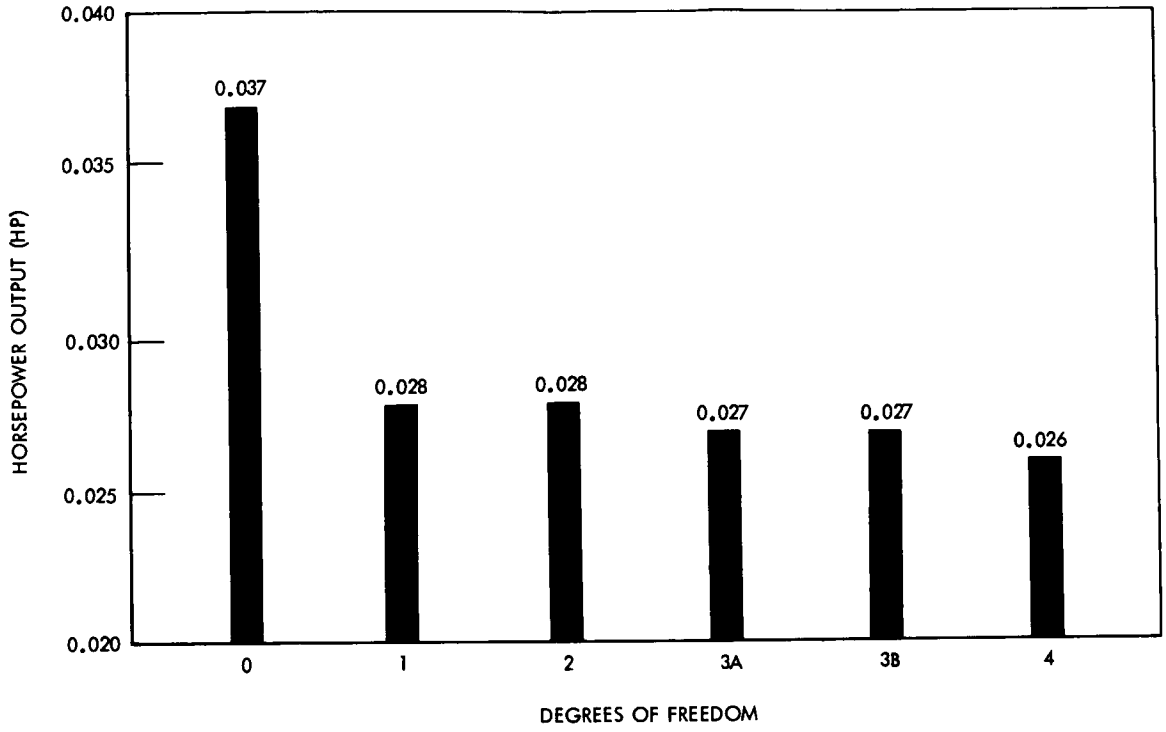

Figure 16. Horsepower Output Versus Degrees of Freedom (Reference 19)

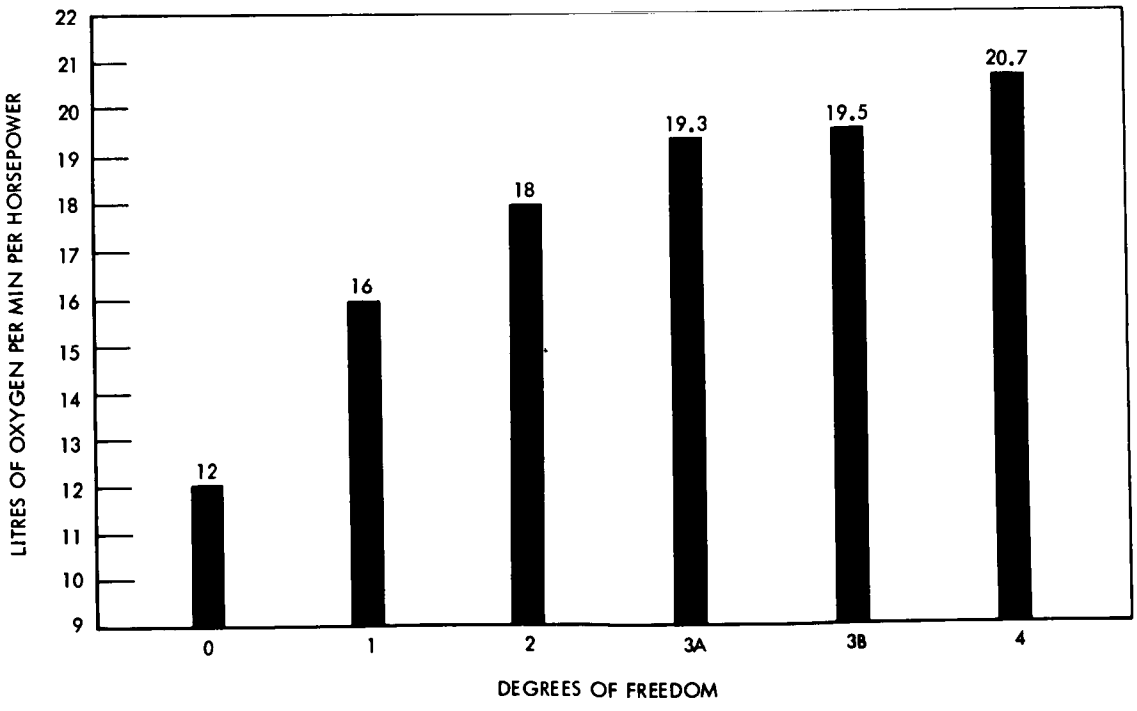

Figure 17. Oxygen Consumption Versus Horsepower Output as Affected by Degrees of Freedom (Reference 19)

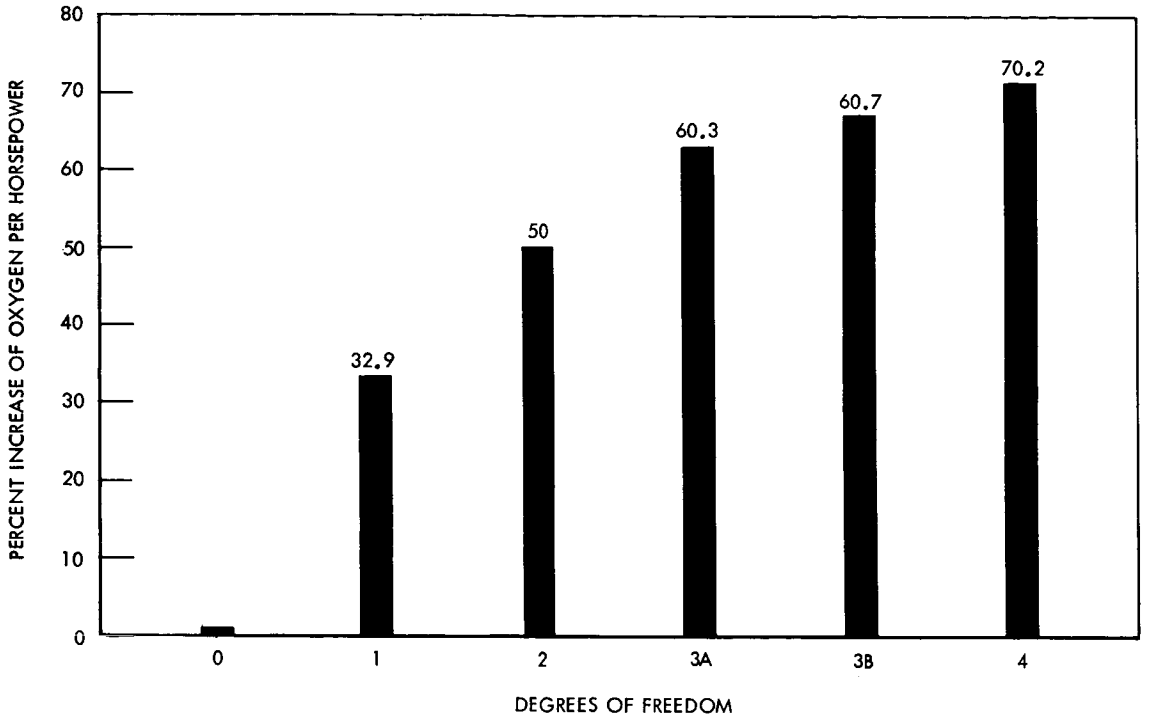

Figure 18. Increase of Oxygen Consumption per Horsepower as Affected by Tractive Condition (Reference 19)

Table 16. Statistical Analysis: Comparison of Means*

HORSEPOWER OUTPUT**						
	Experimental Conditions					
	0	1	2	3A	3B	4
Mean	0.0	0.028	0.028	0.027	0.027	0.026
Difference from "0" Experimental Condition		0.009	0.009	0.01	0.01	0.011
LITERS OF OXYGEN/MIN/HORSEPOWER**						
Mean	12.11	16.02	18.11	19.41	19.77	20.56
Difference from "0" Experimental Condition		3.91	6.00	7.30	7.66	8.45
Difference from "1" Experimental Condition			Not Significant	3.39	3.75	4.54

*Duncan Multiple Comparison Test, Edwards AFB, Experimental Design in Psychological Research, New York: Holt, Rinehart, and Winston (1960) pp 136-140.

**All other comparisons not significant at 0.05 level of confidence.

and work, then a bracing/restraint system must be provided to produce either a fixed man/loose object or a fixed man/fixed object configuration.

In previous investigations, configurations which are necessary to the development of nonimpulsive force and work outputs have been achieved via operator produced forces, usually obtained through isometric muscular activity with consequent losses in overall operator efficiency and productivity. Maximum efficiency in bracing/restraint systems is obtained when applied and reactive forces lie in the same plane and along the same line of action. Efficiency decreases when a deviation to the foregoing condition occurs.

If the establishment of fixed man/fixed or loose object configurations is achieved through the incorporation of external bracing/restraint devices into the overall man-object configuration, additional problems develop that may significantly affect the design of scheduled work cycles. In work cycles that may proceed through both a variety of functions and a diversity of work areas, the attainment of the desired man-object configurations may necessitate installation, removal, and reinstallation of the bracing/restraint devices as the operator proceeds through the programmed cycle of activities. This action necessitates interruption of productive work while the operator adjusts or reinstalls the bracing restraint devices, which results in prolonging the total work-accomplishment time. It is reasonable to assume that equipment configurations, operational requirements, anthropometric factors, etc., will make it difficult to attain an ideal bracing restraint configuration each time a task is attempted.

Experimentation previously cited has examined worker output characteristics in loose man/fixed or loose object configurations in which some portion of the operator energy expenditures has been invested in generating net, work-producing mechanical forces and in overcoming the friction and inertia of the simulation system. In these systems, while most of the operator energy is invested in the production of useful work, some small, and as yet undetermined portion is expended in overcoming normal gravitational effects in activities that tend to produce yaw, pitch, roll, vertical translation, or their combinations.

Experimental evidence exists indicating that impairments in operator capability caused by pressurized suits override all other considerations. These impairments have been manifested as reductions in operator mobility and manual dexterity (References 24 and 27), work and force producing capabilities (References 11 and 12), operator efficiency (References 14 and 23), etc. Increases of 400 percent in task accomplishment times solely attributable to wearing pressurized suits have been reported (Reference 21).

Table 17. Forces Produced Under Experimental Conditions (Reference 20)

TASK	SIMULATOR-MAN TOTAL WEIGHT (LB)																			
	730				805				880				955				MAN IN NORMAL TRACTIVE CONDITION			
	TOTAL WEIGHT/WEIGHT OF MAN ONLY																			
	4.056:1				4.472:1				4.889:1				5.306:1				180 LB-MAN WEIGHT (AVERAGES)			
	CW		CCW		CW		CCW		CW		CCW		CW		CCW		CW		CCW	
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
WHEEL ROTATION (DIAMETER)	TORQUE (FT-LB)																			
21 IN.	87.6	5.6	89.6	15.2	85.4	6.8	90.3	13.7	89.9	10.3	94.2	16.8	90.4	15.1	92.2	15.2	117.9	13.7	124.8	10.9
12 IN.	59.3	9.2	61.6	10.2	59.6	9.8	62.1	8.3	60.0	10.4	62.6	8.7	62.1	5.2	62.7	7.6	69.1	11.1	71.5	9.6
6 IN.	30.2	5.7	30.5	5.1	31.1	4.5	30.7	4.1	31.2	6.5	31.8	5.2	30.9	5.6	31.4	3.9	33.3	5.1	33.8	6.8
SHAFT ROTATION (DIAMETER)																				
4 IN.	25.6	4.8	25.5	4.8	26.6	3.8	26.6	4.8	27.3	5.4	27.4	3.6	27.8	4.5	28.2	4.1	27.6	7.0	27.2	6.7
3 IN.	24.8	3.9	24.3	3.5	26.1	3.3	25.8	3.6	27.2	1.8	26.5	2.1	26.5	3.9	26.3	4.1	26.8	5.4	27.4	5.2
2 IN.	22.3	3.4	22.6	2.5	23.8	2.9	23.3	2.1	22.7	4.2	23.4	4.6	23.9	3.1	23.3	3.3	26.0	4.5	25.5	4.2

NOTE:
CW AND CCW REFERS TO CLOCKWISE AND COUNTER CLOCKWISE DIRECTIONS, RESPECTIVELY
$\bar{X}$ - AVERAGE VALUES
σ - STANDARD DEVIATION

While the foregoing factors are of considerable importance, an additional important factor in work cycle schedule development is the integration of degradations in performance characteristics into a schedule of work that maintains energy expenditure rates during self-paced work at a level sufficiently low to prevent oxygen debt formation. This is expected to result in selection of a maximum energy expenditure rate of approximately 1300 Btu/hr and a typical expenditure rate of approximately 800 to 900 Btu/hr (Reference 28). It is normally anticipated that operator efficiency ranges from 12 to 16 percent during the performance of manual work. If the operator efficiency levels (due to reduced traction and/or work performed in pressurized suits) are integrated conceptually with energy-expenditure-rate controls, it becomes obvious that designers of work schedules have to consider either a reduction in the operator workload or the allocation of more time. Either approach yields an increase in energy expenditure per unit work accomplished. Present system design concepts require provision of a supply of breathing gases sufficient to maintain the operator for four hours at an average energy expenditure rate of 1600 Btu/hr and a peak value of 2000 Btu/hr. As previously indicated, the mean value appears to be in excess of anticipated operator requirements while the peak value of 2000 Btu/hr is far below the requirements that can be engendered by man in an emergency state.

6.1.4 CONCLUSIONS

Further information is needed to assess the relative importance of representative aspects of the work schedule, based on the preceding considerations. As part of such study, an experimental program should be initiated to obtain quantitative data on the performance of workers during simulated mission activities while wearing pressurized suits in a one-sixth g environment. The following relationships must be determined:

1. The ratio of lunar to terrestrial task accomplishment times

2. The ratio of lunar to terrestrial operator work efficiencies

3. The ratio of lunar to terrestrial operator capabilities with reference to force and work-producing capability

4. The physiological cost of work in these environments as modified by;

    a. The nature of the astronaut suit

    b. The availability and nature of bracing/restraint devices

c. Breathing gas mixtures

d. Special tools

e. Terrain and other environmental considerations

In the absence of quantitative data on the above relationships, current predictions can only be based on the information presently available. Accordingly, on the basis of the discussion appearing in Section 6.1.3 and in Reference 9, it is recommended that a multiplication factor "K" of 4 should be applied in converting work task accomplishment time to lunar suited time. Correspondingly, it is recommended that approximately 1200 to 1300 Btu/hr be allowed for average energy expenditure and that rest periods be programmed. It is also estimated that force production capabilities can be no more than 50 to 60 percent of Earth values, and depending on the nature of the force requirement, considerably less production capabilities can be realized at times. Bracing/restraint systems that are more than momentary in nature must be provided during the production of work.

In Section 6.1.2, an energy expenditure increase of three was indicated for walking in a pressure suit. When walking on the lunar surface, the expenditure will be increased due to surface conditions and reduced gravity. It is conceivable that a time ratio of approximately 2:1 can be realized for walking short distances in the lunar versus Earth environments. For an energy expenditure rate of approximately 1600 Btu/hr, this time ratio cannot be sustained. Accordingly, extensive use of wheeled locomotion appears to be warranted to minimize walking expenditures.

Based on the foregoing discussions, an average time ratio of 3:1 (K factor of 3) is recommended to account for both walking and work tasks.

Finally, it appears that improvements in the astronaut pressurized suit and use of special aids will enhance astronaut effectiveness during lunar scientific missions.

6.2 MOBILITY IMPLICATIONS

6.2.1 DIRECT SUPPORT TO INVESTIGATIONS

Mobility is a vital capability for supporting lunar exploration. The basic areas of application for mobile support systems are as follows:

1. Surface locomotion or rocket-propelled surface-to-surface transportation of men and equipment

2. A capability for mission abort or rescue

3. Power, environmental control, and data systems, a platform for mounting instruments and functional equipment such as drill subsystems, and other investigation support capabilities

4. Augmentation of life-support capabilities for local exploration

5. Environmentally controlled facilities for laboratory operations, crew support, and navigation and control for extended exploration

6. A capability for off-loading and deploying equipment

7. A capability for surface modification

8. Support of mining and materials handling operations.

Table 18a presents the distribution of mobility requirements specified for the experiments compiled in this study, within each of the ten Discipline Areas. The heading "None" relates to experiments that do not require direct surface mobility support, including those that are performed in lunar orbit and those that are performed exclusively in the shirtsleeve environment of a lunar shelter. The heading "Walk" refers to requirements for on-foot movement by a suited astronaut, ranging from airlock egress/ingress to kilometer-level movements across local lunar terrain. The heading "LSSM" represents requirements for short-range, open-cabin mobility support within a geological area of approximately an 8-km radius. It also represents duration requirements that can be satisfied by life support extension with additional backpack(s). The designation "Rover" represents requirements for mobility support by a closed-cabin, long-range surface vehicle encompassing a spectrum of potential surface traverses ranging from 100 to 1600 km, lasting 14 to 90 days, and involving two to three men. Mobility requirements for the deployment of a long-wave radio telescope and a 100-inch

horizontal telescope system are special construction requirements and are discussed in Sections 6.3 and 6.4, respectively. The requirements reflected in Table 18a include only those requirements in direct support of the experiments.

Table 18a. Specified Mobility Requirements Distribution

Discipline Area	Specified Mobility Requirements					
	None		Walk	LSSM	Rover	Combination of Vehicles
	Surface, Indoors	Orbit				
Lunar Atmospheres	0	0	2	2	2	0
Geodesy	0	2	0	0	0	5
Geology	0	2	4	2	2	4
Geochemistry	10	4	0	1	1	7
Geophysics	0	10	42	18	23	1
Particles and Fields	0	3	33	2	9	0
Biology	5	0	1	1	0	0
Astronomy	0	3	29	1	4	0
Mission Support Investigation [1]	26	6	27	30	3	0
Miscellaneous Basic and Applied Research	0	0	7	1	1	0
Totals	41	30	145	58	45	17

[1] Four experiments relating to Earth-based analyses of data obtained from other experiments are not included. These experiments require no support on lunar surface. See Table 8 Experiment Summary Information (SMS-ELE), page 137.

It is important to note that the ground rule for specifying mobility requirements was to indicate the lowest level of mobility required for the performance of each experiment. As will be discussed in the following text and under Astronaut/Vehicle Implications, the designated mode is not necessarily the optimum approach. In general, the LSSM mobility requirements heading indicates an early exploration phase activity. However, possible applications for the LSSM in extended exploration also are indicated in the experiment compilation presented in Volume 5 (Appendix B) and under Experiment Descriptions (Sections 2.8 and 3.5) in this volume. Requirements for the larger surface vehicle of the Rover class imply investigations to be performed in later phases of extended lunar exploration. The title "Combination of Vehicles" used in the Experiment Data System identifies mobility requirements for local (LSSM-type) support in the early exploration phase and extension of the scope of the same experiments in the extended

exploration phases, using a Rover when available. This same heading is employed in Table 18a. The only case in which vehicles are defined as being used simultaneously in "combination" (in the sense of "working together") is in the erection of a long-wave radio telescope (Section 6.3).

Table 18a classifies the mobility requirements specified under Experiment Summary Information (Tables 5, 8, and 9) of this volume. These, in turn, are based on the experiment Type-1 card printouts in Volume 4, with the exception of two experiments: 78070103, and 78070104, "Cislunar Wave Propagation" and "Advanced Outlying Station A and B," respectively. These experiments were encoded as requiring a Flying Vehicle, but were summarized in Table 18a as "Flying Vehicle or Rover" to indicate alternatives, and were included in Tables 18a and 18b as "Rover" requirements.

Table 18b presents mobility requirements for experiment support in terms of two alternate criteria: minimum mobility, and the mobility capability that provides for the most effective performance of each experiment. The "Minimum Mobility" portion was obtained by transferring the specified "Combination of Vehicles" requirements to "LSSM" requirements. The requirements for "Most Effective Mobility" were derived by reviewing each experiment individually and identifying the mobility mode for the most effective performance, from either the standpoint of efficiency of performance or scope of data to be derived. Under the latter criterion, the previous "Combination of Vehicles" requirements are logically expressed as "Rover" requirements. The experiments that can be performed better or more effectively by means of a more advanced mobility mode are listed in Table 19.

A brief review of mobility requirements by discipline area follows.

In Lunar Atmospheres, two of the experiments are identified for performance at the initial landing site as a part of the ALSEP. Two other experiments are identified for performance in the early exploration phase as a part of the ESS. By definition, ALSEP experiments do not require vehicle mobility support. The two ESS experiments require LSSM support. The other two of the six Lunar Atmospheres experiments already call out Rover support. Consequently, the specified mobility support requirements are unaffected by the alternate criteria.

Two of the seven Geodesy experiments are performed from orbit and, therefore, have no surface mobility requirements. The other five experiments that involve areal surface measurements are recommended for performance in all exploration phases. Consequently, both the LSSM and Rover are used, each in the appropriate phase. This is reflected in Table 19 by the LSSM listing for minimum mobility and the Rover for most effective mobility.

Table 18b. Mobility Requirements Comparison

Discipline Area	None Required	Minimum Mobility			Most Effective Mobility		
		Walk	LSSM	Rover	Walk	LSSM	Rover
Lunar Atmospheres	0	2	2	2	2	2	2
Geodesy	2	0	5	0	0	0	5
Geology	2	4	6	2	1	1	10
Geochemistry	14	0	8	1	0	1	8
Geophysics	10	42	19	23	37	21	26
Particles and Fields	3	33	2	9	30	2	12
Biology	5	1	1	0	0	1	1
Astronomy	3	29	1	4	26	4	4
Mission Support Investigation [1]	32	27	30	3	18	22	20
Miscellaneous Basic and Applied Research	0	7	1	1	5	3	1
Total	71	145	75	45	119	57	89

[1] Four experiments relating to Earth-based analyses of data obtained from other experiments are not included. These experiments require no support on lunar surface. See Table 8 Experiment Summary Information (SMS-ELE), page 137.

The Geology area includes two orbital mapping experiments and one surface experiment (on-site deep drilling) that do not require mobility support beyond the "walk" mode. To be most effective the other 11 geological exploration experiments use areal operations as shown in Table 18b under most effective mobility (LSSM and Rover). Four of these areal-type surface experiments, including sample collection, age dating, and geologic surface mapping, are defined for performance in all exploration phases. Thus, LSSM and Rover requirements ("Combination of Vehicles") are indicated for each of these experiments. Formation Stratigraphic Correlation and Subsurface Sampling require support of drilling (10 to 30 meters), coring, core sample analysis (in the vehicle laboratory), and logging at selected sites along traverse routes, thus requiring a Rover. Table 19 identifies the specific geology experiments that are performed more effectively with a Rover. Table 18b pointedly indicates the desirability of a Rover for support of geological exploration of the Moon.

Requirements for long-range traverses in lunar exploration, posed by the Space Science Board in the summer study at Woods Hole (Reference 1) include the following:

Table 19. Mobility Changes for Most Effective Mobility Support

Experiment Number	Title (Abbrev.)	Specified Mobility	Most Effective Mobility
	LUNAR ATMOSPHERES		No Changes
	GEODESY		
11010101	Selenodetic Astronomy Observations for Improving Map Accuracy	Combination of Vehicles	Rover
11010505	Earth-Moon Distance Observations for Determining Librations, Etc.	Combination of Vehicles	Rover
12010202	Selenodetic Surveying to Establish Ground Control for Satellite Mapping	Combination of Vehicles	Rover
13030303	Gravity Measurements at Lunar Surface to Supplement Surveying Observations	Combination of Vehicles	Rover
13040404	Seismic Measurements to Supplement Gravity Observations	Combination of Vehicles	Rover
	GEOLOGY		
21010203	Detailed Mapping of Lunar Surface Geologic Fine Structure	Combination of Vehicles	Rover
21010204	Geologic Mapping General, Including On-Site Verification of Features Identified From Orbital Experiments	Combination of Vehicles	Rover
21010309	Sample Collection From all Sites and Traverse	Combination of Vehicles	Rover
24030310	Age Dating of Lunar Rocks and Formations	Combination of Vehicles	Rover
21040205	Surface Photogeology on Traverse Routes	Walk	Rover
21040411	Visual Subsurface Logging for Fine Structure	Walk	Rover
24030413	Paleomagnetism of the Moon	LSSM	Rover
23010320	Sample Collection	Walk	Rover
	GEOCHEMISTRY		
32010101	Chemical Analysis Using Neutron Activation	Combination of Vehicles	Rover
34010402	Mass Spectrometric Analysis of Gases on Lunar Surface	Combination of Vehicles	Rover
33010101	Gamma-ray Spectrometry on Traverse	Combination of Vehicles	Rover
32010118	IR Reflectance and Emmissivity In Situ	Combination of Vehicles	Rover
32010115	UV and Visible Reflectance Spectra In Situ	Combination of Vehicles	Rover
32010114	Mineralogical Study With X-Ray Diffractometer In Situ	Combination of Vehicles	Rover
32010113	Density Measurements by Gamma Scattering In Situ	Combination of Vehicles	Rover
	GEOPHYSICS		
40010101	Seismic Velocity, Surface	Walk	LSSM
40010102	Seismic Velocity, Subsurface Logging	Combination of Vehicles	Rover
46040619	Magnetic Field Components	Walk	LSSM
40010103	Seismic Profiling, Shallow Reflection	Walk	LSSM
46040619	Magnetic Field Components	Walk	LSSM
41040681	Electrical Surveying, Earth Current	LSSM	Rover
40130773	Natural Radioactivity at Diff. Lunar Locations	Walk	Rover
	PARTICLES AND FIELDS		
53070102	Vertical Comp. of Electrostatic Field	Walk	Rover
53040101	Electrons Escaping Earth Auroral Zones During Geomagnetic Storms	Walk	Rover
53040102	Electrons Escaping Earth Auroral Zones During Geomagnetic Storms, Later Solar Activity	Walk	Rover
	BIOLOGY		
61040102	Evidence of Existing Life	LSSM	Rover
	ASTRONOMY		
75040101	Nondirectional Radio Astronomy	Walk	LSSM
78070101	Cislunar Wave Propagation, Study of Medium	Walk	LSSM
77070101	Lunar Ambient Vector Magnetic Field Measurements	Walk	LSSM
	MISSION SUPPORT INVESTIGATIONS		
82010102	Engineering Properties of Lunar Surface	Walk	LSSM
82010201	Lunar Surface Dust Environment	Walk	LSSM
81021103	Calibration of Remote Sensing Techniques	LSSM	Rover
81021102	Lunar Drill Bit Technology	LSSM	Rover
81021101	Gas Requirements for Lunar Core Drilling	LSSM	Rover
81021203	Explosive Energy Coupling	LSSM	Rover
82053901	Explosive Tech. for Surface Modifications	LSSM	Rover
83064101	Detect. of Hydrogen, Neut. Activ.	LSSM	Rover
82010208	Effects of Leakage	Walk	Rover
82053602	Dangerous Terrain Warning Tech.	LSSM	Rover
82010109	Lunar Surf. and Subsurf. Elect. Param.	LSSM	Rover
82043501	Dynamics - Long Antenna Structures	Walk	LSSM
82010204	Antenna Dust Accum.	Walk	LSSM
82043203	RF Ground Wave Propagation	LSSM	Rover
82023202	RF Forward Scatter Techniques	LSSM	Rover
82010105	Radiation Shielding - Soil	Walk	LSSM
82010108	Shelter Shielding and Construction - Soil	LSSM	Rover
82043301	Lunar Surface Trans. Line	Walk	LSSM
82043402	Damage to Lunar Equipment	Walk	LSSM
82010206	Thermal Radiation Intens.	LSSM	Rover
82043201	Lunar Environ. Effects - Antenna	LSSM	Rover
82010122	Lunar Strata Propagation	LSSM	Rover
83064201	Char. of Lunar Ores - Self-Welding	LSSM	Rover
83064303	Particle Adhesion in Mech. Process	LSSM	Rover
82010207	Lunar Impact Spherics	Walk	LSSM
	MISCELLANEOUS BASIC AND APPLIED RESEARCH		
90030201	Solar Furnace - Controllable*	Walk	LSSM
90030101	Radiation Cryostat**	Walk	LSSM

*For Setup Support
**For Location on Prominence

"Investigations on the lunar surface are needed on at least three different scales. The smallest features, ranging in size from near microscopic to hundreds of meters, the fine structure of the lunar surface, can be studied by men on foot during early Apollo landings. Very detailed investigations of features at this scale and the processes by which they are produced may require a small lunar base to sustain men over much longer periods of time than is available during the early Apollo landings. To study features ranging in size from one to many kilometers requires a vehicle to carry men over these distances from the landed spacecraft. This is the scale on which most of the contact relations of regional geologic units and mesoscale structures, such as relatively large craters, faults, folds, and possible igneous intrusions and volcanoes must be examined. Finally, surface traverses of ten to hundreds of kilometers in length are required to examine features of crustal and subplanetary dimensions, such as the basin and surrounding mountain ring of Mare Imbrium and other circular maria. These traverses are needed to obtain deep seismic reflection and refraction profiles correlated with surface gravity measurements and geology. Such traverses provide extensive opportunities to sample and study areal variations in the regional geologic units."

Data contributing partial answers on a lesser scale are obtainable in the early exploration phase from the local exploration near landing sites. The LSSM will provide vital support for the acquistion of these data. However, to obtain information on larger features of primary interest and to support the formulation of a broad, integrated model (or understanding) of the structure, composition, and history of the Moon, extended traverse capabilities are essential, involving extensions of range, duration, and scientific payload capability and the incorporation of on-board analytical facilities.

As indicated in Tables 18a and 18b, the majority of the Geochemistry experiments does not require direct mobility support for performance. Most of them are analytical and are performed on-site within an environmentally controlled laboratory. Of course, indirect mobility support performs a vital function in acquiring and delivering the samples to the laboratory for analysis. Surface vehicle mobility is required for support of in situ measurements such as UV, visible, and IR reflectance; density determination by gamma backscattering; and mass spectrographic analysis of gases on the surface. Consideration of the most effective mobility results in selection of a Rover mode for these experiments.

The Geophysics area, like Geology, establishes strong requirements for all classes of surface mobility. On-site experiments, such as "Plasma Variations with Height and Time, "can be performed without vehicle support.

Others, such as "Natural Radioactivity at Different Lunar Locations," which can be performed by the suited astronaut on foot, can be performed more effectively from on-board a surface vehicle. The Geophysics experiments, in total, present a spectrum of surface mobility requirements that appear amenable to phasing consistent with the support vehicle.

For purposes of organization, the Geophysics and Geology experiments are defined in separate discipline areas. Frequently, however, they are closely interrelated in answering major scientific questions, in actual performance, and in mobility support requirements. "Seismic Profiling - Deep Reflection" and "Seismic Profiling - Deep Refraction" are examples of this interrelation. The objectives of the reflection experiment are to locate deep stratigraphic horizons and to determine elastic constants for the interior of the Moon. The objectives of the refraction experiment are to determine the existence of major subsurface boundaries and to check for isostatic conditions in the lunar crust. These deep reflection and refraction experiments, in conjunction with surface Geology investigations performed from a mobile vehicle in the same traverses, are directed toward examining major features such as maria, mountain ranges, and large craters. As with major Geology investigations, extended range and duration, appropriate payload capability, and facilities are required. For 100-kilometer-radius operations, a range capability of at least 300 kilometers is indicated.

More consideration was given to the effects of mobility limitations in defining Geophysics experiments than in the other discipline areas. As a result, experiments were defined for specific expected levels of mobility support, as related to exploration phases. Thus, many experiments defined in the early exploration phase (specifically with LSSM support) were substantially redefined for the extended exploration phase (specifically with Rover support), which results in a better definition of mobility support requirements in the basic support specifications, and contributes, in part, to the relatively few changes for "Most Effective Mobility" listed under "Geophysics" in Tables 19 and 18b.

Meteorology and Oceanographic experiments (under the Geophysics Discipline Area) require only limited-duration, suited operations, primarily for setup and deactivation of observational equipment, and are unchanged for the alternate mobility criteria.

Many of the Particles and Fields experiments, like the Meteorology and Oceanography experiments, require surface operations support by the suited astronaut primarily for setup and deactivation. Major mobility requirements are specified for : "Solar Energetic Electrons Associated with Solar Flares," which involves use of lunar limb stations; "Solar Wind Interactions with Moon and Geomagnetosphere," which requires permanent

stations at the disk center and limb and a traverse to the limb; and "Magnetohydrodynamics of Solar Wind Flow Past Earth and Moon," which has similar surface mobility requirements. An alternate approach to fulfilling special selenological separation requirements is the employment of Earth-Moon transportation systems in separate missions. The tradeoff between very long-range surface mobility, Earth-Moon transportation, and long-range lunar flying vehicle modes is a major systems problem and is not addressed in this study.

Review of Particles and Fields experiments to determine the most effective mobility mode indicates that except in investigations of the lunar electrostatic field and the escape of electrons from the Earth's auroral zones the specified modes are sufficient. The Electrostatic Field experiment could be extended by using a Rover with simultaneous measurements obtained at separated sites (landing site and Rover site). The "Auroral Electrons" experiment can be performed more effectively by simultaneous use of stations near the disk center and at the limb. The resultant changes in mobility requirements are shown in Tables 18b and 19.

In the Biology area, requirements for surface mobility are posed by the two exobiology experiments. The Soil Bank experiment (62030401) already defined for both the "walk" and "LSSM" modes, is included as "walk" for "Specified" and "Minimum Mobility" criteria, and as "LSSM" for "Most Effective Mobility." The experiment entitled "Evidence of Existing Life" could incorporate broader and more diverse sampling from a Rover, as is indicated in Table 19. Fundamental studies of plant and animal behavior and rhythms do not require mobility support.

Optical Astronomy experiments, being observational from a fixed site, require surface mobility in the suited mode only for performance. As discussed later, mobile equipment is required for installation of major facilities.

Other specialties within the Astronomy Discipline Area include UV, IR, X-ray and Gamma-ray Astronomy, Radio Astronomy, and Wave Propagation. The experiment entitled "Nondirectional Radio Astronomy" can be performed more effectively by using the LSSM to transport the antenna to an area relatively free of man-made interference originating at the landing site. The same consideration applies to measurement of the ambient magnetic field vector. Measurements of electromagnetic wave propagation in the cislunar medium can also benefit from the LSSM mobility mode, which permits use of a longer baseline for point-to-point and interferometric wave propagation experiments. These changes are noted in Table 19. Vehicle mobility support requirements for Radio Astronomy include a deployment support within a 5-kilometer radius for total separation distances to 10 kilometers, and very long range deployment and support. The latter are defined for support of a

limb-located submillimeter radio astronomy experiment and of two outlying cislunar wave propagation stations, one separated in longitude by 1000 kilometers and the other in latitude by 1000 kilometers from a central station. As noted in the previous comments pertaining to mobility for Particles and Fields experiments, the approach to implementing very long-range mobility represents a system tradeoff problem beyond the scope of this study.

In the Mission Support Investigations discipline area, Table 18a indicates that one third of the experiments may be performed without surface mobility support. Of the 32 experiments that do not involve surface mobility, six are performed from lunar orbit, nine involve biomedical and human factors tests performed in a shirtsleeve environment, and eight are on-site biological experiments primarily in ecology. Approximately one third of the experiments in this discipline area require operations by a suited astronaut in the lunar environment, including experiments of surface and environmental characteristics (8), materials research (11), and other engineering support technologies (6). Surface vehicle support is vital to the performance of approximately one third of the experiments. An LSSM-type capability is specified where travel time, distance, or equipment transport are beyond the capability of the astronaut. The long-range mobile laboratory of the Rover class is specified for a very limited number of mission support experiments, in accordance with the "minimum requirements" criterion.

As shown in Table 19, 25 of the mission support experiments have been identified as being performed better or more effectively with more advanced mobility support capabilities. The resulting distribution of mobility requirements for the alternate criteria is incorporated in Table 18b.

In the Miscellaneous Basic and Applied Research discipline area, two experiments requiring mobility support for performance are "Lorentzian Plasma Environment Physics" and "Atomic Species Life." Two additional experiments can be performed better with LSSM support, as is indicated in Table 19.

It should be noted that the collation and definition of investigations and experiments in this study have been directed primarily toward defining the objectives, parameters, equipment support requirements, and experiment sequencing; the study does not consider geographical distribution or mission scheduling in a quantitative way. Consequently, firm distance requirements for a "Rover" class of vehicles are not derivable directly from this study. Integration of experiments into alternate traverse missions is a recommended future activity that can contribute to tradeoff analyses. An additional consideration in such a study should be the number of repetitions of experiments required at various locations representing different geological or geophysical "units." Such analysis would yield a more comprehensive picture of experiment operations requiring advanced mobility support.

6.2.2 ASTRONAUT/VEHICLE IMPLICATIONS

From the discussion in Section 6.1.4, it is indicated that, on the basis of current suit concepts, task accomplishment in the lunar external environment requires four times the man-time investment required for the same task in the Earth environment. An energy expenditure factor of two was indicated for walking in a pressurized suit. Reference to the experiment compilation in Volume 5 (Appendix B), Type-3 card, indicates substantial operational times (based on Earth environment criteria) to be spent in spacesuits. If all of the predicted spacesuit hours are multiplied by an average factor of three (four for work tasks and two for walking), the impact on the overall lunar scientific mission program is profound.

In analyzing the problem posed by this potential man-hour escalation, the astronaut activities should be divided into two categories; those attendant with the transport of the astronaut(s) and ancillary equipment, and those attendant with the execution of required work tasks. The work tasks aspect was discussed in Section 6.1. This section is addressed primarily to the transport activities by examining mobility implications of the scientific missions, particularly as affected by decrements in astronaut performance and the resulting growth in man-time investment requirements.

To examine the mobility implications quantitatively, the following data were used as being representative of values appearing in the literature:

1. In normal work, man expends energy at a rate of about 750 Btu/hr; in sedentary-type work, his energy expenditure is about 450 Btu/hr.

2. A suited man seated in a space environment expends energy at about 900 Btu/hr.

3. For walking on the lunar surface, man can walk in a pressure suit at a sustained speed of 2.0 km/hr for about one hour. His energy expenditure rate is expected to be approximately 1600 Btu/hr, and he incurs an oxygen debt.

4. A two-man lunar scientific survey module (LSSM) of 6-by-6 semi-articulated configuration* has an unladen mass of 454 kg and a fully loaded mass of 957 kg. The LSSM is capable of an average speed of 8 km/hr over the Aberdeen terrain profile with RMS roughness of one foot. Speed capability over the ELMS maria

*A four-wheel forward unit with a two-wheel aft unit, connected by a multielement flexible frame. All six wheels are driven. Both the front wheels and the aft unit wheels are steered, connected by a mechanical system.

model is 8.1 km/hr; over the ELMS uplands model, 6.2 km/hr; and over a "Surveyor-type" terrain, 11 km/hr.

5. Average locomotion energy for the LSSM is 130 watt-hr/km. Power is supplied by a battery system capable of supplying 9000 watt-hours under LSSM operating conditions, but rated at 5400 watt-hours to limit the depth of discharge to 60 percent of the available capacity. Assuming a coefficient of friction of 0.6, the step obstacle capability of the LSSM is 45 inches, crevice-crossing capability is 49 inches, static sideslope stability is 52 degrees, and static longitudinal slope stability is 62 degrees.

Using the foregoing assumptions, simple performance comparisons between walking and wheeled-vehicle locomotion can be made. These comparisons consider time investment and energy investment sequentially. Two mission activities will be considered here: (1) the transport and emplacement of scientific equipment one kilometer travel distance from an AAP laboratory site, and (2) the gathering of surface samples in a local geological survey. In performing Mission 1 in the walking mode, the astronaut time investment in the transport activity is approximately 2 km ÷ 2 km/hr, or 1.0 hour. Energy expenditure by the astronaut in this activity is 1600 Btu's. He will also require midpoint rest of about 0.25 hour. In his suit, he will rest at 900 Btu/hr. Thus, the total time and energy expenditures for this mode are 1.25 hour and 1825 Btu respectively. In the vehicle mode, assuming an average speed of 8 km/hr, the total travel time is 0.25 hour. Energy expenditure is 225 Btu for the astronaut and 260 watt-hr (895 Btu) for vehicle locomotion. Thus, the time and energy expenditure for this mode are 0.25 hour and 1120 Btu, respectively. Considering also the obstacle, crevice, and slope capability of the LSSM versus the suited astronaut capability, it may be concluded that maximal employment of the LSSM for local surface transport of astronauts and ancillary equipment offers a means of maximizing astronaut availability and utility in lunar surface operations.

The second mission activity, that of gathering surface samples in a local geological survey, is considered qualitatively. Figure 19 shows an LSSM design concept illustrating (on the left) utilization in a local geological survey. The utilization illustrated is conventional in that the LSSM has transported the astronauts to the exploration area and, subsequently, shorter-range sorties for sample collection and other activities are performed in the walking mode. Referring to the performance comparisons in the previous mission activity, the distance, time, and energy investments may be subdivided to represent the smaller sorties for local survey and sample

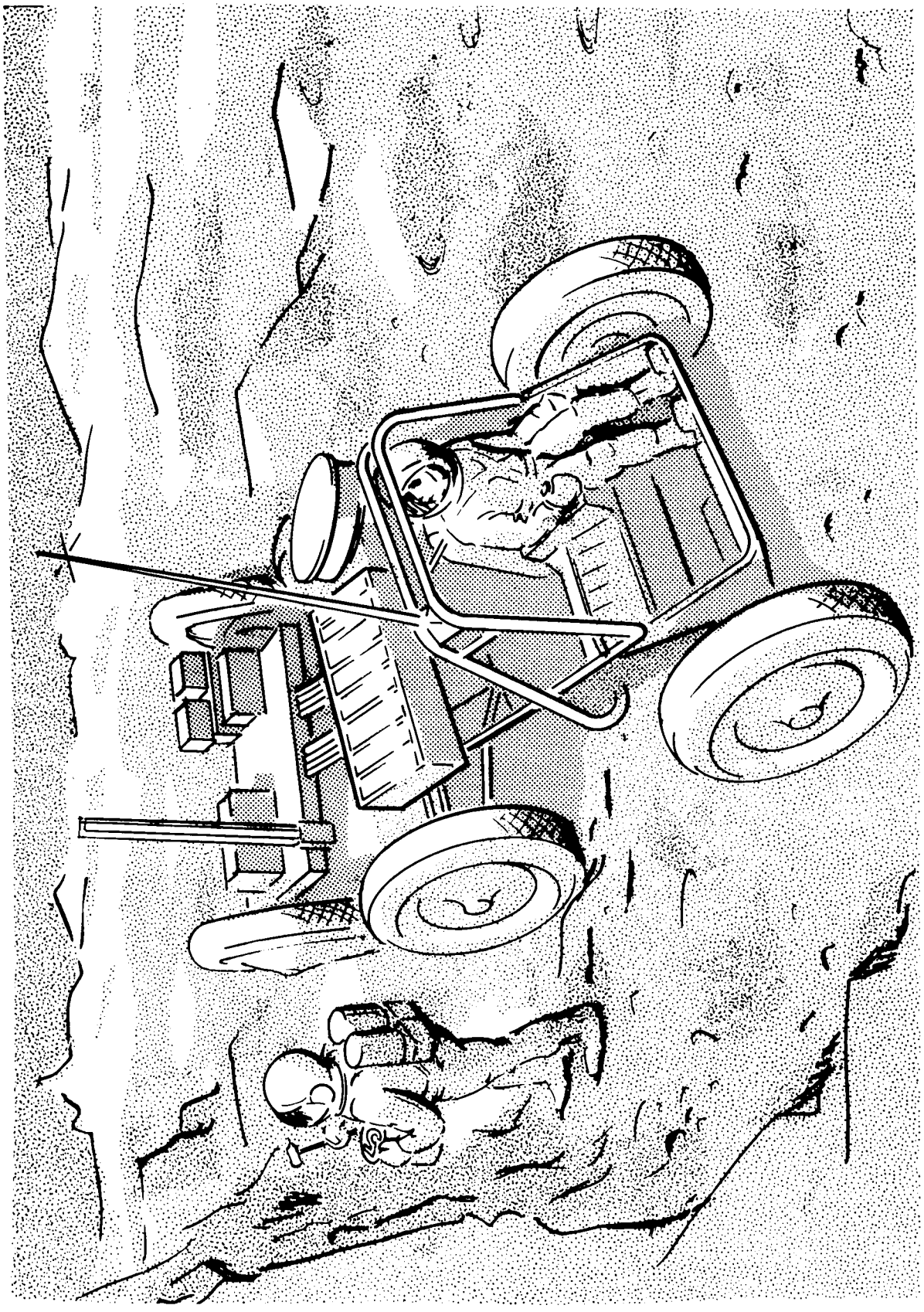

Figure 19. LSSM Design Concept

collection. Thus, the previous conclusion also applies to the second mission activity. It would appear that, from a standpoint of time and energy, the LSSM should, where feasible, be employed to transport the men to the exact location of each mission activity.

The work-time investment factor of 4 indicates that time and energy expenditures will be severe for conventional lunar surface work tasks; therefore, consideration should be given to the actual procedure followed in the performance of scientific experiments and activities. For example, the question should be asked, "Can many of these activities be performed from a seated position in the front end of the LSSM?" A substantiated answer to this question requires analysis of experiment operations and equipment. The procedure for collecting uncontaminated samples may require such an approach. It is noted that the Bioscience Working Group of the NAS 1965 Summer Conference (Reference 2, pp. 241) recommended "that a feasibility and design study be initiated immediately that will lead to the development of a manually actuated lunar sample collection tool for acquiring organically and biologically clean surface and near-surface samples." Although this recommendation does not imply that the astronaut should be seated in the LSSM for this activity, separation from the sampling action is consistent with sample noncontamination intent.

At this time, it appears that major improvement in mission effectiveness can be accomplished by further integration of the astronaut and the LSSM as a man-machine exploration system. Accordingly, it is recommended that serious consideration be given to incorporating tiltable seats in the forward portion of the LSSM. These seats should permit forward rotation of the astronauts to positions that are essentially normal to the tasks to be accomplished. When the astronaut is in the vertical position, his feet should be proximal to the lunar surface. The restraints normally supplied for locomotive accelerations may need to be redesigned to meet the bracing/restraint needs for efficient work task performance.

6.2.3 MOBILITY REQUIREMENTS CONCLUSIONS

The study indicates that limited surface mobility support, such as that provided by an LSSM-type vehicle, is required to accomplish the following:

1. Increase ability of the suited astronaut to negotiate adverse lunar surface terrain conditions, reduce man-hours for surface locomotion, and extend allowable duration of local exploration and/or deployment activities

2. Reduce astronaut fatigue

3. Support the astronaut in the performance of investigations and experiments through restraints and aids

4. Provide mounting for sensors and operational equipment

5. Provide basic subsystem support, such as power and data management

6. Increase operating radius for early exploration

7. Transport equipment and supplies

8. Increase probability of mission success

To provide optimal local exploration support, the LSSM must extend the effectiveness and safety of the astronaut in conducting a range of investigations. Since the LSSM is more than a personnel and logistics carrier, it should evolve as a primary component in the integration and execution of experiments.

The same study indicates that extended surface traverse capabilities are required to accomplish the following:

1. Increase exploration range to a regional scale

   a. Extend terrain negotiability to permit travel to areas of major geological significance

   b. Extend the duration capability for manned traverses consistent with range and with extended traverse site operations (20 hours per site is estimated for deep reflection and refraction investigation operations.)

   c. Provide the investigation and experiment support functions described above for the LSSM, but on a scale consistent with increased size, duration, and complexity of extended duration investigations

2. Provide on-board analytical facilities for timely interpretation and correlation of findings and for rescheduling of missions, if necessary.

These general requirements may be summarized as expressing the need for a self-sufficient, extended range mobile exploration support system. Employment of such a system is vital to the fulfillment of major lunar exploration objectives on a regional scale.

The provision of a basic mobile operations support capability, which, through specialized modular additions, makes possible the deployment and installation of major scientific facilities, such as a long-wave radio telescope and a 100-inch telescope for a lunar astronomical observatory, is an additional requirement, and is discussed in Sections 6.3 and 6.4.

6.3 LUNAR LONG-WAVE RADIO TELESCOPE MILLS-CROSS CONCEPT

6.3.1 INTRODUCTION

One of the major objectives of the Radio Astronomy Research Program for AAP lunar Surface Missions (Reference 1) is to evaluate the suitability and potential of the Moon as a base for sensitive, long-term, detailed radio astronomy studies of the universe (determination of environment etc.). Another major objective of investigations in the early exploration period is to extend radio astronomy technology in the space environment in order that advanced radio telescopes may take full advantage of the unique features of lunar basing.

Reference 29 suggests that the far side of the Moon may provide a unique listening environment, shielded from terrestrial interference and enjoying a greatly widened "window" in the radio spectrum. As part of a program to determine whether the lunar far side would make an ideal or necessary listening post, it was suggested that a preparatory radio astronomy experiment be performed to determine the feasibility of more extensive later efforts. One possible experiment would involve making synoptic measurements of the noise environment on the Earth-side of the lunar surface, and employing a lunar orbiting radiometer to determine the effectiveness of the lunar mass for shielding radio frequency signals emanating from the Earth. These measurements should also be capable of defining the electrical properties of the lunar surface material such as conductivity and loss tangent as a function of frequency. The adaptability of sensitive radio frequency equipment to the harsh lunar environment would also be proven by such a preliminary experiment.

Reference 29 reports the results of studies of a radio astronomy program that may be performed during the AAP phase of lunar exploration. Fundamental and mission-support investigations from the AAP study are included in the experiments compiled for this study. An evolutionary program of lunar-based research, when coupled with anticipated Earth-based advancements in areas such as broadbanding, integrated antenna elements, and receiving and processing (including aperture synthesis), can logically be expected to aid in the development of versatile, expandable, sensitive radio telescopes for the long-term lunar radio astronomy observatory.

This section presents a basic concept for a long-wave radio telescope for possible application to the long-term radio astronomy observatory. Operation in the wavelengths beyond those receivable on Earth is desired to complement Earth-based radio astronomy. Applications would include resolving and locating galactic and extragalactic sources; i.e., spiral arms, core and halo structures, supernova remnants, gaseous nebulae, and very distant radio stars.

6.3.2 GENERAL PERFORMANCE

The candidate concept is a broadband crossed array of Mills-Cross (Reference 30). The nominal design frequency is 1 MHz, corresponding to a wavelength of 300 meters. A frequency range of 0.3 to 1 MHz is considered, with possible extension to 10 MHz. A resolution in the neighborhood of at least one square degree at 1 MHz is desired with sufficient separation between the interference fringes to avoid ambiguities in pointing, identification, and measurements. Providing the one-degree resolution capability at 1 MHz requires an antenna baseline of 18 kilometers.

In the Mills-Cross, two long arrays are arranged at right angles to each other. By means of a phase switching or multiplication technique, a pencil beam centered at the intersection of the two arrays is produced. This is brought about as follows: Similarly polarized fan beams are produced by the two arrays. The outputs of the arrays are alternately added in phase and in phase opposition at a specified rapid switching rate. For a source inside the small region common to both fan beam patterns, the output is modulated by the switching frequency. However, the output due to a source outside this region is unaffected. The modulated output may be recorded by a narrow-band amplifier and a phase-sensitive detector. The resultant beam pattern of the Mills-Cross array is found to be given by the product of the voltage patterns of each array. The simple data handling techniques afforded by this system account for its selection over other possible array configurations.

Other possible array configurations are the multi-element or grating interferometer and the crossed multi-element interferometer (Reference 31). A multi-element interferometer consists of a system of identical, equally spaced antenna elements. The crossed multi-element interferometer, often called the Christiansen-Cross, is a combination of the Mills-Cross and the multi-element interferometer. These array configurations should be subjects for future studies.

An especially attractive alternative to the cross, as proposed here, would be an array in the form of a Y. An array of this type is currently being studied by Dr. George Swenson of the National Radio Astronomy Observatory and the University of Illinois for employment at NRAO to

achieve a pencil beam of the order of seconds of arc (Reference 50). In this case, all spatial frequencies which would be present in a cross are also present in a wye of somewhat smaller size. The simple data handling techniques, e.g., phase switching, which are applicable for signals from two orthogonal elements are not applicable in the case of the wye, but, instead, a system by which all voltages and phases are recorded and the beam synthesized in a computer is to be employed. In this case, a 15 km traverse capability for the wye would yield the same resolution as an 18 km traverse required for the Mills-Cross, and would require one less trip. Thus, for a given available mobility, the resolution accomplished by the wye is about one and one-half times better than that obtained by the cross. A larger telemetry bandwidth may be desired to feed the data to ground-based astronomers. However, it may be possible to establish a communications relay at one of the stable Lagrangian liberation points. If the array were placed some 30 to 45 degrees around the limb, this relay satellite would be able to see the entire array and the Earth simultaneously, allowing such a system to be operable with no manned intervention after construction.

6.3.3 SYSTEM REQUIREMENTS

It is anticipated that each antenna leg of the Mills-Cross system will consist of a uniformly spaced array of several dipoles suitably interconnected by elevated lines. Since simple dipoles are essentially narrowband devices, the end-loaded, folded dipole is indicated as an aid to broadbanding and impedance matching. To cope with surface interference effects, intensive development work may be necessary, based on the data on lunar dielectric characteristics gathered in earlier missions. For signal-recording purposes, each array should be treated as a single functional antenna, optimized for a particular frequency (1 MHz), and degrading in performance elsewhere in the operating spectrum. To compensate for transmission line losses, tunnel diode or transistor amplifiers may be introduced in the array. To provide proper matching, magic T's with lumped parameters can be incorporated at the junctions of feed lines.

Inherent in radio astronomy within a new, unchartered frequency domain is the basic dilemma involving tradeoffs between resolution, sensitivity, and the number of mutually confusing sources likely to appear within a single antenna beam. Detection and analysis of the generally weak radio sources of interest is a function of the actual physical antenna aperture. When aperture size is increased and sensitivity is improved, however, a number of detectable sources may appear within the solid cone of space intercepted by the effective antenna beam. Such multiple-source confusion would be a demonstration of inadequate resolution, since the signals received with a single beam cannot be distinguished and analyzed by simple means. Therefore, it is desired that the telescope system incorporate

means to help resolve the confusion-limit dilemma. Two approaches appear to offer solutions to this problem: (1) provision of variable sensitivity, under a lunar operator's control, which yields instantaneous data but requires manning; and (2) resolution improvement through refinement of data-storage and data-integration techniques. This second approach has the potential advantage of retaining and using all collectable data, although analysis may be delayed until the package is transmitted or physically returned to Earth.

Resolution of a number of critical system parameters, ranging from the choice of step-frequency or sweep-frequency receiving and detection techniques to the height of the dipoles, is required. It is also required that techniques be developed and proven, leading to the provision of self-extensible or erectable support towers for ease of field deployment. It is suggested that techniques developed on Earth and refined in orbit be tested on the lunar surface in an earlier mission.

The beamwidth, unwanted sidelobes, and the accuracy of pointing will all depend upon the degree of correct alignment as well as on the constancy of the adjustments with the lunar environment and the stability of the component parts themselves. Accordingly, techniques should be developed for calibrating, adjusting, and phase aligning the antenna array and its component parts. The development will be greatly aided by the experimental erection and testing of a similar array on Earth.

The initial configuration of the proposed lunar-based radio astronomy telescope should be "open-ended" to allow for future extensions of the antenna arrays for improving angular resolution and for measuring signal polarization phenomena. Step-by-step improvements of the initial signal processing and recording methods must be facilitated by the use of modular circuit components with well-matched input and output impedance characteristics, synchronized by a central clock system of sufficient accuracy. The following major phases in this growth can be anticipated:

1. Operation of the Proposed Single-Beam System: extended observations of individual radio sources; occasional observation of occultation phenomena by the limb of Earth.

2. Simultaneous Two-Beam Operation: introduction of "virtual beam" circuits in the central signal processor would allow coordinated recording of two radio signal sources, such as the Sun, and the RF signal from the Sun reflected by Earth or Venus.

3. Large-Field Recording Techniques: recorded signals of selected sources retain only a vanishing fraction of the information intercepted by the dipole array from an angular field amounting to nearly six steradians. A spectacular increase of the observational yield could be achieved by recording the signals from every dipole separately on a carefully timed multi-channel recording tape. These tape records may be then used for extracting rf-signal information from any desired direction within the large field covered by the dipole array.

4. Linear Extension of the Mills-Cross Array: achievement of increased angular resolution.

6.3.4 GENERAL DESCRIPTION OF ARRAY

The antenna system consists of two crossed arrays that may be operated in various multi-element spacing configurations. The configuration is shown in Figure 20. Each of the N-S and E-W arrays is composed of 48 elements uniformly spaced along an overall baseline of 18 km. All the array elements are horizontally polarized and supported above the lunar surface at a height of about 30 meters or 0.1 wavelength at 1 MHz. The number of elements chosen represents a reasonable compromise between weight and performance. Grating lobes will be introduced in the antenna pattern at frequencies above about 400 KHz since the spacing between elements then exceeds one-half wavelength. Even so, the ambiguities may be resolvable by analysis of the records, especially if a limited number of strong sources exist at these low frequencies—as indeed many suspect the case to be.

The half-wave dipoles, cut for the center frequency of 1 MHz, are 150 meters long and consist of No. 10 B&S (Brown & Sharpe standard gauge) hard drawn aluminum wire. (No. 12 B&S hard drawn copper or copperweld wire may be used if necessary).

The twin-lead feeding each dipole is utilized as a tuned line or a folded section of the antenna, depending on whether the antenna is operated above or below the center frequency of 1 MHz. The lower end of the twin-feed line is connected to an antenna tuner and amplifier unit housed near the base of the antenna tower. The characteristic impedance of the twin-lead is not critical and may be between 300 to 600 ohms (a polystyrene insulated type 300-ohm twin line may be used, provided the insulation is able to withstand the lunar environment). Tuned lump circuits are strategically placed in the dipole for fundamental resonance operation on several frequency bands.

The N-S and E-W transmission lines are supported about ten meters above the ground and consist of redundant No. 10 B&S hard drawn aluminum,

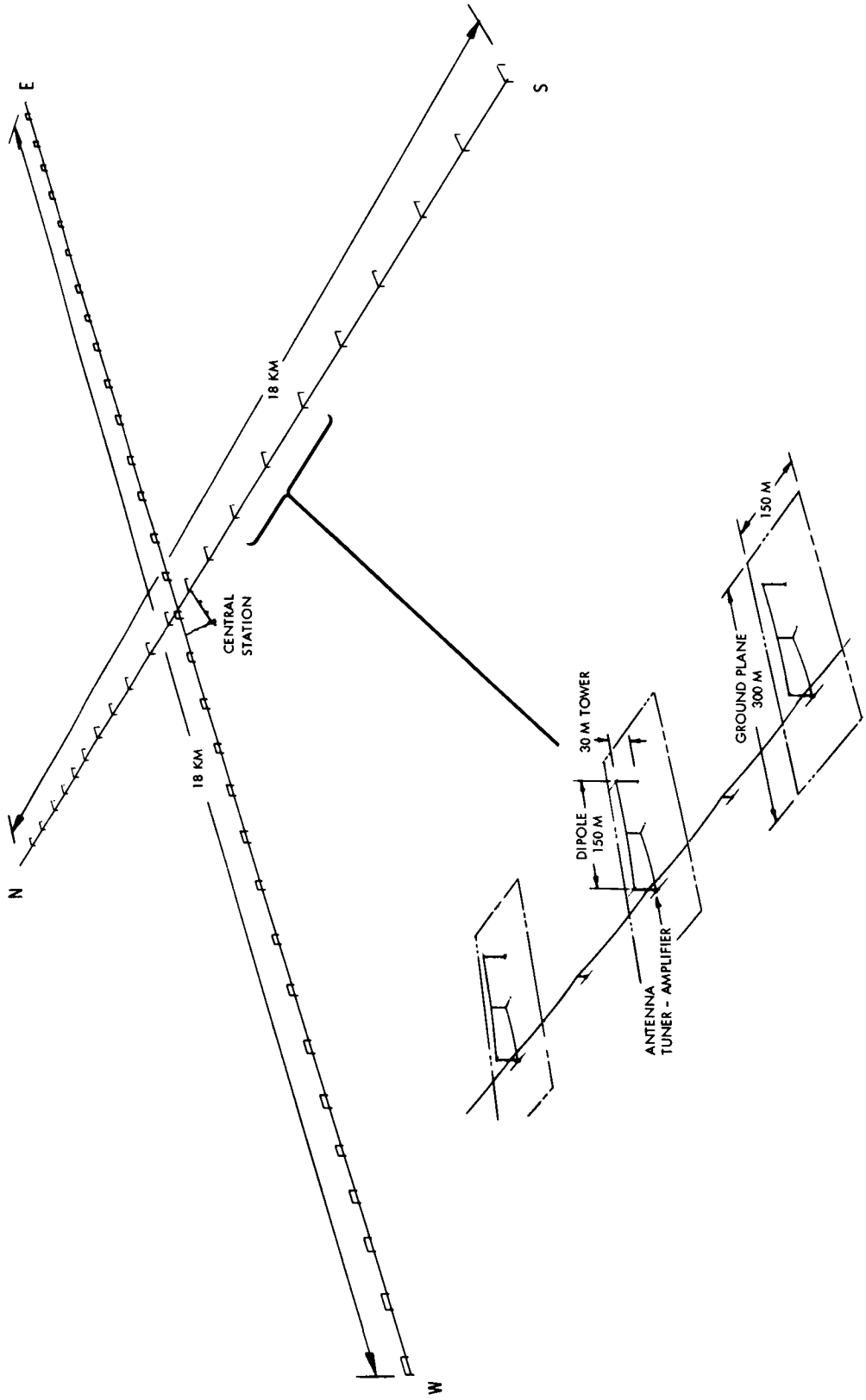

Figure 20. Lunar Long-Wave Radio Telescope - Mills-Cross Concept

two-wire lines suitably spaced with strip insulators to present a characteristic impedance of about 500 to 600 ohms. This is a wide-spaced (15 cm) open line and is desirable in a line of this type in order to keep any small variation in spacing from greatly affecting its impedance. A suitably designed plastic insulated twin line of lower characteristic impedance or an open trough type line may be used, provided the attenuation is not excessive. An open two-wire line has an attenuation between 1 and 2 decibels per kilometer at 1 MHz and less than 0.6 decibel per km at 100 kHz. The open trough line is a single-wire line, enclosed on three sides by a metallic conductive sheet or fine screen and having the properties of a coaxial line. It has the great advantage of being laid directly on the ground; however, its weight and assembly on the Moon poses some problems.

6.3.5 ANTENNA ELEMENTS

A center-fed dipole antenna with strategically placed tuned circuits or traps can be made to operate efficiently on a frequency higher than its fundamental resonant frequency and, with somewhat lower efficiency, on frequencies as low as one-half the fundamental resonant frequency. Operation at still lower frequencies is possible but with greater reduction in efficiency. Used with a tuned open-wire parallel conductor feeder in conjunction with an antenna tuning and matching unit, the single wire antenna is the simplest and most flexible wide wavelength range antenna that can be used. End-loaded, folded dipoles are capable of operating over a wider band than a normal antenna, but satisfactory operation over a 10-to-1 frequency range is not possible. On the other hand, a long periodic array is operable over such a range but is not practical from size and weight considerations.

When the dipole is operated just below the fundamental resonant frequency, the open feed line becomes a folded part of the antenna system. At still lower frequencies, additional loading is provided by the antenna tuner, which also properly matches and couples the received signal into the input of the amplifier.

6.3.6 GROUND SCREEN OR WIRES

The antenna height, tentatively shown at 30 meters which is 0.1λ at 1 MHz, is rather close to the lunar surface. For a ground having a conductivity in the neighborhood of 3×10^{-4} mhos per meter, determined from reflectivity measurements of the Moon, the proximity loss becomes substantial at and below 1 MHz. In order to reduce this loss, a ground screen or counterpoise of wires is required. A set of 15 to 20 No. 18 copperweld wires 300 meters long and lying on the ground is suggested for the ground plane. These wires are placed parallel to and directly below each horizontal dipole element

and evenly spaced over a distance of about 150 meters. All the wires in a set can be electrically connected at their centers to furnish a grounding point for the instrumentation.

6.3.7 RECEIVING AND PROCESSING SYSTEM

The output from each antenna dipole in the array after being transformed in the antenna tuner is coupled into the rf amplifier of the antenna unit shown in Figure 21. Each unit contains four to ten preset frequency channels matched to the frequency bands for which the antenna is designed. A phase shifter provides a means not only for alignment of the array but also for presetting a linear phase shift in the elements of the array to control the pointing direction of the main beam. The signal is further amplified in a high impedance output amplifier that is coupled lightly to the main transmission line which conveys the signal to the processing system. Each antenna element in the array is coupled to its main transmission line in the same manner.

The outputs of the N-S and E-W transmission lines are applied to the input of the phase switching processor in a central station, as shown in Figure 21. In the i-f section of the unit, the signals are phase switched by a 400 Hz square wave source to perform the required multiplying function. The i-f signals are thus modulated at 400 Hz and, after detection, the modulation voltage is filtered out, synchronously rectified, integrated, and finally recorded.

In Reference 32, T.A. Clark of MSFC suggested incorporation of a more advanced data processing system to yield greater flexibility. It was suggested that amplitude and phase information be telemetered separately from each dipole antenna to earth, where the correlation could be obtained for any arbitrary position in the sky with variable illumination to suppress sidelobes. This requirement would best be accomplished by providing either separate leads from each dipole to a central telemetry site, or a common phase reference to all dipoles and establishing a receiver/telemetry unit for each dipole.

6.3.8 WEIGHT AND PACKAGING

Table 20 presents a preliminary weight statement for the Mills-Cross radio telescope system, based on cursory, first estimates.

In the projected time period (late 1970) for the lunar long wave radio telescope, larger capacity launch vehicles may offer the possibility of delivering the radio telescope and its deployment equipment together with the shelter and traverse-type vehicle in a single mission. In this payload concept, the radio telescope and development-construction equipment are housed below the shelter and vehicle in the cylindrical section of a 260-inch diameter payload

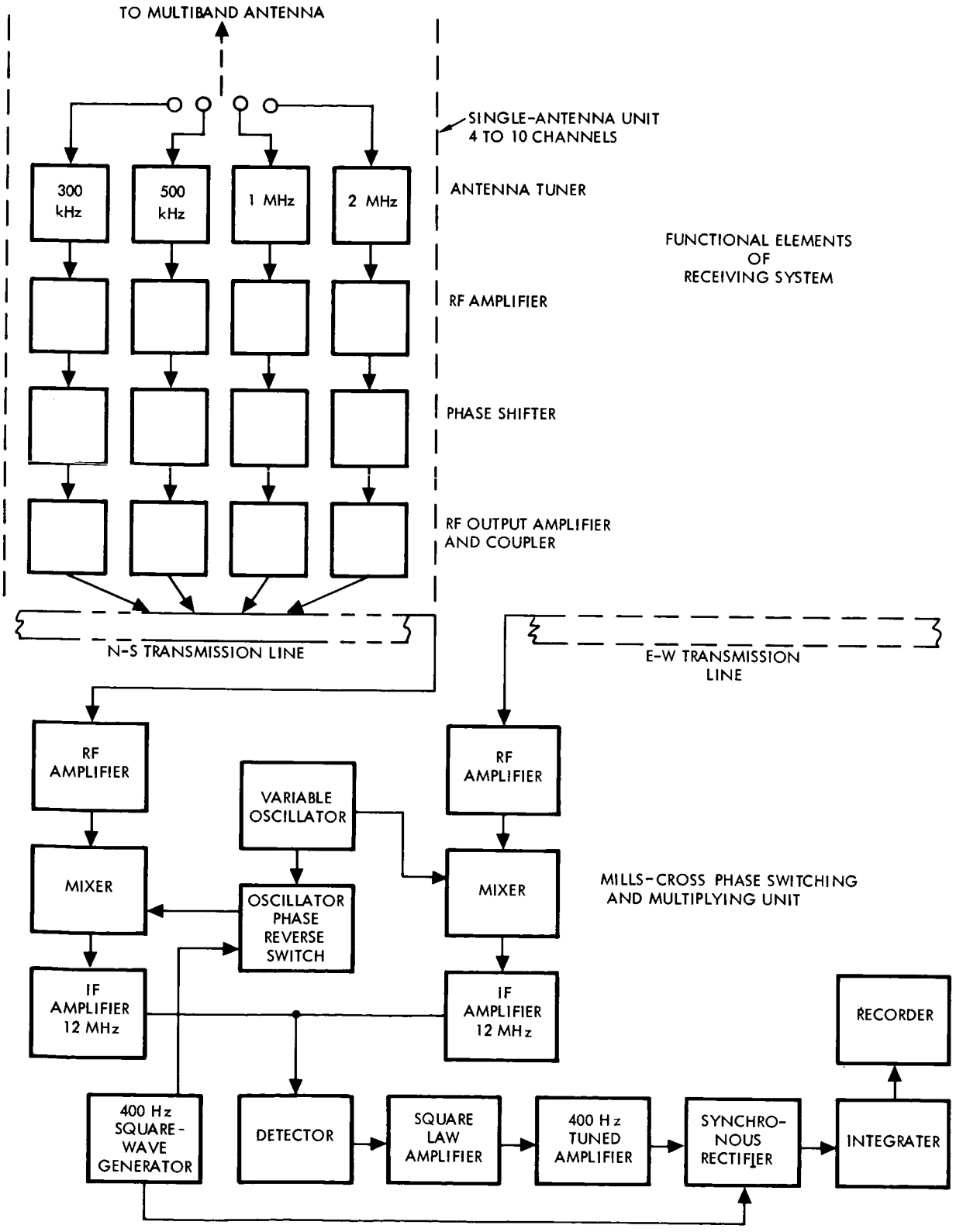

Figure 21. Functional Elements of Receiving System

Table 20. Mills-Cross Concept—Preliminary Weight Summary

Item	Weight (kg)		Weight (lb)	
		Subtotal		Subtotal
Antenna System		3,816		8,395
Dipoles	212		466	
Transmission line leads	120		264	
Main feed lines	2,240		4,928	
Remote control cable	524		1,153	
Instrument leads	36		84	
Antenna electronics	682		1,500	
Ground Plane Wire		4,512		9,925
Structural Supports		2,600		5,720
Towers and supports	2,362		5,196	
Intermediate support poles	238		524	
Central Station and Miscellaneous Equipment		1,600		3,520
Receiving, control, recording instrumentation	450		990	
Recording tape and expendables	250		550	
Spares and supplementary equipment	900		1,980	
Basic Interferometer System Total		12,528		27,560

A preliminary packaging arrangement for the radio telescope portion of this payload is shown in Figure 22. Most of the radio telescope equipment can be packaged in a relatively short, 78-inch section of a 240-inch diameter cargo compartment. Additional space is provided for storage of an LSSM and deployment-construction equipment. For an advanced vehicle payload of 66,000 pounds, identified by the MIMOSA study, this leaves approximately 38,000 pounds of payload available for a shelter module, Rover, LSSM, experiment equipment, payload compartment for the radio telescope components, construction support modules, and miscellaneous equipment.

An alternate scheme to the packaging concept shown is the delivery of the radio telescope payload and the shelter-vehicle payload in two separate smaller-capacity vehicles. Since the total weight of the basic interferometer system is 27,560 pounds, this sets a lower limit in the payload capacity.

6.3.9 UNLOADING AND DEPLOYMENT

As indicated in Figure 22, the radio telescope and supporting cargo can be unloaded with an overhead crane. The crane and its lateral tracks ride on a circular track as in a railroad roundhouse. For unloading from either side, the internal lateral tracks mate with two pairs of extended, fixed-position tracks. The LSSM contour permits attachment to the crane within its overall envelope, which minimizes cargo compartment height.

Deployment of the 18-km Mills-Cross on the lunar surface places extra demands on surface mobility. The surveying and erection procedures will normally require simultaneous operations at two points. Emplacement of anchors for guy wires, the deployment of the dipoles and feed lines, and antenna erection and stabilization procedures indicate a need for a second vehicle. An LSSM operating in conjunction with a longer range roving type vehicle appears to meet this need and is included as part of the payload.

The size and weight of individual Mills-Cross radio telescope components are individually small and the components are packaged so that their size and weight are compatible with transport along the surface in a cargo attachment to the back-hoe (see Lockheed's Deployment Procedures for LESA, Reference 33). Consequently, a separate logistics carrier is not shown.

The construction concept for the array is directed toward minimizing the man-hours required for deployment, erection, and activation. The antenna towers are of telescoped-tube construction, employing five sections each. After emplacement of a base plate and anchors, the retracted unit is erected and the outer lower portion supported with guy wires. Extension is accomplished by releasing gas to an internal accordion-type mylar tube. The

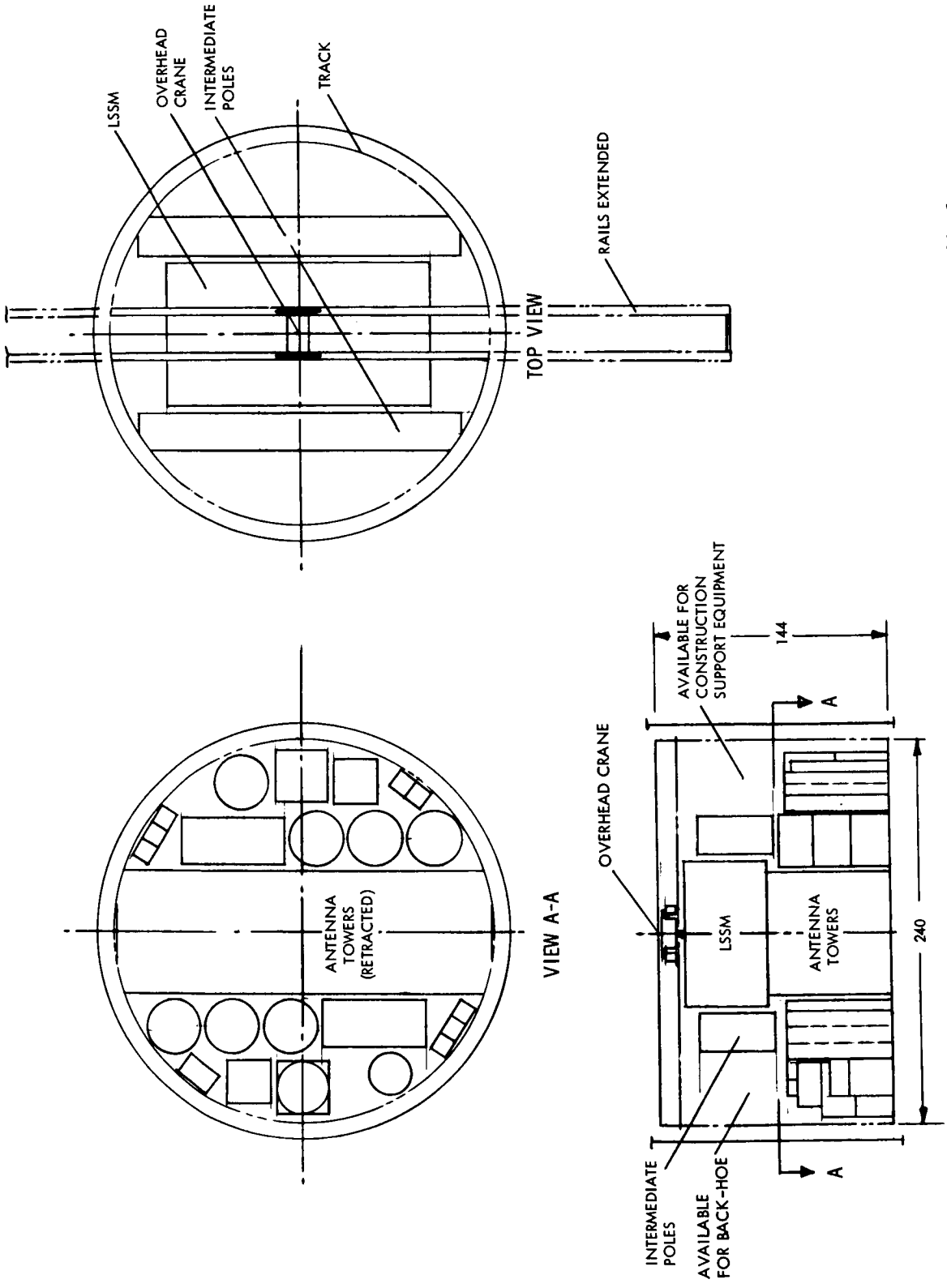

Figure 22. Lunar Long-Wave Radio Telescope Packaged Under Shelter in 66,000-Pound Payload

antennas will be erected and stabilized in pairs with the dipoles attached. The next steps are the deployment and attachment of the main feed and control lines, the installation of the antenna electronics, and the laying of the ground plane wires. These operations will require the use of attachments (including the personnel platform) to the back-hoe frame.

The control station for the radio observatory may be housed in the shelter module and does not require deployment. Following installation and activation, the radio observatory would operate in a remote mode. Power, environmental control, and communications support would be required over an extended period of time.

6.3.10 EXPENDABLES AND MANPOWER

The output of the radio telescope can be in the form of electrical signals recorded on tape and transmitted at intervals. After transmission, the tapes may be erased and reused. However, it is expected that some tapes will be preserved for Earth return and analysis. Therefore, a provision for 550 pounds of tape and secondary expendables is included in the weight summary (Table 20).

The survey, deployment, and activation of the antenna array on the lunar surface are expected to require the major portion of the operational man-hours of an early fixed site crew. Three men appear to be a minimal requirement, including two operating from a large mobile vehicle and one using the LSSM. An analysis of the operational man-hours required is beyond the scope of this activity. For planning purposes, it is suggested that the following man-hour requirements are representative.

Item	Time (man-hours)
Central station (shirtsleeve)	120
Large vehicle (shirtsleeve)	600
LSSM and on foot (suited)	480
Total to install and activate	1200

6.3.11 DEVELOPMENT PLAN

Figure 23 presents a development schedule for the lunar long-wave radio telescope. The research and component development will emphasize the development of broadband antennas, integrated antenna elements, and receiving and processing. A comprehensive program is anticipated to achieve reliabilities associated with long life.

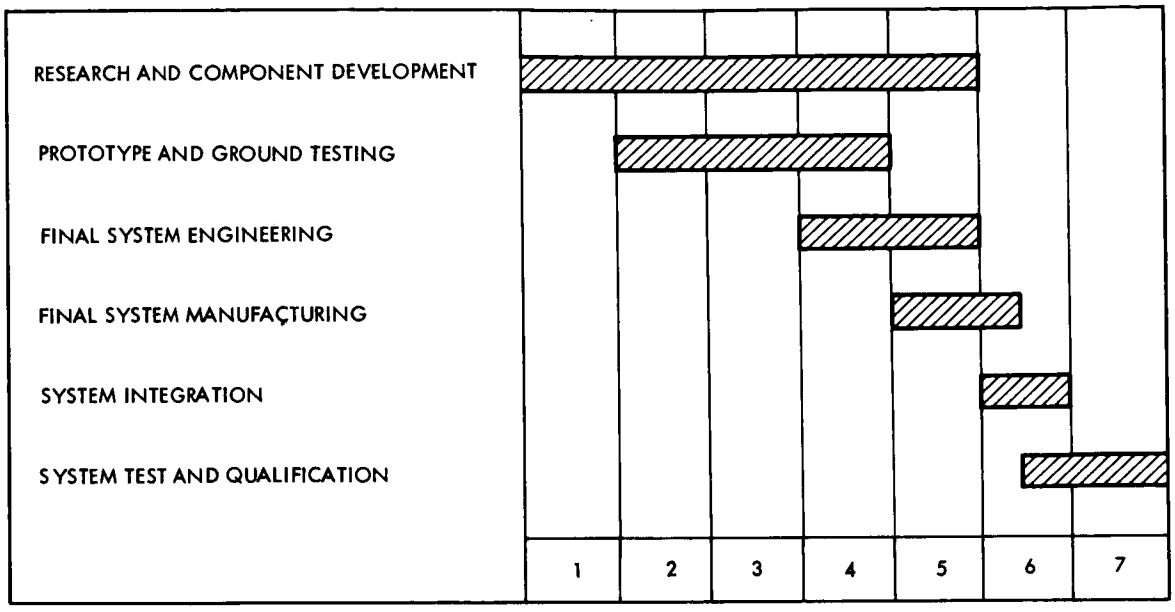

Figure 23. Preliminary Development Schedule for Long-Wave Radio Telescope

6.3.12 CONCLUSIONS

Installation and initial operation of a long-wave radio telescope as a major system in a long-term lunar radio astronomy observatory appears to be scientifically highly desirable. Based on current considerations and criteria, this facility appears to be feasible in the second half of the 1970's.

6.4 LUNAR ASTRONOMICAL OBSERVATORY, 100-INCH HORIZONTAL TELESCOPE CONCEPT

The lunar astronomy mission program which can be derived from the investigations assembled in this study is an evolutionary one. The fundamental investigations (particularly in the areas of optical, ultraviolet, and infrared radiation) are strongly related to the telescopes and man-hours available. These, in turn, are dependent on technology developments and are related to mission support capabilities.

Telescopes to be utilized in this mission program range from small instruments to major installations. These telescopes include a 5-inch photographic refractor; a 12-inch, high-resolution reflecting telescope; a 12-inch wide-field (5 degrees) reflecting telescope; a 40-inch reflecting telescope; and a 100-inch, diffraction-limited reflecting telescope. The program of utilization of the 12-inch reflecting telescope is primarily directed toward evaluation of the suitability of lunar basing for astronomical observations and for acquiring technology support data and operating experience for application to larger, more sophisticated instruments. A broad range of fundamental investigations is outlined for the 40-inch reflecting telescope. Subsequently, by the end of the 1970's, the program envisions the addition of the 100-inch diffraction-limited telescope installation as the prime instrument of the lunar observatory. The 100-inch telescope would be designed to maximize performance to yield major scientific returns, maximize operating life, and to take full advantage of lunar basing features. A 100-inch telescope was selected as a representative size in order to assess typical support requirements for a major observatory and should not be construed as a final recommended size. Selection of the telescope size and concept, employed in this study, allowed the direct application of information from a previous study (Reference 3).

In prefacing his panel member report in Reference 3, Dr. G. H. Herbig suggested that the experiments themselves must be (1) nontrivial, (2) clearly justifiable to the scientific community as requiring performance on the Moon rather than elsewhere (as, for example, on Earth or in Earth orbit), and (3) of such character that the scientific return will be, to a reasonably dispassionate observer, commensurate with the effort invested. Dr. Herbig also stated a belief that the preceding conditions can be fulfilled by the establishment of a large reflecting telescope on the lunar surface and suggested a concept which is the basis for the concept shown in Figure 24.

The following conditions for the 100-inch telescope were offered:

1. If the telescope is to be diffraction-limited and operate effectively in the 1000 to 1500 Å region, it should have an aperture no less than approximately 100 inches, for which the theoretical angular resolution is approximately 0.01 arc second.

2. To deliver the desired performance the telescope must be designed to feed fixed receivers that can be operated under shirtsleeve conditions. Adequate radiation shielding for personnel should be provided at the same time.

3. The large optics and other critical components must be protected from major thermal perturbations and from moving solid material near the lunar surface.

4. To the extent feasible, full advantage should be taken of the peculiarities of the lunar environment in departing from conventional telescope design.

The telescope configuration which was suggested by Dr. Herbig, as a means of accomplishing the scientific objectives within the staged conditions, is a horizontally mounted, off-axis concept fed by a single moving flat mirror. An initial design approach for this 100-inch horizontal telescope was presented in Reference 3. In this section the performance and support requirements of the design concept indicated in Reference 3 are reviewed, a size reduction in the dome and tunnel is suggested, packing for delivery to the lunar site is analyzed, and a deployment concept is presented.

6.4.1 CONCEPT SUMMARY

The concept includes a 200-inch aperture optical flat siderostat in a protecting dome, a 100-inch aperture paraboloidal primary mirror, a 12.5-inch aperture hyperboloidal secondary mirror, a long focus reflecting grating, a rotating photographic film or plateholder, and a photoelectric photometer. The 100-inch and 12.5-inch mirrors are off-axis portions of 240-inch and 30-inch mirrors, respectively, mounted so that there is no obstruction of the primary mirror by the secondary mirror.

The 100-inch horizontal telescope consists of six major components: (1) a 200-inch movable flat mirror installation, (2) the dome for its protection, (3) a 100-inch primary off-axis mirror installation, (4) an observation room, (5) an instrument room, and (6) a horizontal tunnel. The components are designed to be landed as units, moved into position, and installed with reasonable assembly procedures. The horizontal protective tunnel enclosure would be foam-filled in place. Total weight is estimated to be 39,600 pounds (18,000 kilograms). Delivery of all the components and support equipment for this observatory in two logistics payloads appears feasible. Packaging studies have also indicated that the telescope system can be delivered in a single advanced, 396-inch OD payload being considered for lunar mission support in the MIMOSA study.

The outside diameter of the dome over the 200-inch siderostat is reduced from 590 inches to 356 inches. In addition, the dome has been located some 28 feet closer to the primary mirror. As a result, the overall length of the installation is about 128 feet (37 meters). Deployment requirements have been found to be compatible with general techniques and procedures developed by Lockheed in Reference 33.

The light-collecting vertical angle of the 200-inch flat siderostat is limited in the direction of the primary mirror optical axis; therefore, the primary axis is placed in an east-west line so that complete viewing in this direction will be provided by the Moon's rotation. North-south viewing down to the horizon permits observation of almost the entire sky. It is desired that the observatory be located in a readily accessible topographic high. To the north and south, the terrain should slope away from the observatory and should present no major prominences.

6.4.2 OPTICS

The basic design (Figure 24) is a horizontal Herschelian optical system utilizing a siderostat and f/10 photographic and f/100 spectrographic configurations of 100-inch aperture. Because a Herschelian telescope focuses skew rays off the optical axis, the image deterioration, even in an f/10 mode, may be more than is desirable for good photography. Therefore, use is made of a 100-inch off-axis portion of a larger paraboloidal mirror at the prime focus on-axis for the f/10 photographic telescope. A Cassegrainian secondary can then be added for the f/100 spectrographic telescope.

A 240-inch, paraboloidal, primary mirror and a 30-inch hyperboloidal, secondary mirror allow a 100-inch off-axis portion of the primary to be used without masking by the secondary mirror.

For light gathering and resolution purposes, the configurations are those of a 100-inch aperture with 1000-inch focal length at the f/10 prime focus and with 10,000-inch effective focal length at the f/100 Cassegrainian focus. They may be expressed as off-axis portions of an f/4.167 prime focus and an f/41.67 Cassegrain—both with a 240-inch aperture.

Only a 12.5-inch off-axis portion of the secondary mirror, matching the 100-inch off-axis portion of the primary is used.

The Gaussian image plane for photography at the prime focus is located in an observing room 1000 inches from the primary mirror. The secondary mirror is located 875 inches from the primary and 125 inches from the observing room. To have the Gaussian image plane of the Cassegrainian

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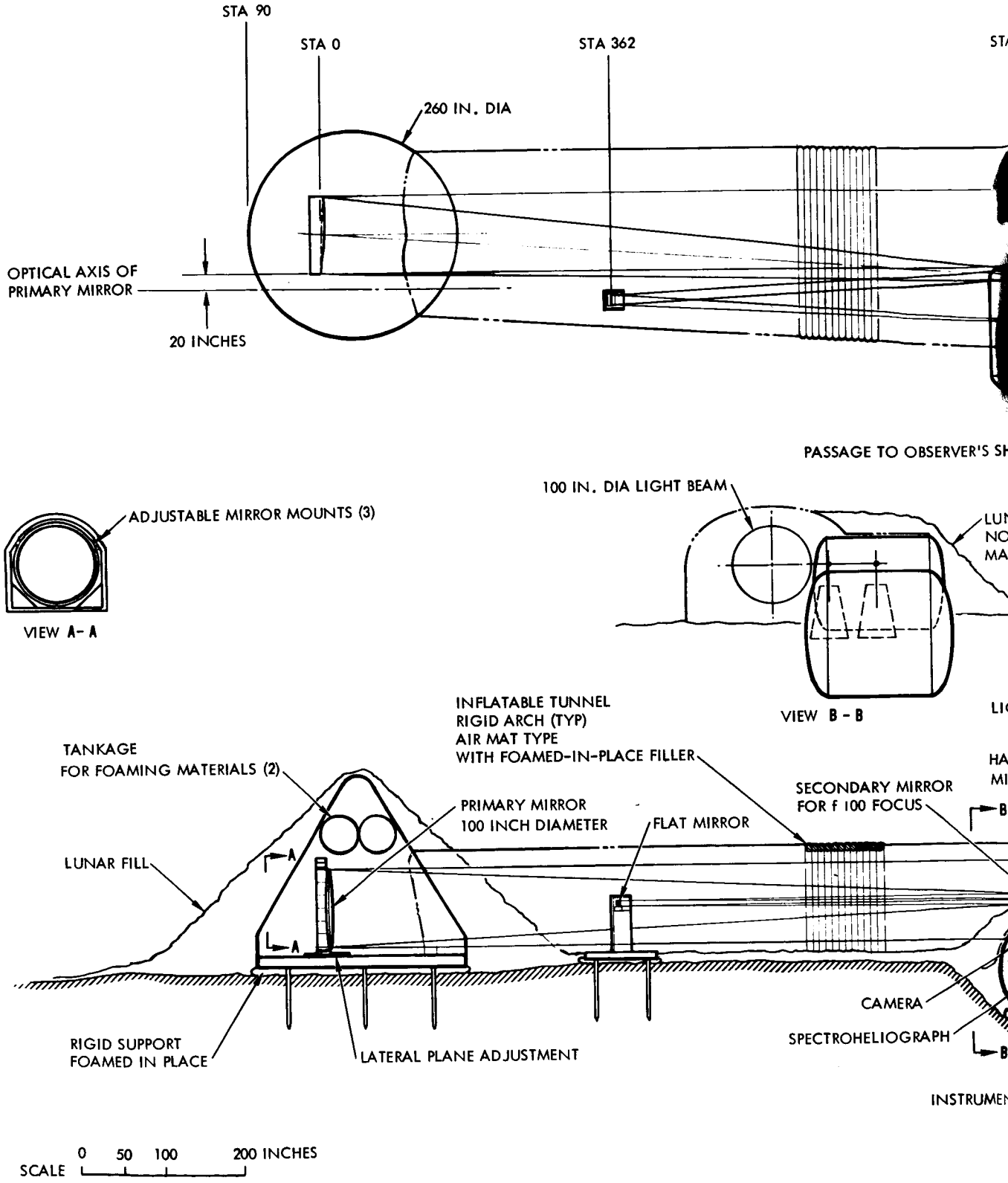

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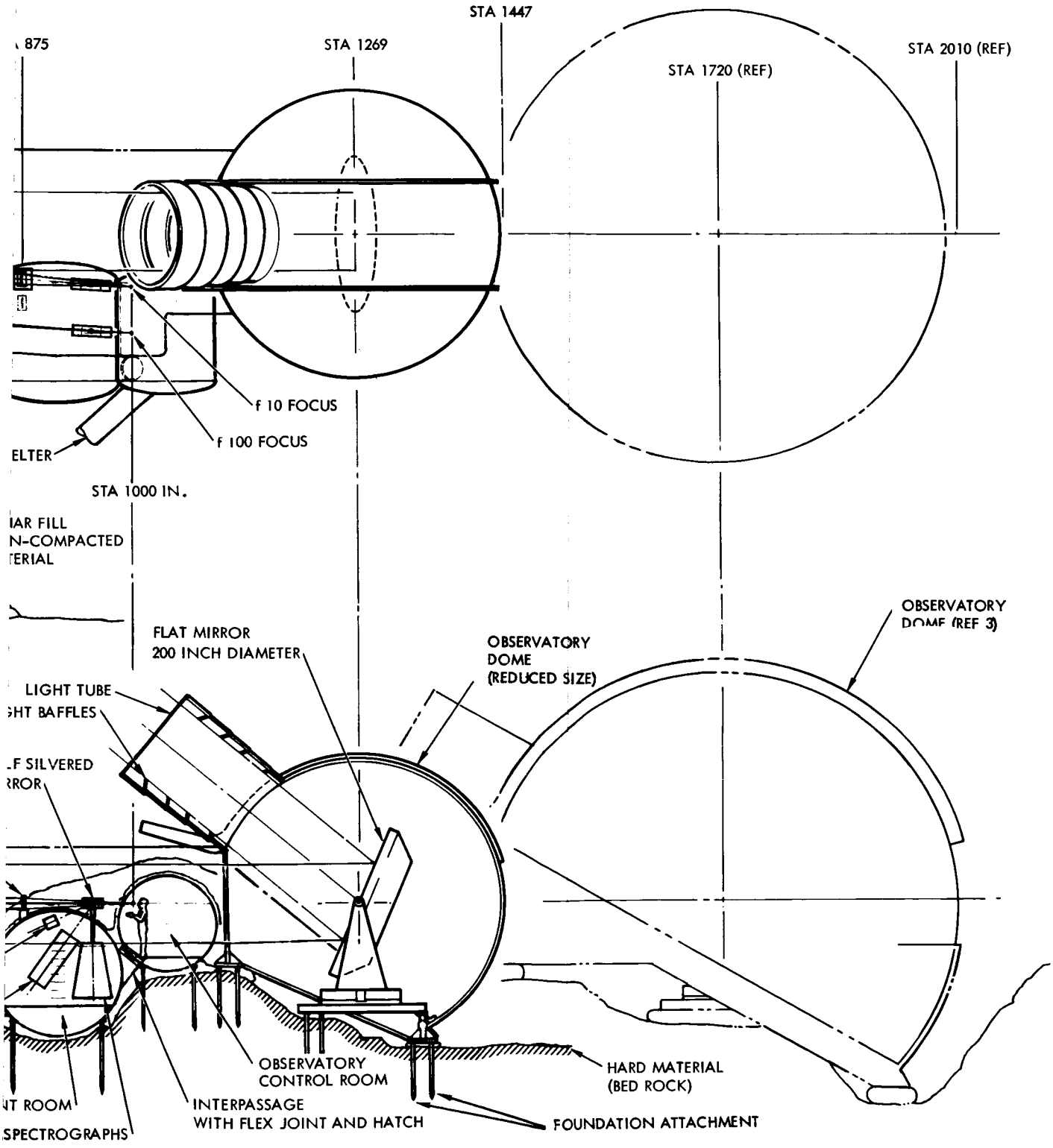


Figure 24. 100-Inch Horizontal Telescope Concept Showing Reduced Dome (Modified From Reference 3)

focus in or near the same observing room, the system is folded with an optically flat mirror located 513 inches from the secondary mirror, and 638 inches from the observing room location of the image.

The spectrograph can be folded so that both the reflection grating and the photographic emulsion are in or near the observing room. The optically flat mirror for this folding would be located in the tunnel at a distance of one half of the focal length of the grating. Theoretically, the focal length of a spectrograph is independent of the focal length of the telescope forming the image. Since the quality of the image formed by the spectrograph can be no better than the quality of the image received, the focal length of the concave reflection grating should be of the same order of magnitude as the focal length of the telescope for high dispersion spectroscopy.

The siderostat is a 200-inch optically flat mirror that reflects the light from the observed object into the optical train. The siderostat is housed in a dome that is opened only in the direction of the area under observation. The image of the siderostat rotates about the optical axis; allowance for this condition must be made in mounting the photographic plateholder, the spectrograph, and a spectroheliograph.

Visual pointing, guiding, and/or observation can be achieved without interruption of the photographic or spectrographic modes by the introduction of half-silvered, optically flat mirrors into the optical train. Basic operation, however, should be computer controlled, including siderostat, dome, and receiving instrument rotation. It is also visualized that Star-tracker guidance will be utilized.

6.4.3 PERFORMANCE

Some performance data are summarized (in Table 21). Control characteristics are preliminary estimates.

Although most of the presently conceived programs relate to observations in the ultraviolet region of the electromagnetic spectrum from about 1000 Å, the telescope can also be used in the visual region and in the infrared region out to 20 microns, or farther.

It should be pointed out that, at present, the largest diffraction-limited mirror has a 36-inch aperture at 5500 Å. To make mirrors approximately three and six times the aperture with about six times the accuracy is a major undertaking. In addition, the mirrors will be required to maintain their figure in the lunar environment of one-sixth g.

For the optical configuration of this telescope, the image deteriorates very rapidly away from the center of the field of view. Consequently, the field of view is very restricted, particularly at the large focal lengths.

Table 21. Linear Diameter of Diffraction Image Data (100-Inch Telescope)

Focal Length	Wavelength		
	1000 Å (10^{-5}cm)	5500 Å (5.5×10^{-5}cm)	20μ (2.0×10^{-3}cm)
10^3 in.	1.0μ	5.5μ	0.2 mm
10^4 in.	10.0μ	55.0μ	2.0 mm

Telescope Control Characteristics

Item	Characteristic
Slewing rate for siderostat	120 deg per min
Setting rate	2 arc sec per sec
Guiding (close control) rate	7×10^{-3} arc sec per sec
Deflection drift	1 arc sec in 1 hr
Pointing accuracy	20 arc sec over celestial sphere

6.4.4 DESIGN

The configuration for the 100-inch horizontal telescope is presented in Figure 24. This is a composite illustration showing the initial design from Reference 3 with the shortened installation, employing the 356-inch dome superimposed upon the initial drawing. The shortened length implements, in part, a suggestion in Reference 34 that the foundations be as compact as possible. Additionally, weight is made available for the interconnecting structure between the primary, secondary, and receiving optics, if needed to minimize alignment dependence on the subsurface state. Basically, the concept utilizes lunar rock in place of the heavy structure of conventional large telescopes and minimizes the amount of heavy equipment that must be precisely moved during the course of an observation. A design description of the concept is presented in Reference 3. To limit the amount of assembly work performed in the lunar environment, the concept permits the telescope components to be delivered in complete units.

Table 22. Lunar Astronomical Observatory, 100-Inch Horizontal Off-Axis Telescope—Weight Summary

Item	Weight (kg)		Weight (lb)	
		Subtotal		Subtotal
Flat 200-inch collector installation		5,920		13,000
Mirror and backup structure	3,640		8,000	
Mirror base and jacks	2,050		4,500	
Drive mechanism, heaters	230		500	
Dome and foundation		2,730		6,000
Primary 100-inch mirror installation		2,860		6,300
Mirror and backup structure	910		2,000	
Mirror base and jacks	770		1,700	
Housing (nose-cone) and foundation	1,180		2,600	
Observatory control and instrument rooms		2,140		4,700
Control room	820		1,800	
Instrument room	1,320		2,900	
Observatory equipment		1,230		2,700
Secondary optics installation	320		700	
Instruments, consoles, and supports	910		2,000	
Horizontal tunnel enclosure		1,870		4,100
Foam material	1,280		2,800	
Mylar bags and supports	230		500	
Installation provision	360		800	
Environmental control provisions		820		1,800
Interconnecting structure (contingency)		450		1,000
Total		18,000		39,600

Table 21 presents preliminary weight estimates of the 100-inch telescope system and its major components.

6.4.5 PACKAGING AND DEPLOYMENT

A preliminary approach to packaging the telescope components in two 260-inch OD payloads is shown in Figure 25. The payload envelopes used are those supplied by the MIMOSA study for an LLV vehicle which will transport the payload to the lunar surface. Corresponding payload weight capability is 66,000 pounds per payload, for a total of 132,000 pounds. As noted in Figure 25, most of the volume is used for telescope system components which weigh a total of 39,600 pounds. Thus, the weight capability of the payload envelope is not consistent with the weight requirements of the telescope payload. It should be noted that the envelope given is 21 inches shorter than that for the LESA 1 payload (Reference 33).

The second payload envelope identified by Lockheed has an outer diameter of 396 inches and an internal clearance envelope of 356 inches. Weight capability for this payload is 55,000 pounds, which is more compatible with the 39,600-pound telescope system weight. Figure 26 shows how the 100-inch telescope can be packaged for delivery to the lunar surface in one payload of this size.

The deployment approach adopted is to utilize, to the degree feasible, the deployment techniques and equipment recommended in the LESA deployment procedures study (Reference 33). Since the 356-inch diameter payload is the most complex to deploy, the steps are reviewed for this package to assess feasibility. The procedures are illustrated in Figures 27 and 28. Deployment steps are:

1. Remove entire payload from LLV using extendable track system.

2. Attach powered track and wheeled outriggers.

3. Move (self-propel) payload to observatory site.

4. Set up track for removal of 100-inch primary, enclosure (forward nose cone), and contents.

5. Move primary mirror and support system, enclosure, and instrument room to intermediate position on track.

6. Lower instrument room to surface between tracks and cross ties.

7. Deploy primary mirror and support system to previously prepared foundation.

8. Extend davit (or extensible boom crane) and unload secondary equipment.

9. Detach and lower 12.5-degree sections of nose cone, using unloading davit. (One blowout section in nose cone is required.)

10. Remove dome base and set aside.

11. Remove main dome and set aside.

12. Move (self-propel) payload into position for deployment of 200-inch flat mirror and support system.

13. Remove side panel and attach tracks to final installed position for 200-inch mirror and support system.

14. Deploy 200-inch mirror and support system and emplace on previously prepared foundation.

15. Remove observatory control room from base and emplace on previously prepared supports.

16. Pick up dome base with davit and emplace on previously prepared supports.

17. Pick up rotatable dome with davit and emplace on dome base.

18. Unload, deploy, tie down, and fill inflatable tunnel with foam.

19. Connect observatory control and instrument rooms.

20. Lower and secure 100-inch primary mirror; install and position secondary optics.

21. Make all mechanical, electrical and structural connections. Activate power and environmental subsystems.

22. Check out and align optics.

Once positioned in an approximate manner, final precise positioning can be accomplished with integral adjustment units that can be powered by an electrical deployment source.

Activation and checkout procedures for complete observatory are then performed.

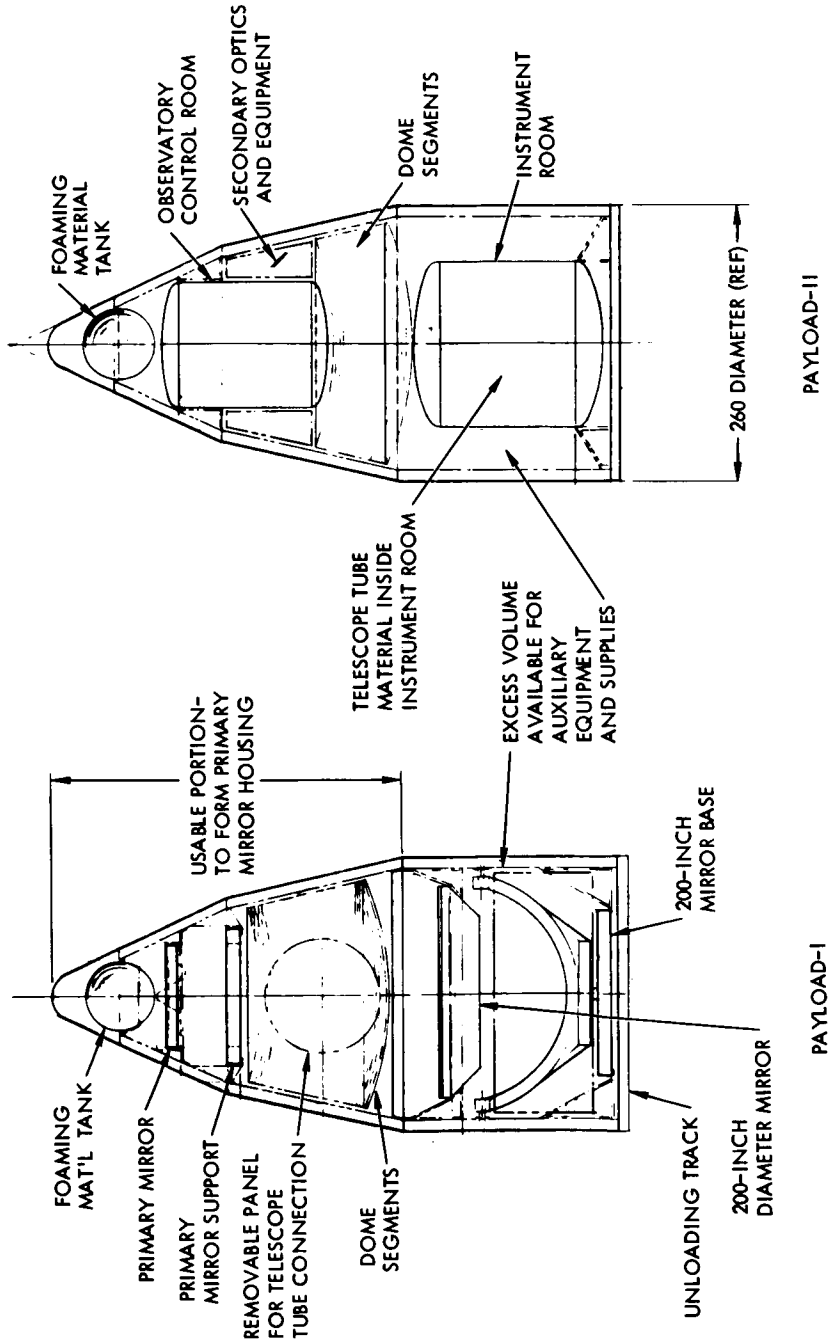


Figure 25. 100-Inch Lunar Telescope Packaging Concept—Two 260-Inch Diameter Payloads

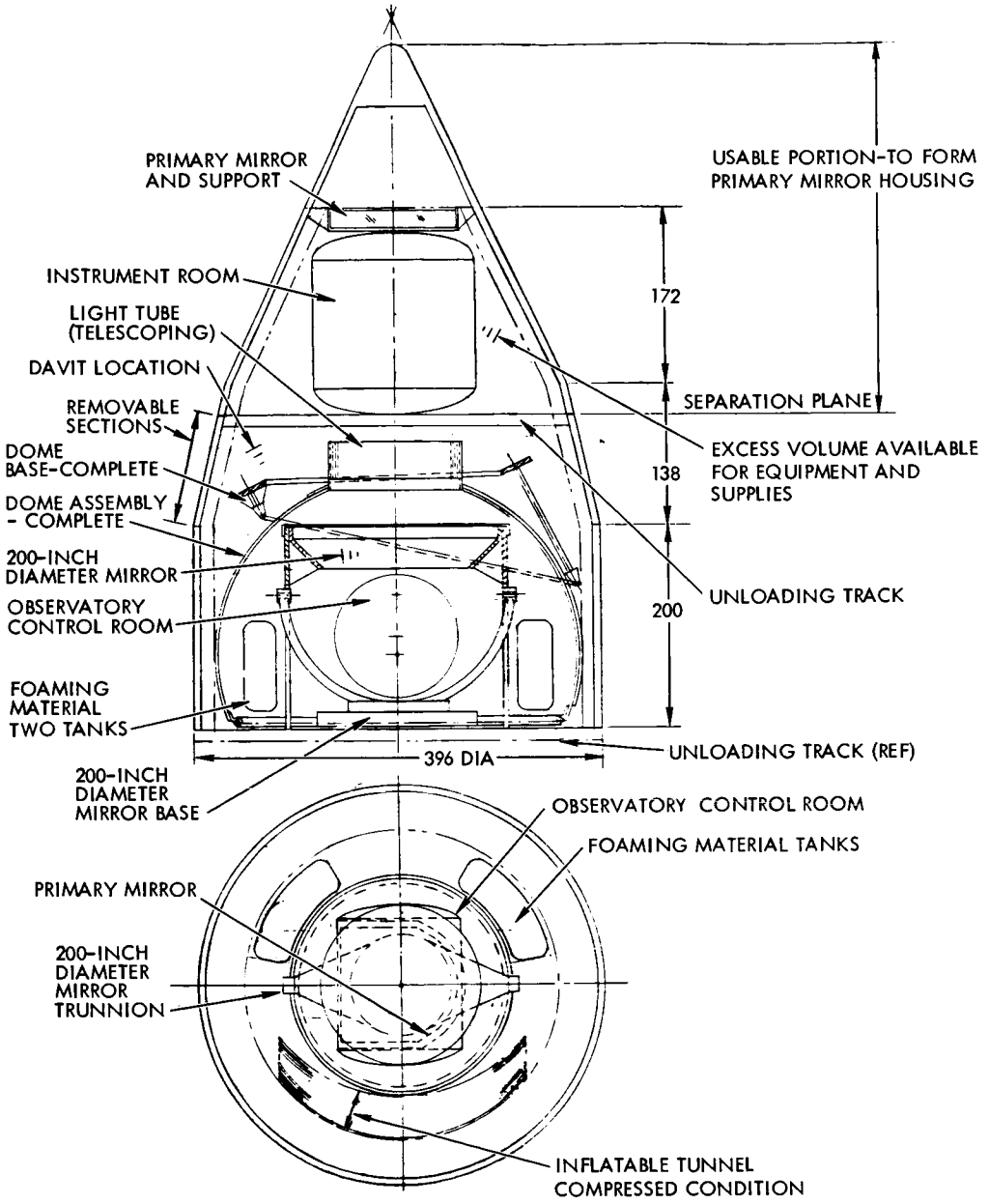


Figure 26. 100-Inch Lunar Telescope Packaging Concept—396-Inch Diameter Payload

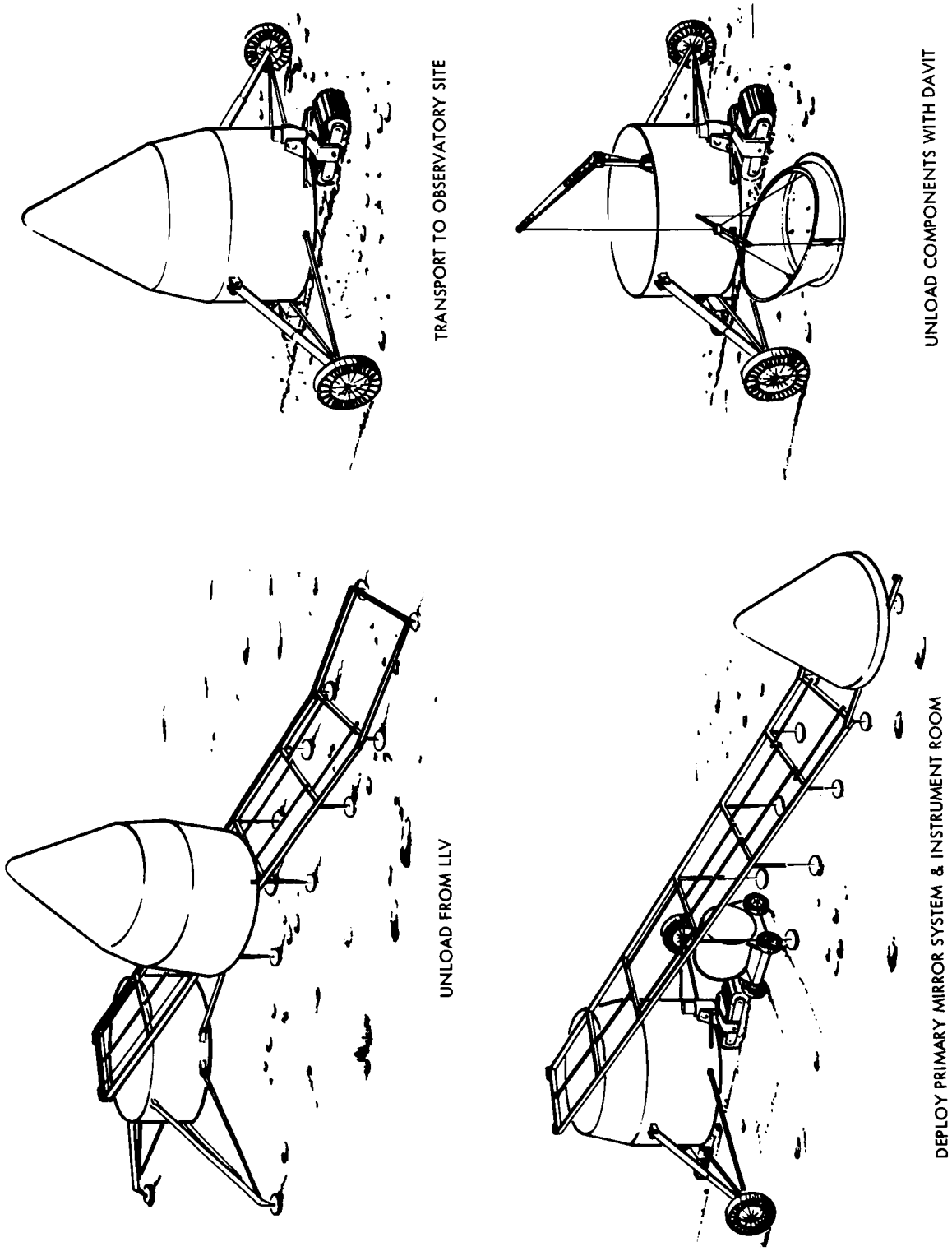
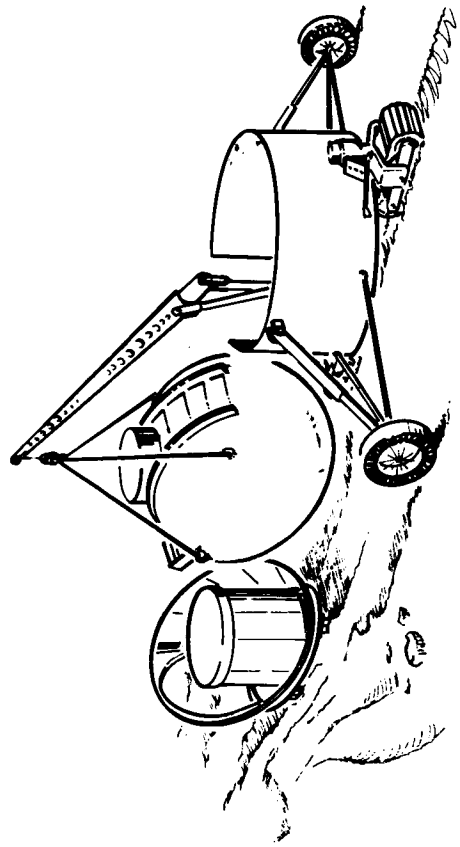
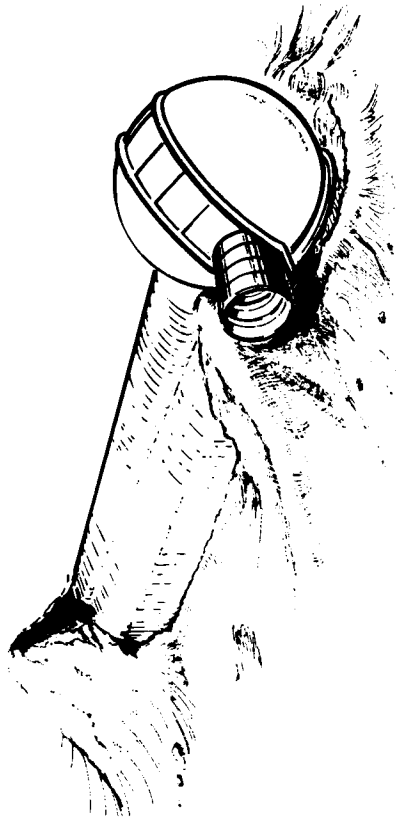


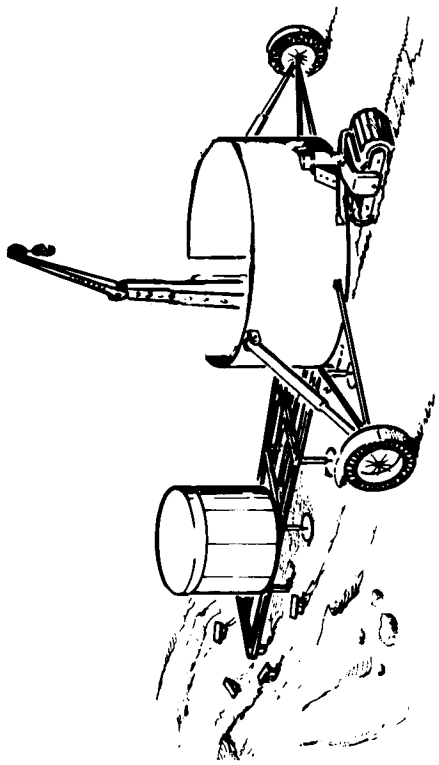
Figure 27. Deployment of 100-Inch Horizontal Telescope, Part I



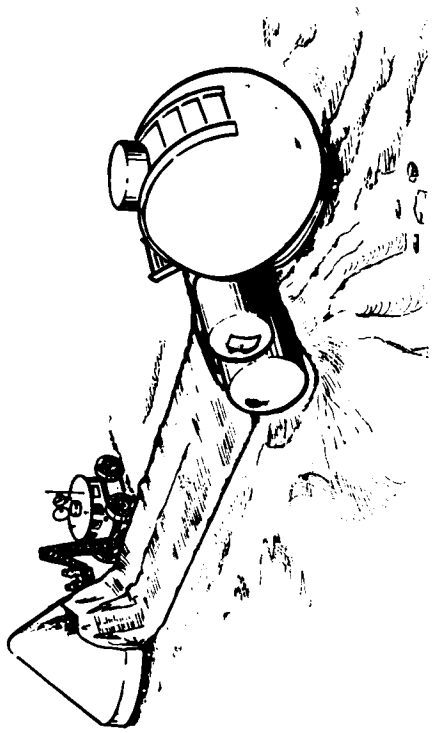
INSTALL DOME SEGMENTS



ALIGN OPTICS, ACTIVATE & CHECKOUT



UNLOAD 200-INCH SIDEROSTAT



DEPLOY INFLATABLE TUNNEL

Figure 28. Deployment of 100-Inch Horizontal Telescope, Part II

6.4.6 MANPOWER

Manpower requirements for deployment and activation of the 100-inch telescope, based on information in Reference 3, Volume IV, are 740 man-hours. Of this total, approximately 400 man-hours are required in space suits for external setup, which includes unloading, module emplacement, and structural assembly and alignment. The balance of time, 340 man-hours, is utilized in a shirtsleeve environment for component installation, vernier alignment, and systems checkout.

7.0 EXPERIMENT SEQUENCING

7.1 INTRODUCTION

The experiments compiled under this study effort have been organized into four separate sequences to provide a tool for evaluating program decisions concerning costs, schedules, operations, and requirements for alternate lunar exploration systems. The sequences developed are as follows:

1. The Discipline Sequences order the experiments defined in each discipline area according to a logical sequence of scientific accomplishment allowing an orderly progression of scientific understanding. The Discipline Sequences form the basis for the development of the Exploration Phase and Composite Sequences, items 3 and 4 below.

2. Mission Support Sequences order the experiments within each discipline and across disciplines by increasing mass, energy, and man-hour requirements. These sequences show the distribution of these critical parameters and can be used to evaluate combinations of experiments for mission planning purposes.

3. The Exploration Phase Sequences order the experiments within a given discipline area into logical phases of progressive scientific knowledge and increasing mission requirements.

4. The Composite Sequences are interdisciplinary ordering of experiments within each Exploration Phase. Figure 29 illustrates the logical progression of sequences.

Experiment sequences are formulated to better understand the scientific-mission support requirements and to aid in the development of future lunar exploration programs. The planning of lunar exploration requires the organization of scientific experiments and investigations into logical order and groups so that maximum advantage can be taken of the amount of equipment and man-hours available to perform the scientific investigations on the lunar surface during any particular period. Optimum planning must consider individual experiments and their related support requirements, as

well as the relationship between experiments within and across various scientific disciplines. The approach to experiment sequencing in this study is based on an orderly scientific progression.

The Discipline Sequences are supplemented by consideration of experiment support requirements which are used to arrange the experiments into Mission Support and Exploration Phase Sequences. Finally, Composite Sequences consider experiment interrelationships across scientific discipline areas. All sequences are assembled unconstrained by the capabilities of any single candidate mission system but within the generally accepted system operational capabilities for the appropriate period of lunar exploration. A building-block approach was utilized with the disciplinary sequences forming the basic foundation. In this manner, consideration of the scientists' desires is maintained throughout.

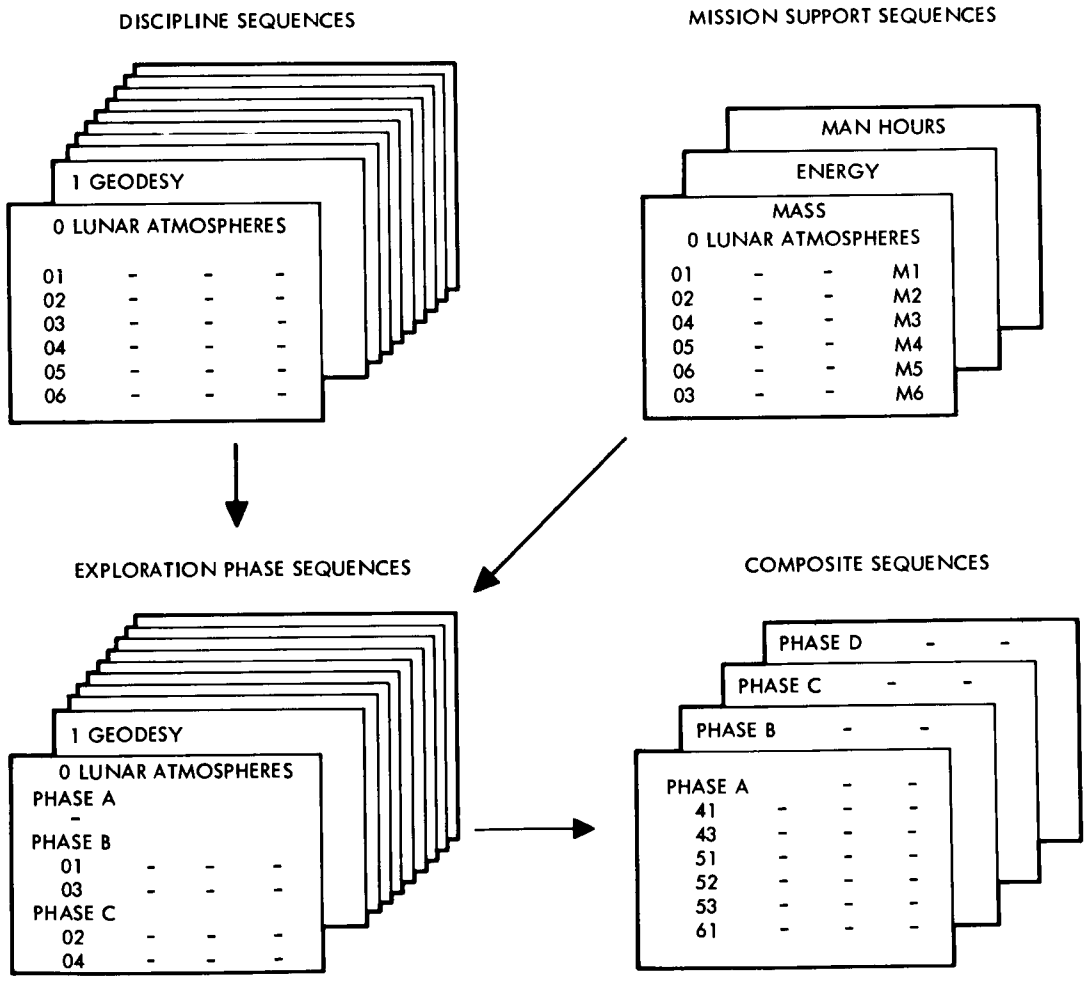


Figure 29. Experiment Sequences Schematic

7.2 DISCIPLINE SEQUENCES

As mentioned in Section 7.1, the Discipline Sequences order the experiments within a given discipline according to an orderly progression of scientific accomplishment, based on the desires of the scientific community as interpreted by the NAA scientific staff. The Discipline Sequences form the basis for the development of the Exploration Phase and Composite Phase sequences, discussed in Sections 7.4 and 7.5. The location of an experiment within the Discipline Sequence is referred to as the "order of the experiment." The summary of the experiment information, arranged in this order by discipline, is shown as a printout of computer-generated and manually-arranged Type-1 cards in Volume 4 (Appendix A)

7.3 MISSION SUPPORT SEQUENCES

The Mission Support Sequences are listings of the experiments within each discipline and across disciplines according to increasing mass, energy, and man-hour requirements. These sequences were generated by utilizing a sorter to arrange three separate sets of Type-1 cards by mass, energy and man-hours, respectively. The printouts from this experiment sorting are given in Volume 4 (Appendix A). The sequences can be used to determine various combinations of mass to make up a payload, various energy combinations that are within the capability of a given energy source, and groupings of experiments within a specified stay time on the lunar surface.

7.3.1 DISCIPLINE AREA RESULTS

Figures 30 through 39, appearing on pages 296-305, indicate the distribution of experiments within each discipline area according to mass, energy and man-hour requirements. These diagrams were plotted from numerical data appearing in Volume 4 as computer print-outs of Mission Support Sequences of mass, energy and man-hours within disciplines. No man-hours for orbital experiments have been included in these figures.

The same data are presented in summarized form in Table 23 which lists the minimum, median and maximum mass, energy and man-hour requirements within each discipline area. The median value indicates support requirements imposed individually by 50 percent of the experiments included in a given discipline area. The maximum value is indicative of a support capability that would allow inclusion of any of the experiments listed under a given discipline area as far as the particular mission support parameter is concerned.

From the listings of Table 23, it can be seen that a three-kilogram allowance is a minimum mass requirement for any discipline area except Geodesy. It is also indicated that, with the exception of Geodesy and Particles-and-Fields, the minimum energy requirement for any other discipline area is two watt-hours. The maximum mass requirements of 22,000 and 20,000 kilograms, listed for Geophysics and Astronomy respectively, are due to the large telescopes included in these two discpline areas. The maximum mass requirement of 7,000 kilograms listed for Geology refers to the deep (300-meter) drilling experiment. With the exception of these three entries, Table 23 and Figures 30 through 39 indicate that a 2500 kilogram mass capability would accommodate any other experiment included in this study effort.

Table 23. Mission Support Requirements Summary by Discipline Areas

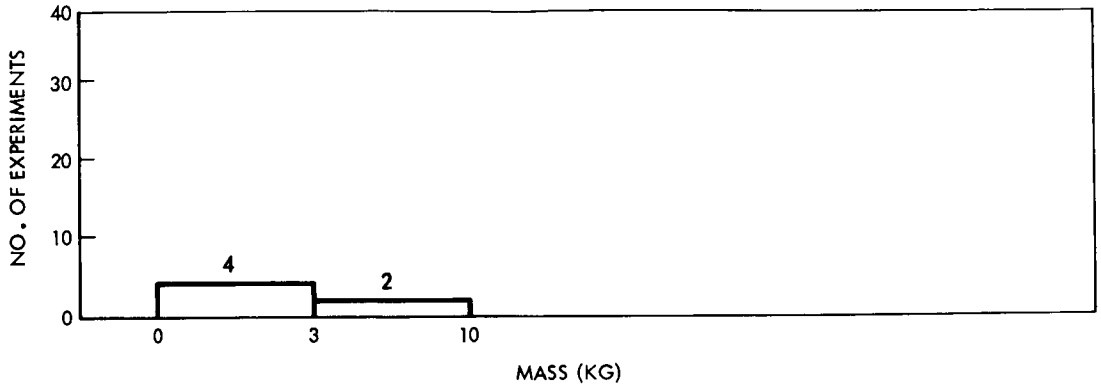
Discipline Area	No.	Parameter	Minimum	Median*	Maximum
0 Lunar Atmospheres	6	Mass (kilograms)	1.0	2.0	8.5
		Man-Hours	0.1	1.0	20
		Energy (kw-hrs)	1.6×10^{-5}	8.0	40
1 Geodesy	7	Mass (kilograms)	27	140	530
		Man-Hours	14	55	73
		Energy (kw-hrs)	1.7	3.4	8.0
2 Geology	14	Mass (kilograms)	1.0	33	7000
		Man-Hours	0.1	5.0	1200
		Energy (kw-hrs)	0	0.17	4500
3 Geochemistry	23	Mass (kilograms)	0.5	15	32
		Man-hours	4.5	22	200
		Energy (kw-hrs)	0	2.0	150
4 Geophysics	94	Mass (kilograms)	0.55	6.0	22,000
		Man-hours	0.1	1.0	1000
		Energy (kw-hrs)	0	0.044	29
5 Particles and Fields	47	Mass (kilograms)	2.0	25	2,500
		Man-hours	0.2	55	520
		Energy (kw-hrs)	0.03	20	1600
6 Biology	7	Mass (kilograms)	0	26	260
		Man-hours	0	240	2,400
		Energy (kw-hrs)	0	0	7.7
7 Astronomy	37	Mass (kilograms)	2.0	51	20,000
		Man-hours	6.0	480	1,100
		Energy (kw-hrs)	2.0×10^{-3}	10	20,000
8 Mission Support Investigations	92	Mass (kilograms)	0	10	700
		Man-hours	0	4.5	500
		Energy (kw-hrs)	0	0.07	40
9 Miscellaneous Basic and Applied Research	9	Mass (kilograms)	3.0	20	100
		Man-hours	0.4	15	70
		Energy (kw-hrs)	0	1.0	10

*If total number of experiments, n, was an even number, the value for $\frac{n}{2} + 1$ was used in determining the median.

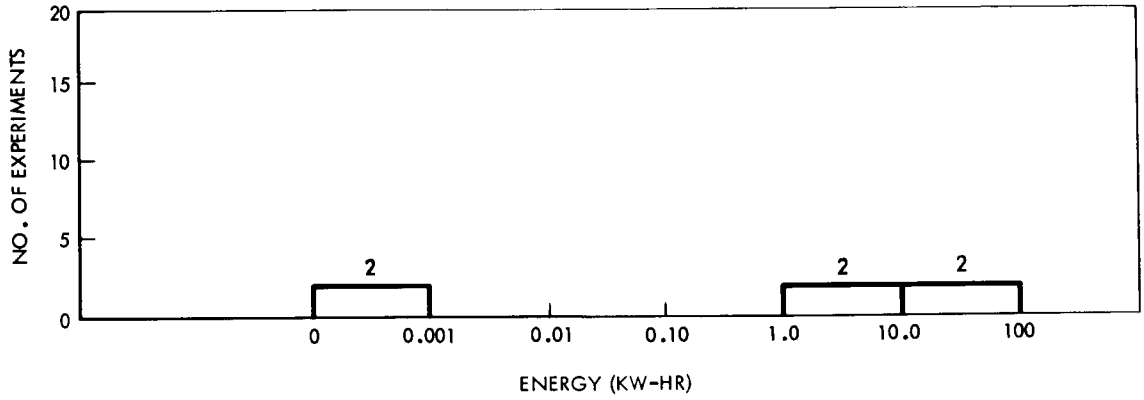
7.3.2 INTERDISCIPLINARY RESULTS

Figures 40, 41, and 42 on page 306 show respectively combined histograms for mass, energy and man-hours. The interdisciplinary histogram for mass peaks at the range of 10 to 30 kilograms, with 67 percent of the experiments less than 30 kilograms. This distribution is such that 17 percent of the experiments have a mass of less than 3 kilograms, 41 percent have a mass of less than 10 kilograms, while only 9 percent have a mass greater than 1000 kilograms. The interdisciplinary histogram for energy, shown in Figure 41, peaks at the range of 1.0 to 10 kilowatt hours. The distribution here is such that only 4 percent of the experiments exceed 100 kilowatt hours, 19 percent require less than one watt hour, and 42 percent require between 0.1 and 10 kilowatt hours.

These histograms can be used in evaluating the selection of experiments within a given system capability. For example, a system may have a capacity for 1000 kilograms of experiments. If it is desired to have the maximum number of experiments from all disciplines and the only restriction is mass, all of the 0 to 3 kilogram experiments would have an expected mass of 84 kilograms, and the 3 to 10 kilogram experiments would produce a total of 540 kilograms. Nineteen of the 10-30 kilogram experiments would produce 380 kilograms for a total of 1004 kilograms. To make up the desired 1000 kilograms, approximately 158 of the lightest experiments would be required. This quick approximation from the histograms compares favorably with the number 179 that would be obtained by selecting only the smallest mass experiments from all ten disciplines. More precise figures require mission formulation to define common equipment use between experiments. Common equipment usage between experiments would be expected to increase the number of experiments which could be performed for a given mass.



(A)



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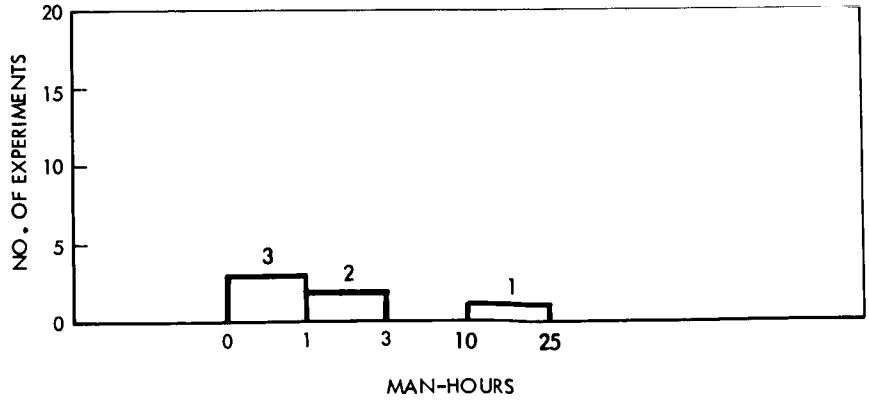
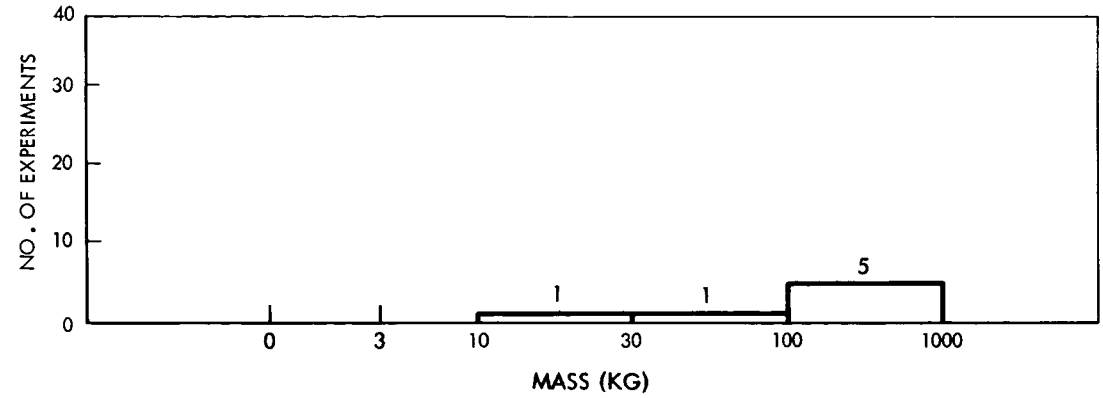
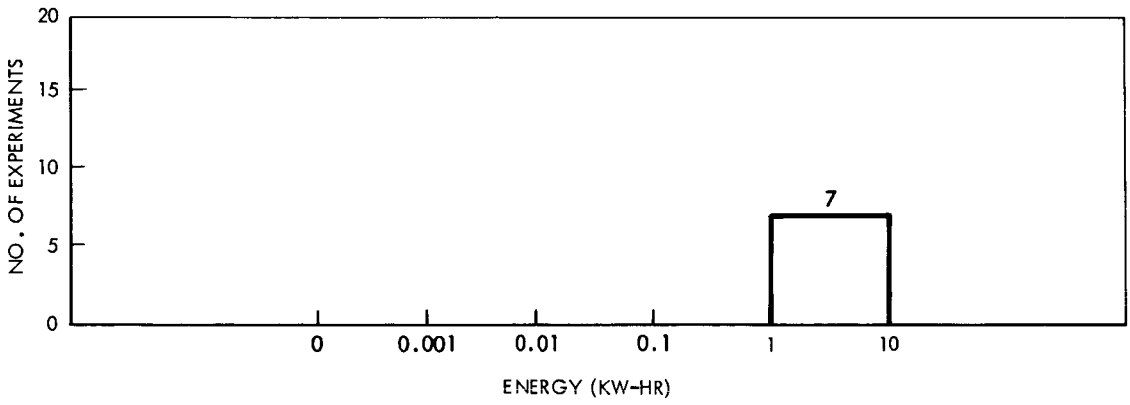


(C)

Figure 30. Histograms of Mission Support Requirements - Discipline Area 0, Lunar Atmospheres



(A)



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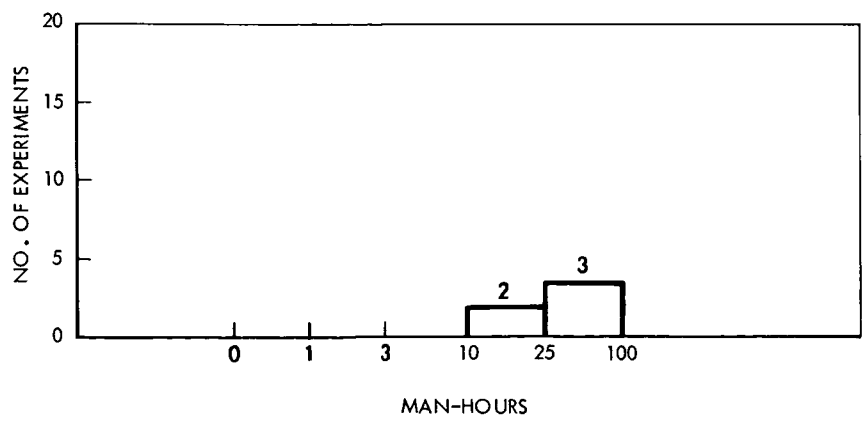

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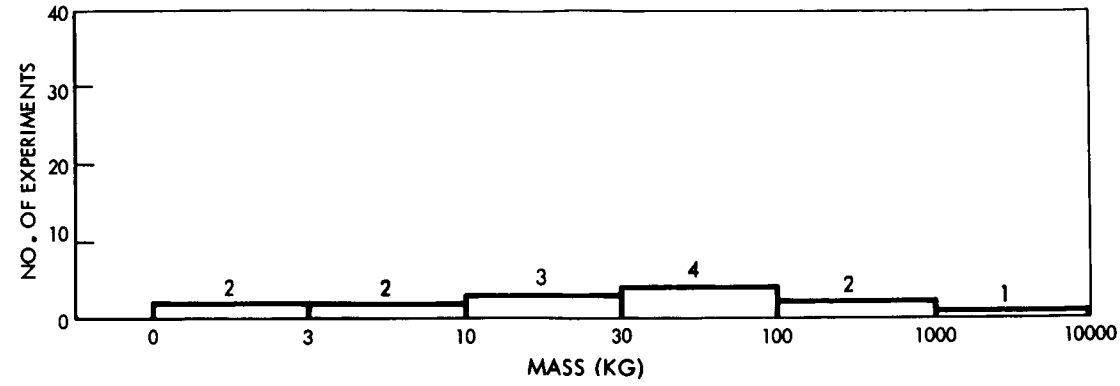
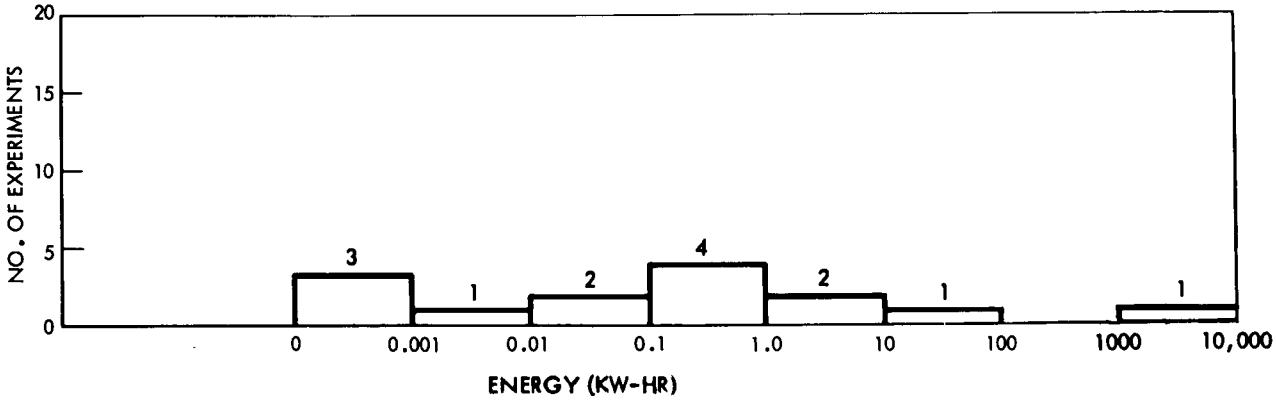
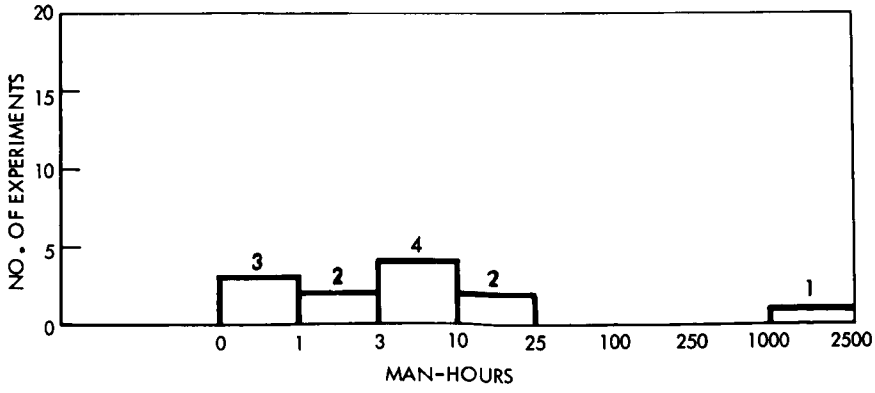
Figure 31. Histograms of Mission Support Requirements - Discipline Area 1, Geodesy



(A)



(B)



(C)

Figure 32. Histograms of Mission Support Requirements - Discipline Area 2, Geology

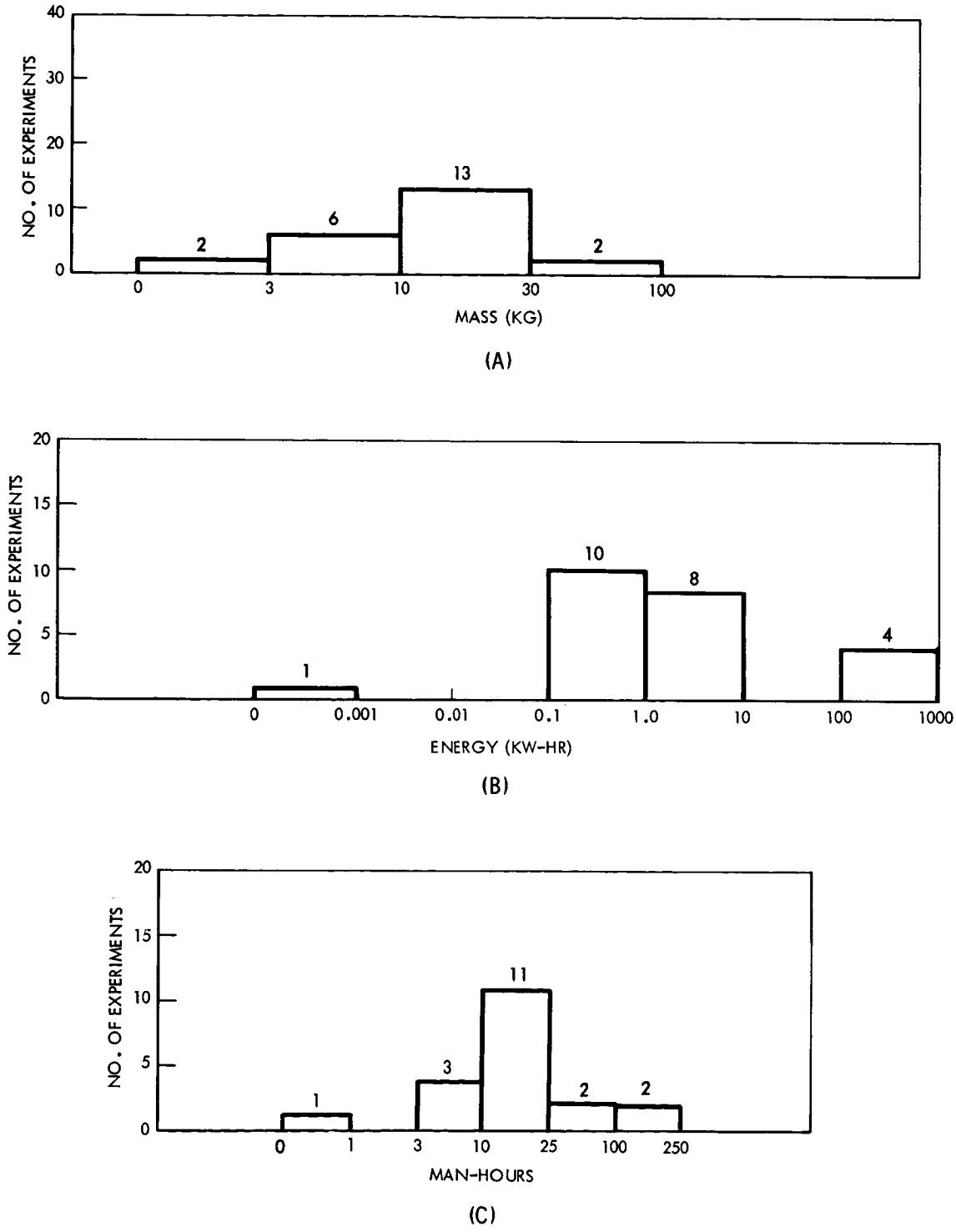


Figure 33. Histograms of Mission Support Requirements - Discipline Area 3, Geochemistry

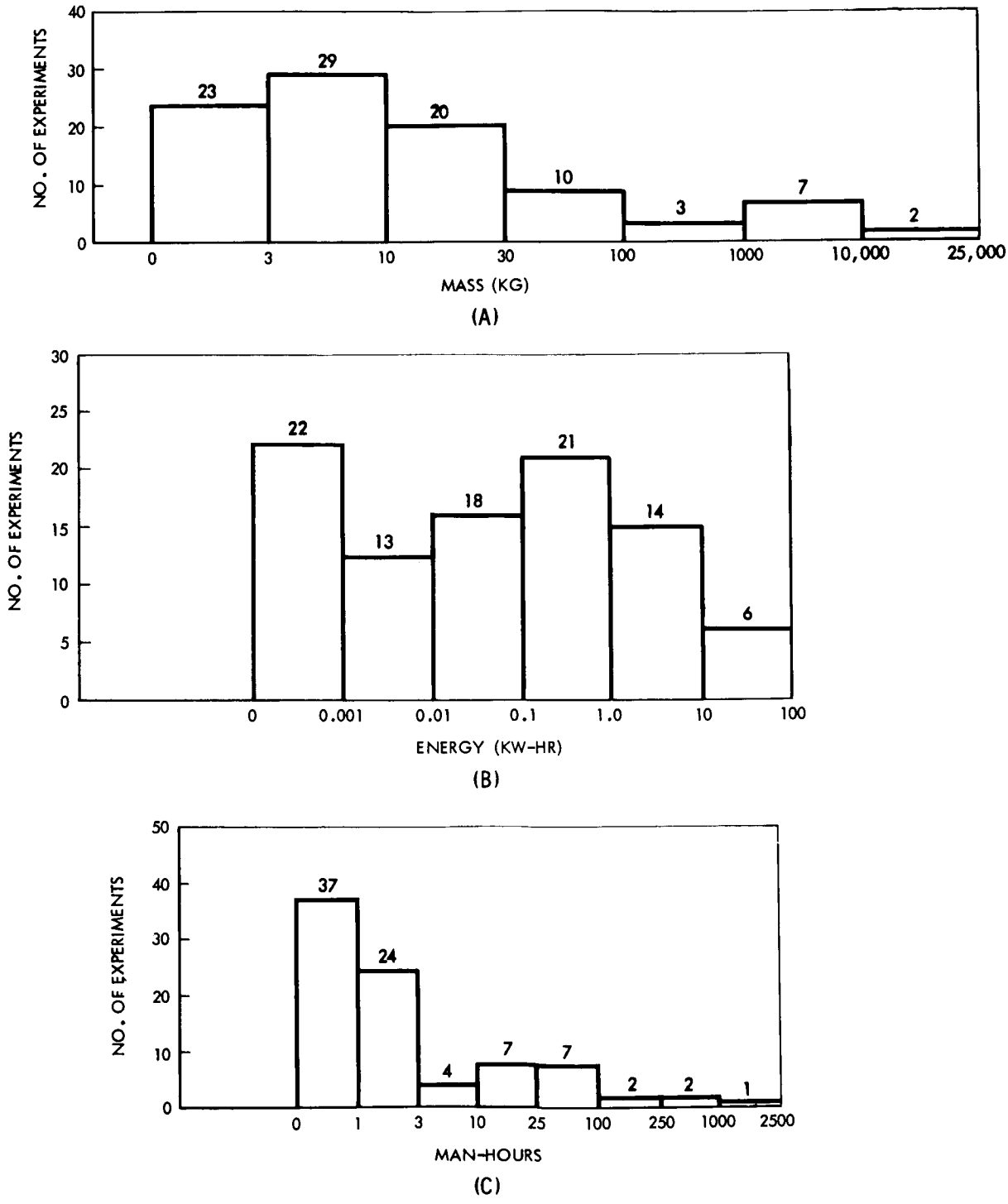
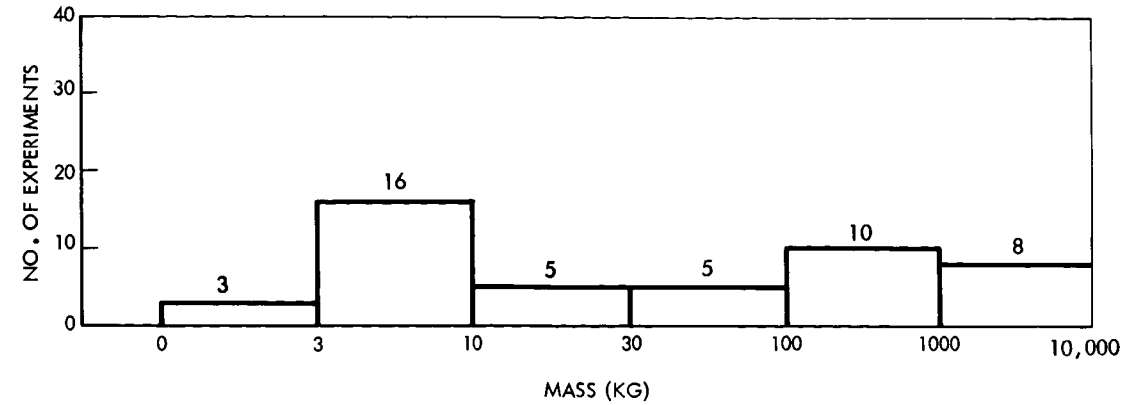


Figure 34. Histograms of Mission Support Requirements - Discipline Area 4, Geophysics



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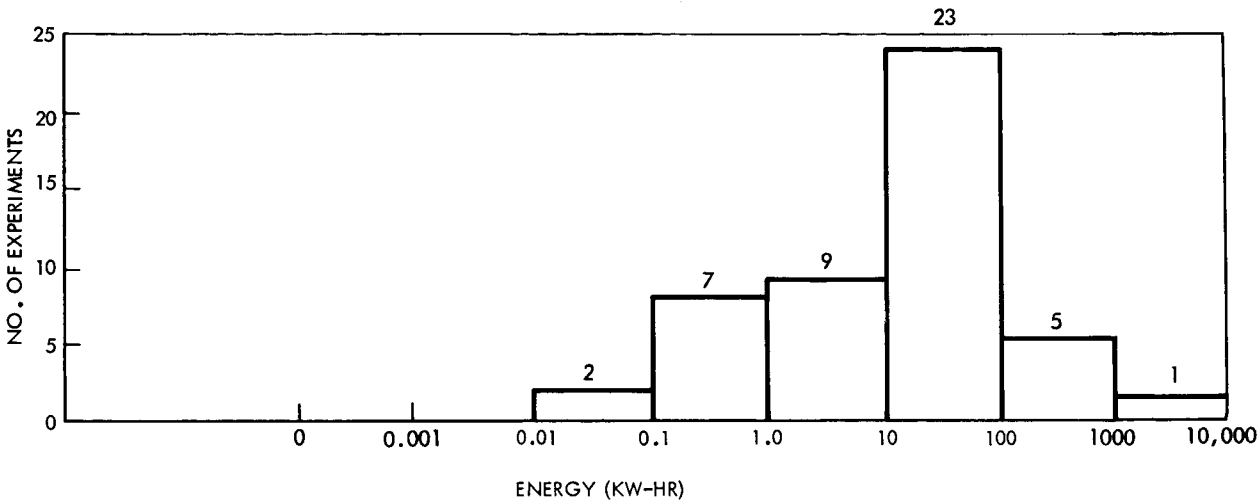

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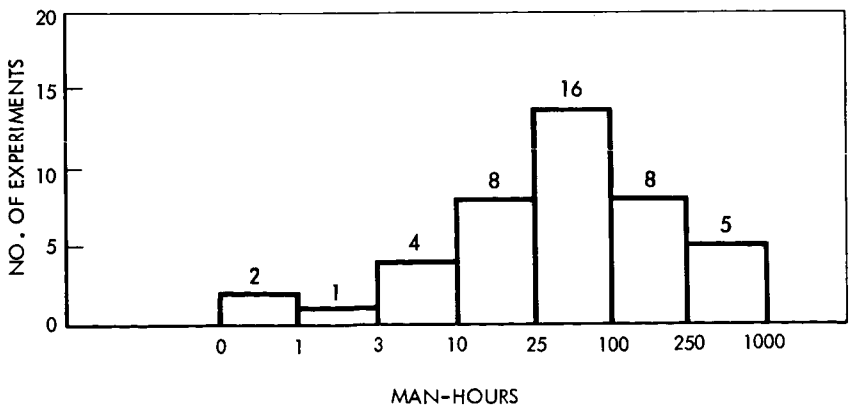

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Figure 35. Histograms of Mission Support Requirements - Discipline Area 5, Particles and Fields

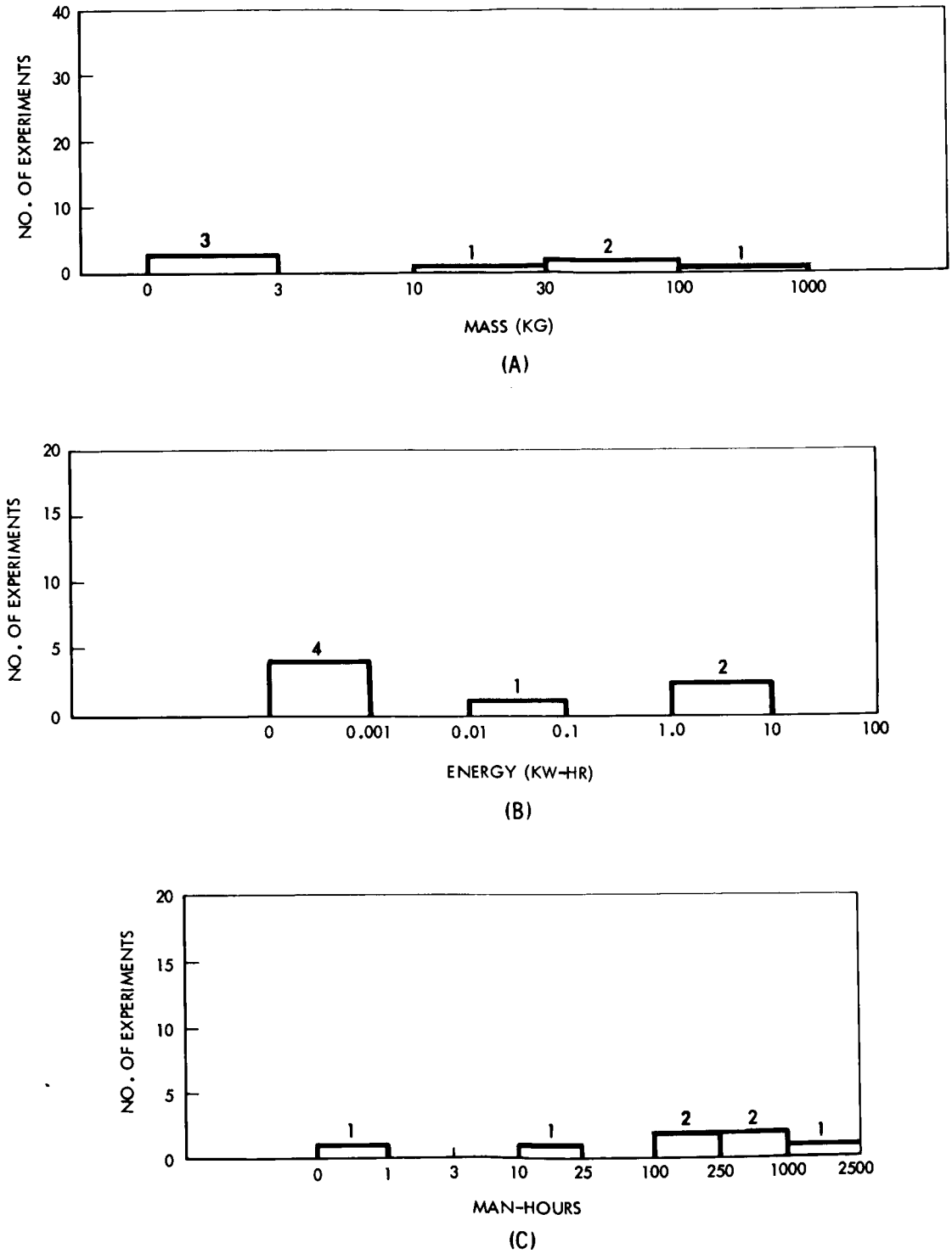
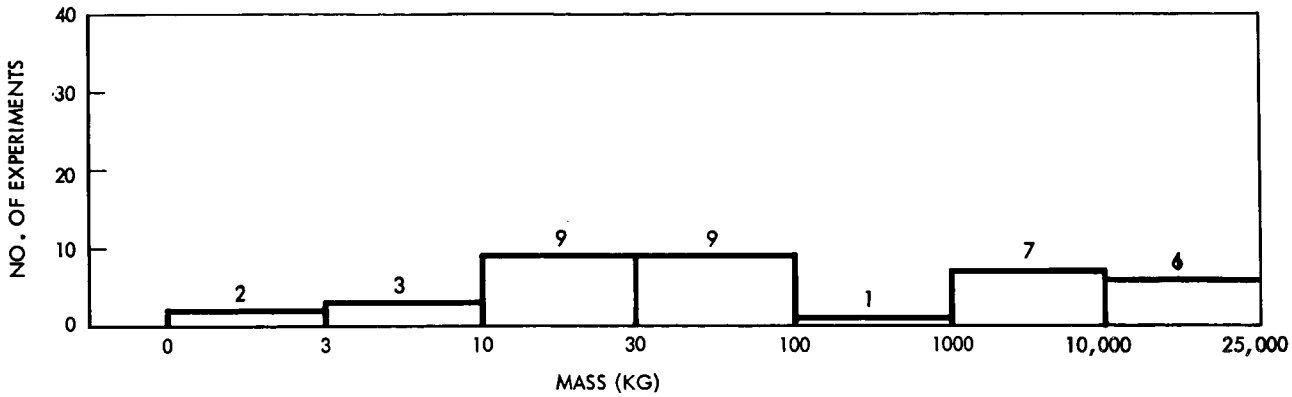
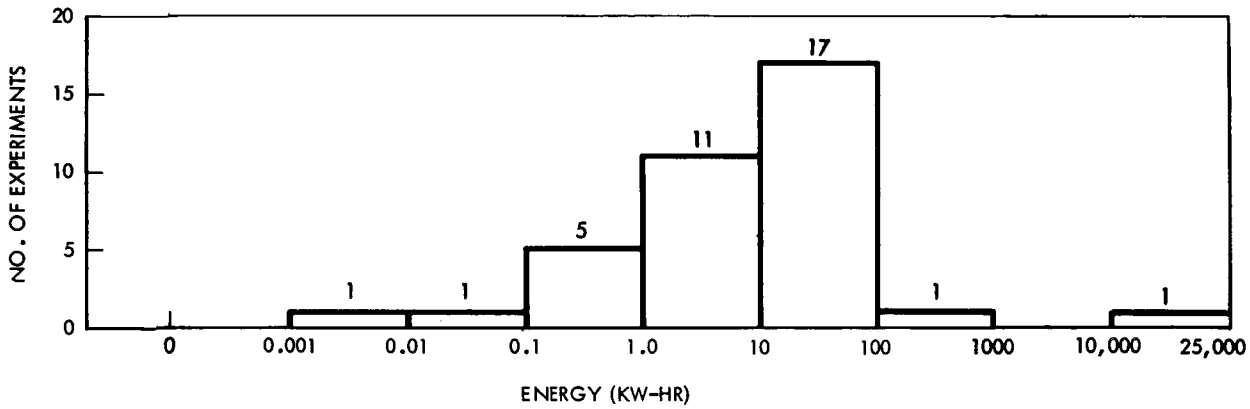


Figure 36. Histograms of Mission Support Requirements - Discipline Area 6, Biology



(A)



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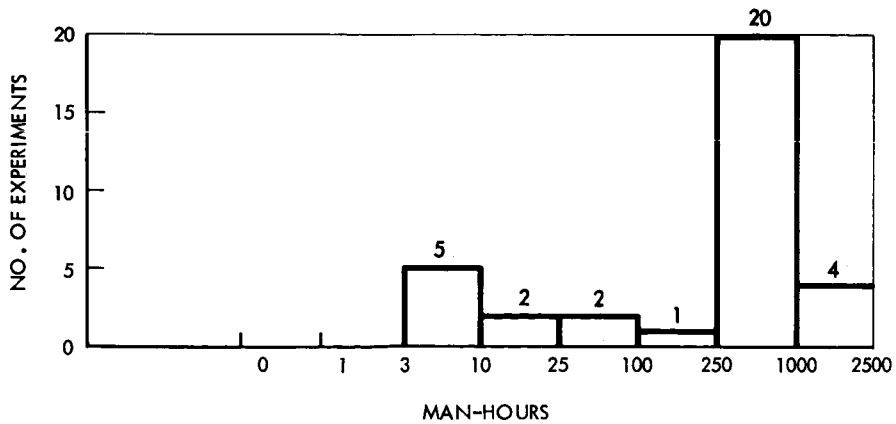

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Figure 37. Histograms of Mission Support Requirements - Discipline Area 7, Astronomy

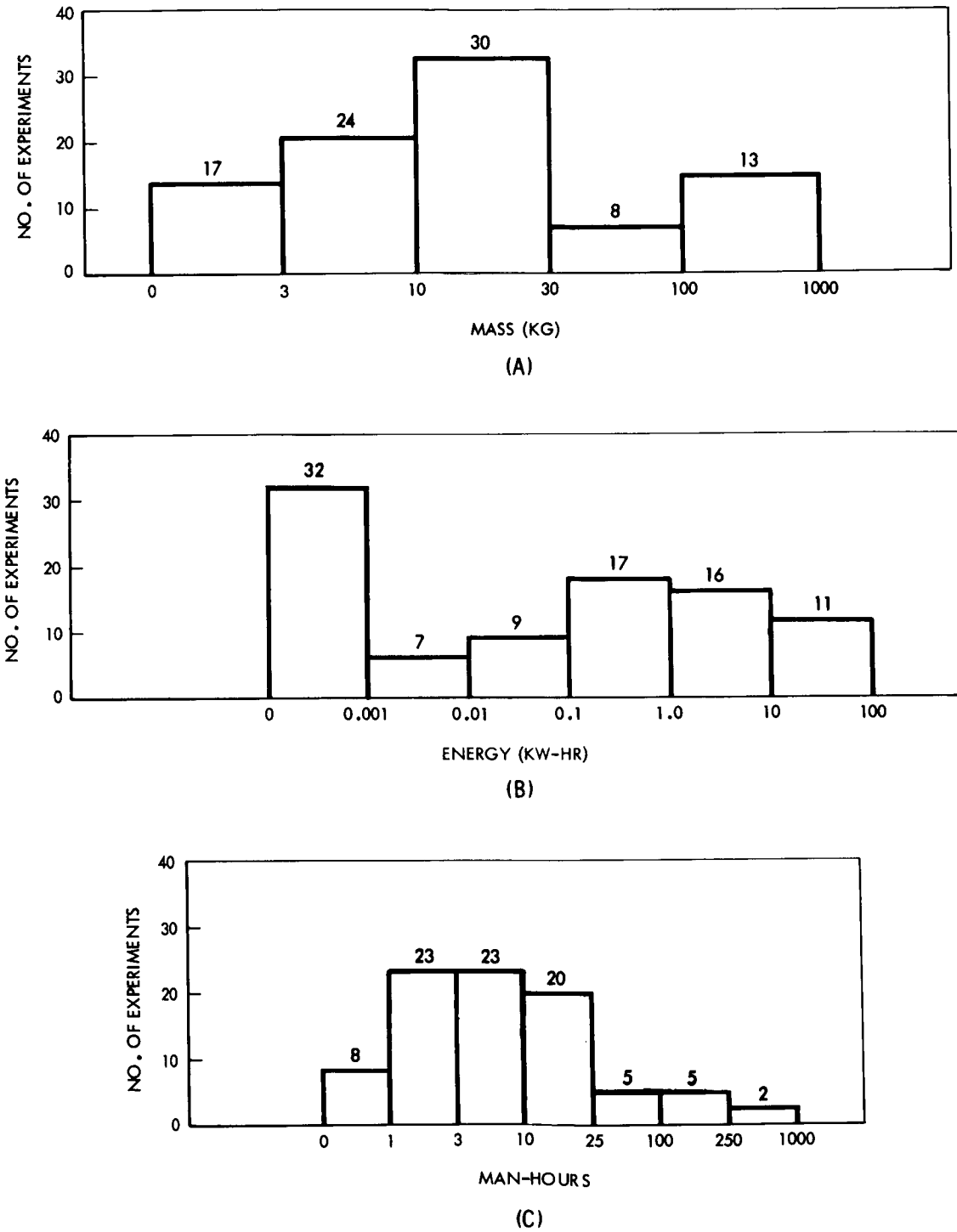


Figure 38. Histograms of Mission Support Requirements - Discipline Area 8, Mission Support Investigations

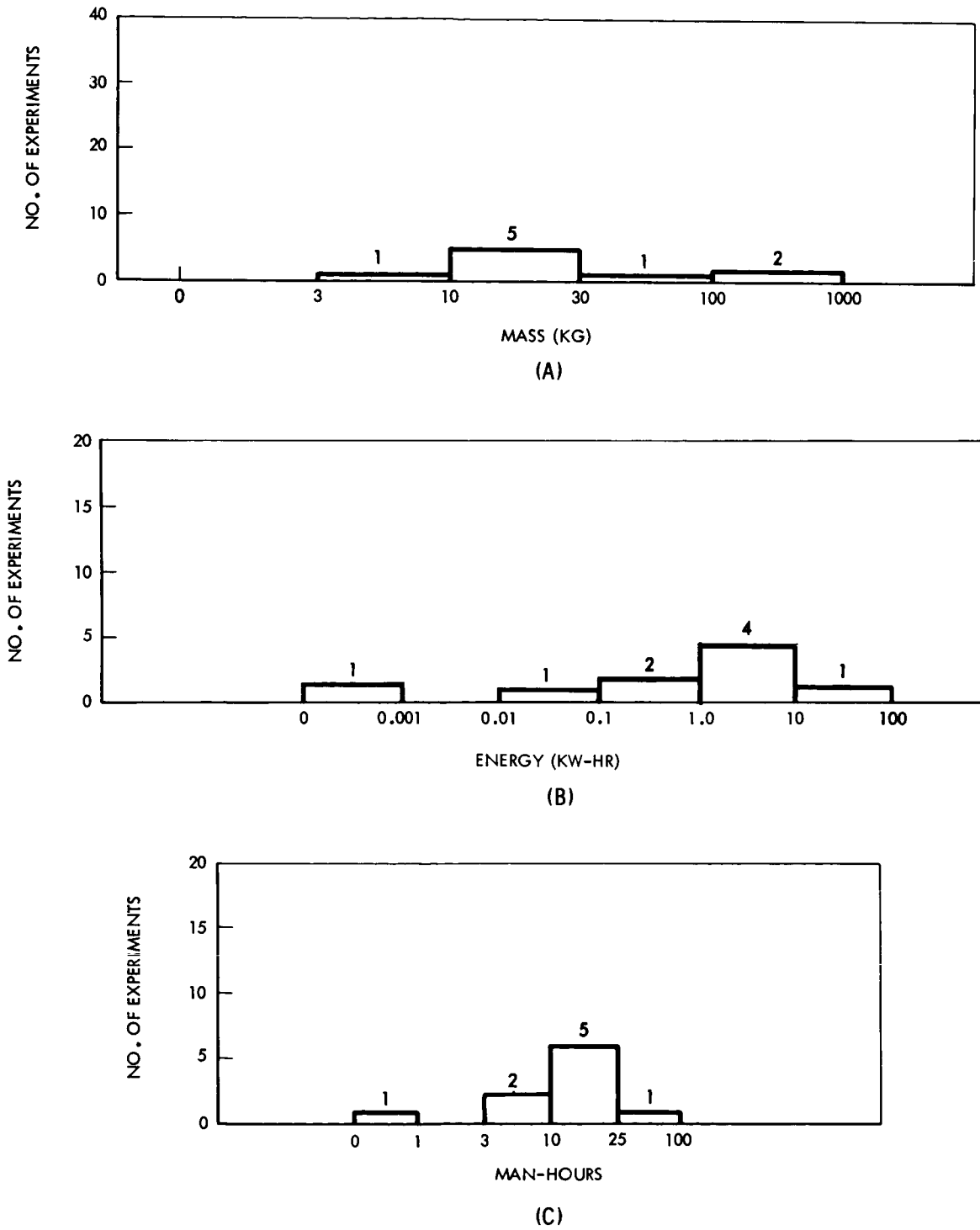


Figure 39. Histograms of Mission Support Requirements - Discipline Area 9, Miscellaneous Basic and Applied Research

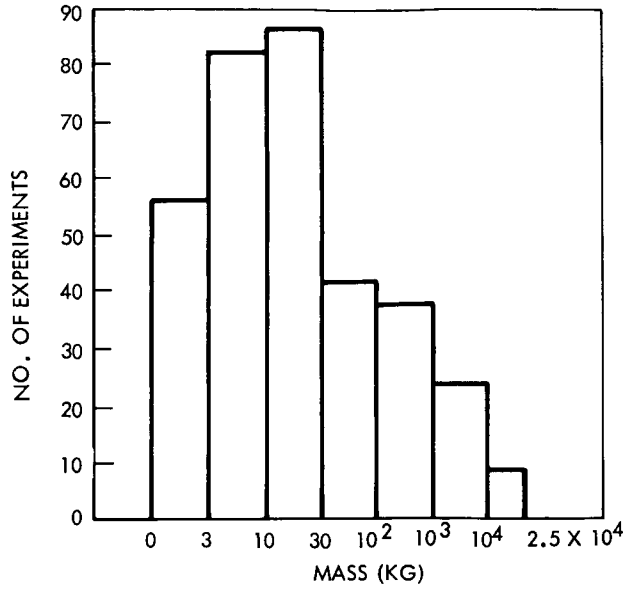


Figure 40. Experiment Distribution According to Mass Requirements - All Disciplines

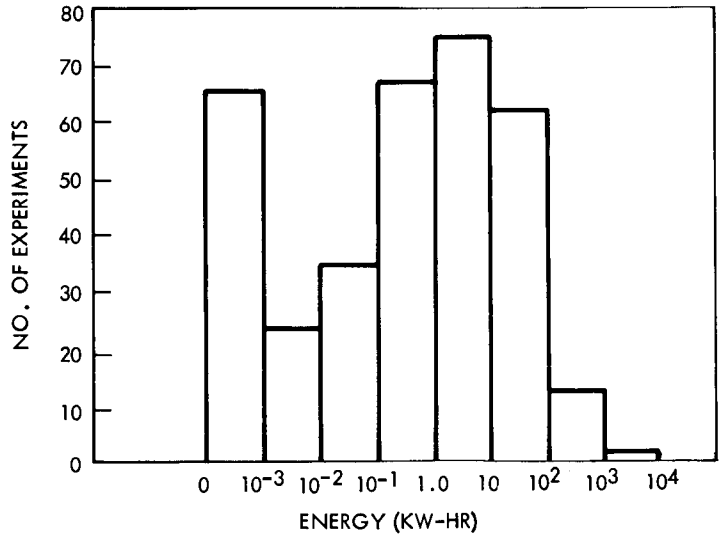


Figure 41. Experiment Distribution According to Energy Requirements - All Disciplines

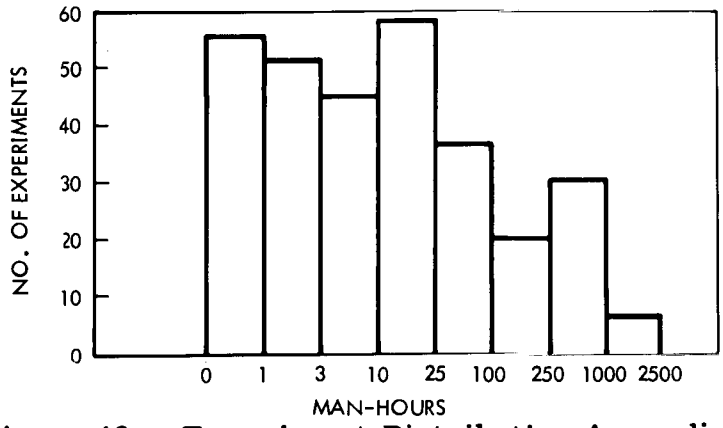


Figure 42. Experiment Distribution According to Man-Hour Requirements - All Disciplines

7.4 EXPLORATION PHASE SEQUENCES

The Exploration Phase Sequences identify logical phasing or periods of lunar exploration within each discipline area and the maximum support requirements per experiment within each phase. These sequences are based upon the premise that an experiment may be performed at the earliest time in which the requisite capability exists.

7.4.1 EXPERIMENT ORDERING

For each discipline, mass and energy requirements associated with a given experiment were plotted versus the experiment order as defined in the Discipline Sequences. Figure 43 shows a schematic diagram of such a plot. This graphical procedure provides insight into distinct and significant levels of experiment support requirements. For some disciplines, these plots can be enveloped by a horizontal line. Such an envelope is illustrated by line ABC of Figure 43 and indicates one level of support per experiment required throughout the whole lunar scientific program. This infers that a single system capable of meeting the support parameter required would be sufficient to accommodate experiments of this class if other support parameters are also satisfied. In some cases, several levels of support requirements are indicated. This is illustrated by line ABDEF for two levels, or by line ABDEGH for three levels. The breaks in levels illustrated by segments BD or EG would be indicative of a possible need in up-grading or modifying existing systems or developing a new system for the particular discipline under consideration. Similar plots for the various disciplines can be superimposed by normalizing the abscissa. The resultant graph provides an indication of the number of distinct levels of support per experiment required for extended lunar exploration.

The purpose of these two-dimensional diagrams was to determine potential phasing criteria based on smooth and gradual upgrading of experiment support requirements. If a point was found that was apparently out of trend, indicating requirements logically fitting later in the order, the experiment, and related subsequent experiments, were reviewed. If the experiment had no other experiment depending on it and appeared to be independent within the Discipline Sequence, the order of the experiment was modified so that the experiment could take place at a more logical point with respect to mission support requirements. In some cases, the experiment could not be moved without making it meaningless or moving a whole series of experiments closely associated with it. In these cases, the analysis

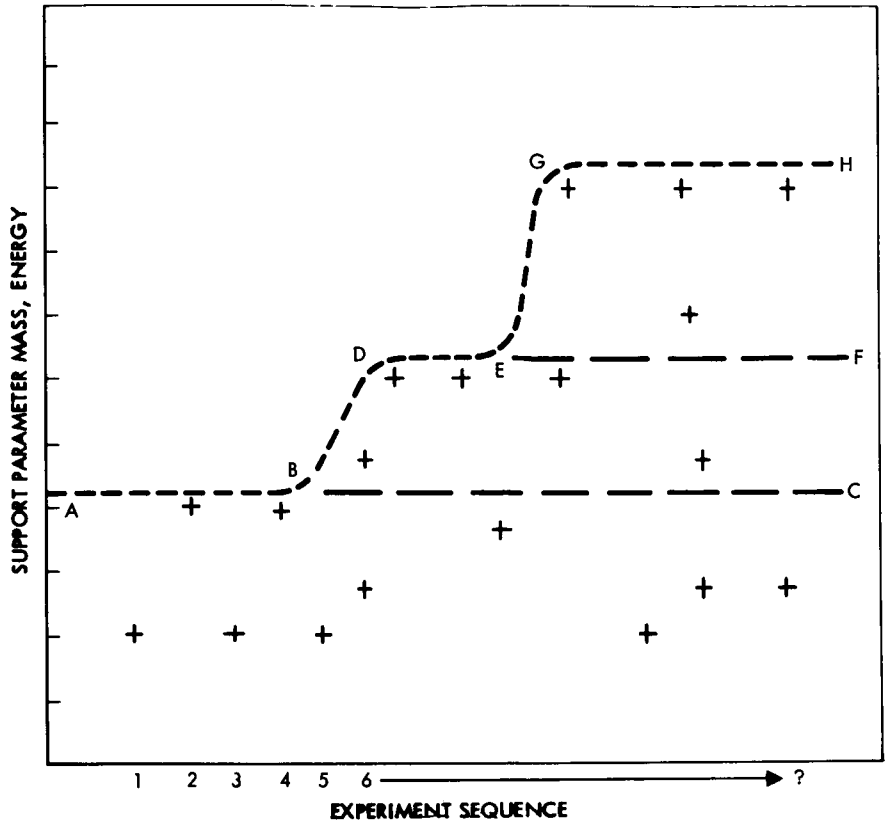


Figure 43. Mission Support Considerations

usually indicated whether the experiment should be included in a new phase with higher support capabilities or whether the experiment should be modified with respect to support requirements. The above analysis did not include orbital experiments which for the purpose of this analysis were considered to constitute a distinct phase of lunar exploration. Figures 47 through 69 (pp. 319-334) show, by discipline, the ordering of the experiments by each of the support factors' mass and energy, into the potential phasing criteria.

7.4.2 MASS AND ENERGY REQUIREMENTS

Figures 44 and 45 present respectively superimposed diagrams of mass and energy requirements versus experiment sequence corresponding to Discipline Areas 0 (Lunar Atmospheres) through 7 (Astronomy) which comprised the fundamental investigations. From these two figures, five phase breaks were identified. Potential phase breaks of 20, 150, 500 and 4000 kilograms were established for mass. Phase breaks of 0.6, 8.0, 50, and 200 kilowatt hours were established for energy. Location of the first phase break was determined from the present known mission support capabilities of the Apollo-LEM. The four remaining phase breaks were determined by the major changes in mass and energy requirements as indicated in Figures 44 and 45.

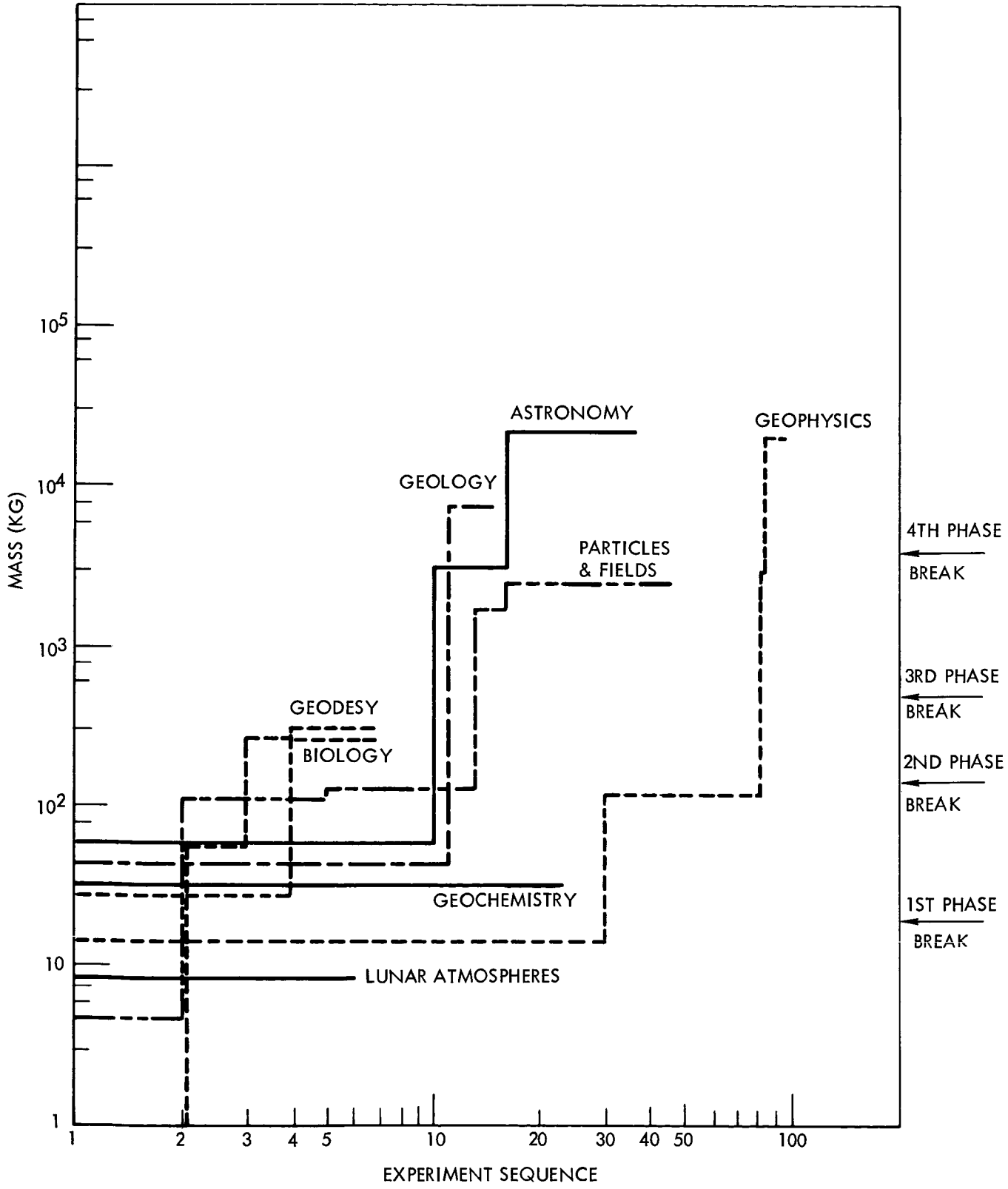


Figure 44. Mass Requirements Versus Experiment Sequence, Discipline Areas 0 Through 7

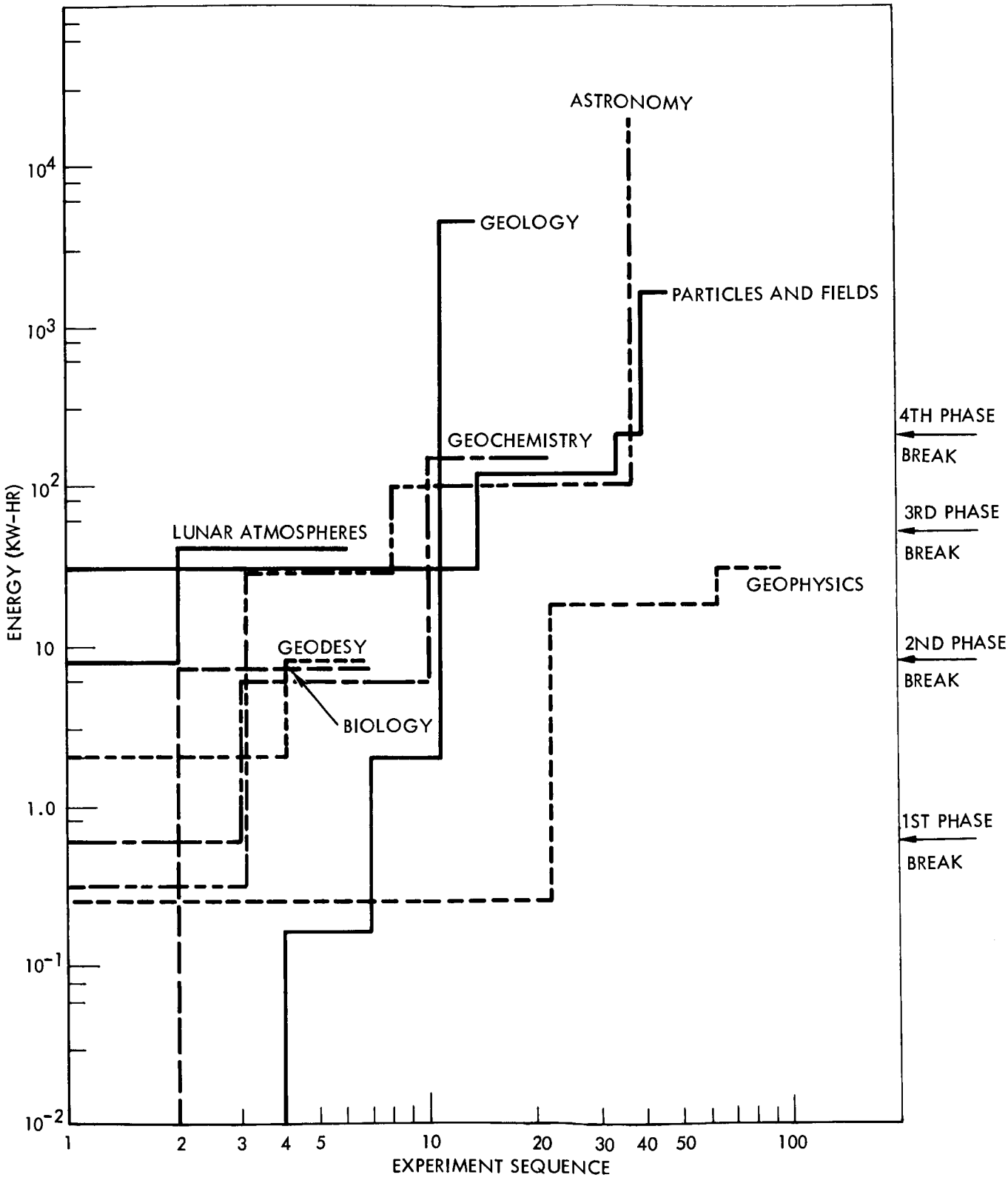


Figure 45. Energy Requirements Versus Experiment Sequence, Discipline Areas 0 Through 7

Based upon the potential phases established by Figures 44 and 45, the distribution of experiments by discipline within each of these potential phase envelopes was charted. Tables 24 and 25 show these distributions. Although these tables show that a large number of experiments are within the mass or energy capability of the Apollo-LEM (of the lunar surface experiments 59% require 20 kg or less and 50% require 600 watts or less) on the basis of either mass or energy alone, simultaneous occurrence of low level requirements in mass and energy is associated with only a relatively small percentage (12%) of the experiments. The largest mass requirements are indicated in Geophysics and Astronomy, where telescopes are the basic equipment. The largest energy requirements is in Discipline 7, Astronomy.

When the mass and energy criteria are combined, the phasing envelopes indicated in Figure 46 result. According to this scheme an experiment will be put into the earliest phase for which a capability to deliver the mass and also to provide the energy required by that experiment exists. The results indicate for example, that the experiments in Phase A would all contain a mass less than or equal to 20 kilograms and an energy requirement of less than or equal to 0.6 kilowatt hours. To accomplish this experiment sorting the Type 1 cards were separated mechanically by discipline into six groupings, namely, into orbital and five exploration phases as shown by the mass-energy envelopes of Figure 46. Within each of the five phases, the ordering of experiments established in the Discipline Sequences was maintained.

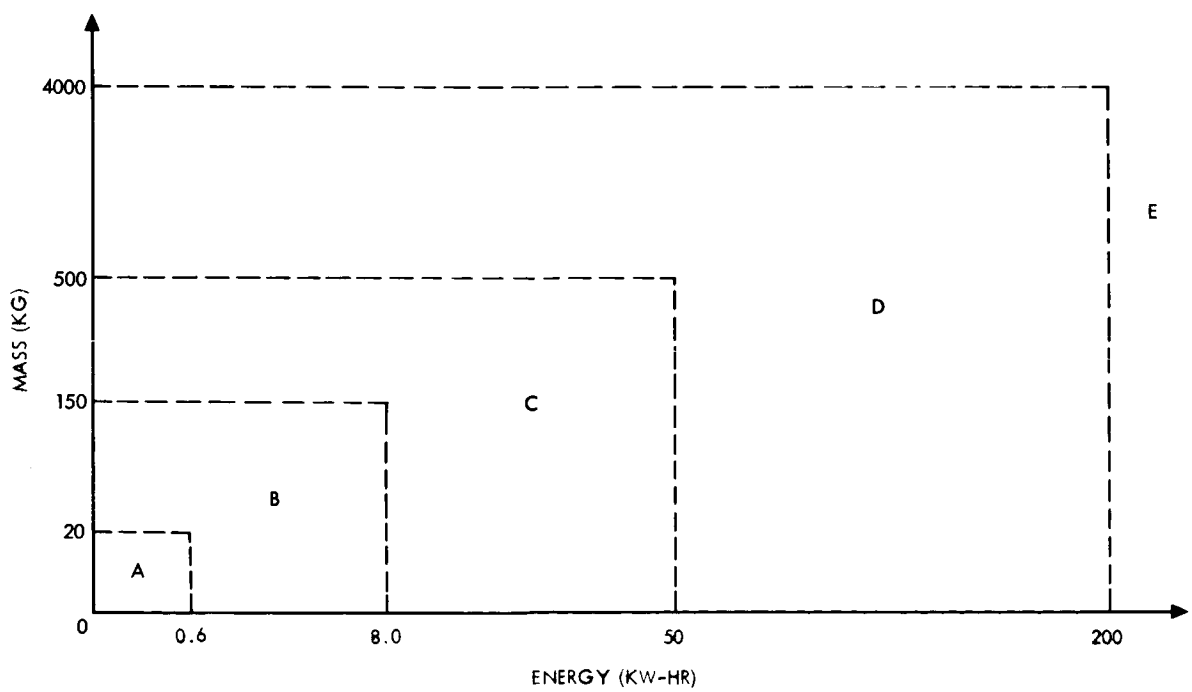


Figure 46. Phasing Criteria Based on Combined Mass-Energy Requirements

Table 24. Experiment Distribution Based on Mass Requirements

Discipline Area	Lunar Atmospheres		Geodesy		Geology		Geochemistry		Geophysics		Particles and Fields		Biology		Astronomy		Total Number of Fundamental Investigations	
	Number of Experiments																	
Mass Requirements (kg) / Experiment Type	S*	O**	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O
20 or less	6				5		16	3	66	5	20	3	3		7	3	123	14
21 to 150			4	1	6	1	3	1	8	5	15		3		13		52	8
151 to 500			1			1					1		1				3	1
501 to 4000				1					8		8				7		23	1
Greater than 4000					1				2						7		10	0
Total Number of Experiments	6	0	5	2	12	2	19	4	84	10	44	3	7	0	34	3	211	24

*S - Lunar Surface
**O - Lunar Orbit

Table 25. Experiment Distribution Based on Energy Requirements

Discipline Area	Lunar Atmospheres		Geodesy		Geology		Geochemistry		Geophysics		Particles and Fields		Biology		Astronomy		Total Number of Fundamental Investigations	
	Number of Experiments																	
Experiment Type / Energy Requirements (kw-hr)	S*	O**	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O
0.6 or less	2				8	1	11		65	7	9		5		5	1	105	9
0.6 to 8.0	2		5	2	2	1	7	1	11	3	8	1	2		11	1	48	9
8.1 to 50	2				1				8		16	2			14	1	41	3
51 to 200							1	3			9				3		13	3
Greater than 200					1						2				1		4	0
Total Number of Experiments	6	0	5	2	12	2	19	4	84	10	44	3	7	0	34	3	211	24

*S - Lunar surface
**O - Lunar orbit

7.4.3 OTHER PHASING REQUIREMENT

The second iteration in the formulation of the Exploration Phase Sequences utilized as additional phase criteria man-hour requirements, mobility requirements, common use of energy source packages and large equipment, and other phase-determining data. The experiments were surveyed for dominant phase-determining criteria that would justify moving the experiment into a later phase than that indicated on the basis of mass and energy alone. Specifically, the criteria for this iteration were as follows:

1. Man-hour requirement was considered only for movement from Phase A (Apollo capability) to Phase B. Beyond Phase B, man-hours were considered to be dependent upon the mission.

2. Mobility requirements were classified as (1) walking, (2) short range mobility (radius of 5 kilometers-LSSM type), and (3) long range mobility (100 kilometers and greater).

   a. Phase A was considered to have walking mobility only.

   b. Phase B was considered to have short-range mobility (5 to 7 kilometers operating radius).

   c. Phases C, D, and E were considered to have long-range mobility (100 kilometers or greater).

3. The ALSEP energy source was considered available in Phase A. For estimating purposes, this source was considered to be a RTG unit with a power output ranging between 56 and 65 watts supplied for a period of one year. Accordingly, on the basis of one year, the ALSEP energy source was estimated to provide a total energy ranging between 490 and 570 kilowatt-hours. Consequently, six experiments whose energy requirements exceed that of Phase A have been included in Phase A because of the availability of the ALSEP energy source. These experiments are identified in the Volume 4 listings.

4. The Astronaut Survey Staff was considered available during Phase A. A battery power source is indicated for this instrument. The batteries would be recharged at the lunar base or batteries replaced, as applicable, to provide the estimated total power expenditure for this unit. Total mass listed for this experiment is the mass of the total Astronaut Survey Staff which is also used for other purposes.

5. The ESS energy source was considered available in Phase B and later. According to Reference 48, this source is presently envisioned as consisting of a 100-watt central station RTG and three 10-watt satellite station RTG units, all operative for a period of at least one year. Accordingly, on the basis of one year, the total energy supplied by the ESS source was estimated to range between 1100 and 1200 kilowatt-hours. Consequently, nine experiments whose energy requirements exceed those of Phase B have been included in Phase B because of the availability of the ESS energy source. These experiments are also identified in the Volume 4 listings.

6. An independent emplaced package for monitoring gas emissions from suspected sources was assumed available for Phase B. This package could be emplaced from a lunar orbiting satellite or from a traverse vehicle. The power source could be similar to that of the ALSEP.

7. Experiments requiring systems capability equivalent to that of the present AAP concept were included in Phase B.

8. Discipline areas 8 and 9 were phased according to their support of the fundamental experiment, adhering to the other phasing criteria of this section and Section 7.4.2.

7.4.4 SEQUENCING

The detailed result of the iteration is shown in a printout of these cards, for the Exploration Phase Sequence in Volume 4 (Appendix A).

Table 26 summarizes the number of experiments in each discipline in each phase at the completion of the two iterations. This table lists the number of experiments within each discipline area for each exploration phase. From these data the following conclusions may be drawn: Geodesy, Astronomy, and Miscellaneous Basic and Applied Research Experiments are not within the capabilities of Phase A; Phase B represents a capability sufficient to perform the majority of experiments; none of the Geochemistry experiments compiled under this study requires support capabilities higher than those ascribed to Phase B; none of the experiments included under Lunar Atmospheres, Geodesy, and Biology requires support capabilities higher than those ascribed to Phase C; experiments requiring Phase E mission support capabilities are included only in the Geology, Geophysics, Particles and Fields, Astronomy and Miscellaneous Basic and Applied Research Areas; Sixty percent of experiments across all disciplines will have been introduced upon conclusion of Phase B, assuming all orbital experiments are included.

Table 26. Experiment Distribution Based on Mass and Energy Requirements Combined

Phase	Mass (kg)	Energy (kw-hrs)	Lunar Atmospheres	Geodesy	Geology	Geochemistry	Geophysics	Particles and Fields	Biology	Astronomy	Mission Support Investigations	Miscellaneous Basic and Applied Research	Total Number of Experiments
			Number of Experiments										
Orbital	1.0 to 700	0 to 150	0	2	2	4	10	3	0	3	6	0	30
A	20 or less	0.6 or less*	2	0	3	4	12	2	2	0	3	0	28
B	21 to 150	0.61 to 8.0**	2	3	6	15	40	12	2	11	52	2	145
C	151 to 500	8.1 to 50	2	2	2	0	22	11	3	7	20	0	69
D	501 to 4000	51 to 200	0	0	0	0	8	16	0	9	11	6	50
E	Greater than 4000	Greater than 200	0	0	1	0	2	3	0	7	0	1	14
Total			6	7	14	23	94	47	7	37	92†	9	336†

† Mission support experiments 81021503, 81021105, 83064107, and 82053902 exert no impact on lunar requirements, hence, 336 of the total 340 experiments are totaled.

*Reflects energy requirements during manned missions. For experiments of long duration, exceeding the manned mission time, an ALSEP energy source is assumed to exist with a power output of at least 56 watts supplied for a period of one year.

**Reflects energy requirements during manned missions. For experiments of long duration, exceeding the manned mission time, an ESS energy source is assumed to exist (one 100-watt central and three 10-watt satellite RTG units), operative for a period of one year.

Following are additional typical conclusions that can be drawn from Table 26. The 12 Geophysics experiments of Phase A, represent 13 percent of the total number of experiments included in the Geophysics area. All are less than 20 kilograms and with a power requirement of less than 600 watt-hours (except for one experiment using RTG source). The 16 experiments in the Particles and Fields area shown for Phase D, represent 34 percent of the total number of experiments included in this discipline area. This large percentage is due primarily to high energy requirements of Particles and Fields as shown in Table 25 and in the histogram of Figure 35(B).

Upon sorting and printing out the Type-1 cards into Exploration Phase Sequences, the experiments of each phase were analyzed for mission support characteristics associated with lunar exploration programs presently under consideration. The results of this analysis indicate that Phase A can be associated with the Apollo exploration era following the first lunar landing mission. Phase A represents the only defined phase with known characteristics. Phase B is within the systems capability of the Apollo Applications Program as presently visualized. Phases C, D, and E represent periods of increasingly growing potential for mass, energy, man-hours, and surface mobility. Table 27 shows the phasing criteria and potential phase names.

The Exploration Phase Sequences list experiments only when a capability to accomplish them first exists. Therefore, experiments appear only once, although they may be repeated several times within a given phase or in one or more subsequent phases after first introduction. Based upon capability alone, an exploration phase represents not only the capacity for performing an experiment introduced in that phase but also any of the experiments introduced in previous phases. In establishing the total capability of the phases, various desirable combinations of experiments must be considered along with the planning of various typical missions. Section 7.5 relates and discusses various combinations of experiments.

(Text Continued on Page 335)

Table 27. Phases of Extended Lunar Exploration

Phase	Characteristic Name	Approximate Lunar Stay Time (Days)	Maximum Energy per Experiment (kw-hrs)	Maximum Mass per Experiment (kg)	Average Man-Hours per Experiment	Characteristic Mobility Mode
A	Apollo	3	0.6*	20	5	Walking
B	Apollo Applications Program	Less than 30	8.0**	150	20***	Short-range open cabin vehicle (LSSM type)
C	Extended Exploration	90	50	500	120	Long-range mobility surface roving vehicle
D		180	200	4,000	210	
E		More than 180	Greater than 200	Greater than 4,000	640	

*Reflects energy requirements during manned missions. For experiments of long duration, exceeding the manned mission time, an ALSEP energy source is assumed to exist with a power output of at least 56 watts supplied for a period of one year.

**Reflects energy requirements during manned missions. For experiments of longer durations, exceeding the manned mission time, an ESS energy source is assumed to exist (one 100-watt central and three 10-watt satellite RTG units), operative for a period of one year.

***Initial man-hour requirements on the following six early-exploration experiments were in excess of reasonable estimates on available astronaut time on the lunar surface during Phase B. Subsequent review of these experiments by the NAA scientific staff resulted in establishing minimum man-hour requirements that were judged sufficient to yield significant scientific results.

	Desirable Man-Hour Estimates	Minimum Man-Hour Estimates
61040102, Evidence of Existing Life	270	22
71010101, Lunar Environmental Test	310	60
72010102, High Resolution Photography	320	60
72010104, Low Dispersion Spectroscopy	310	60
72010205, Sky Survey	920	60
72010206, Variable Brightness	500	60

The original man-hour estimates on the above experiments were not changed in the computer printouts because they represent scientifically desirable times.

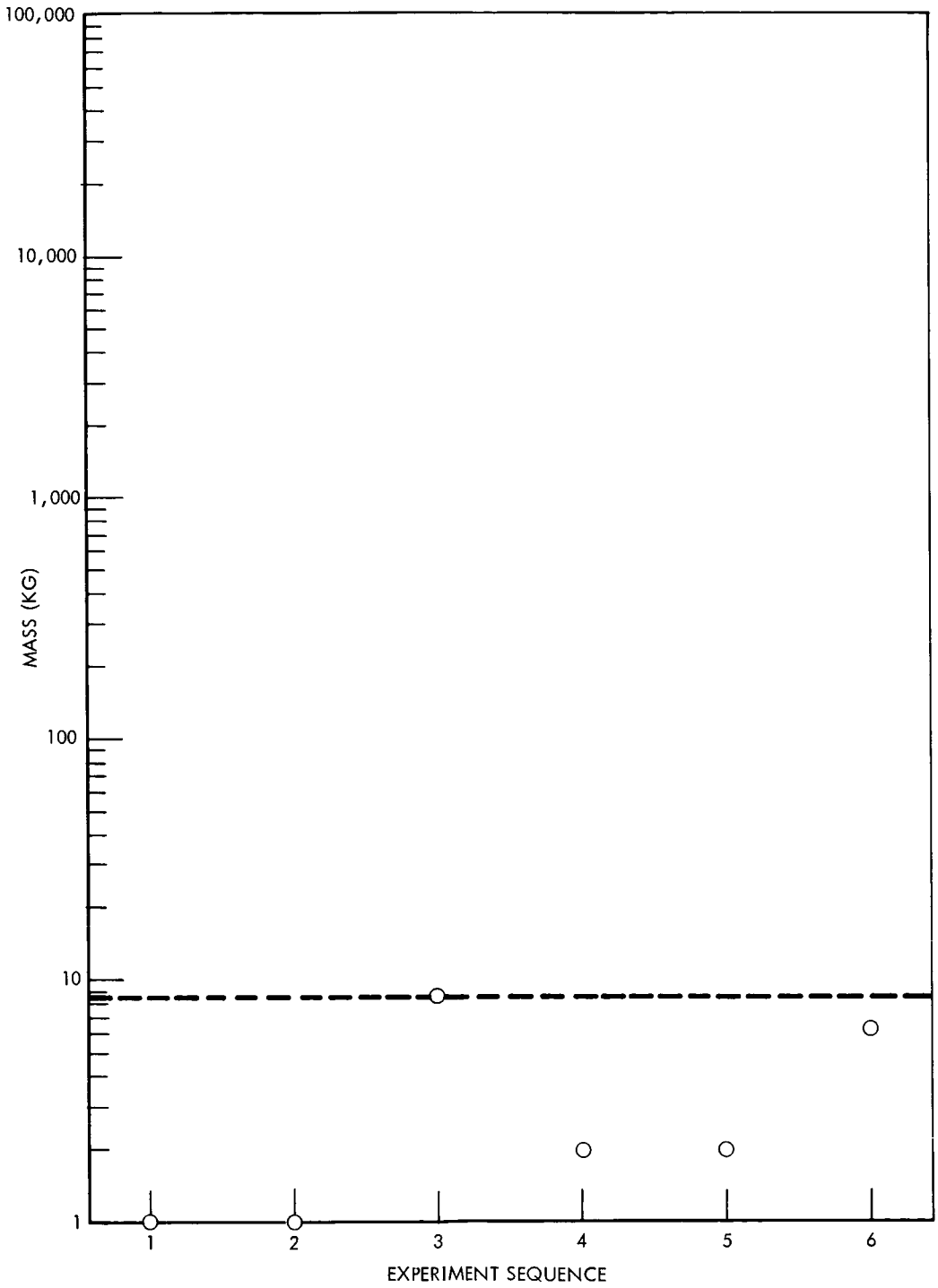


Figure 47. Mass Requirements Versus Experiment Sequence Discipline Area 0, Lunar Atmospheres

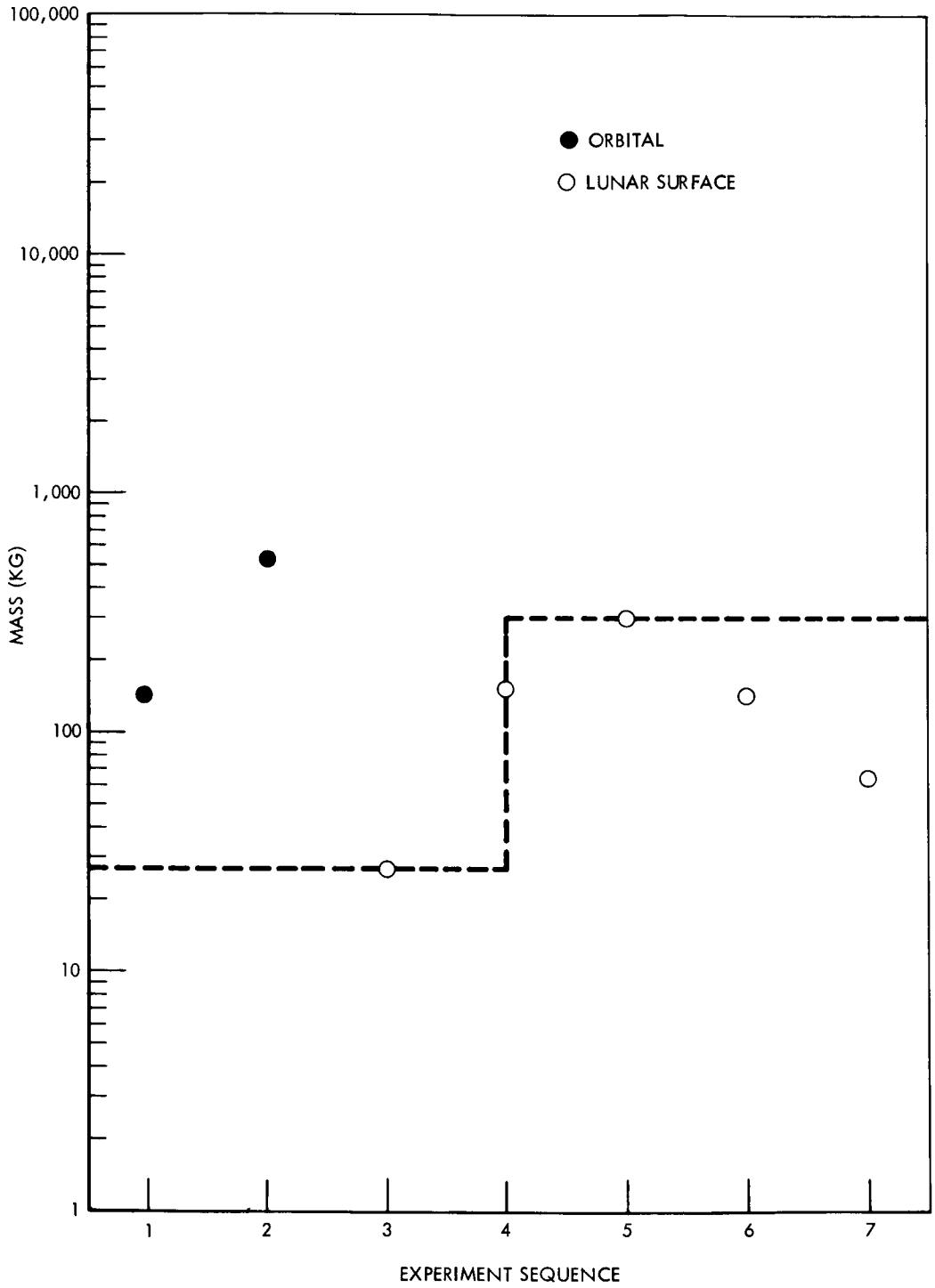


Figure 48. Mass Requirements Versus Experiment Sequence Discipline Area 1, Geodesy

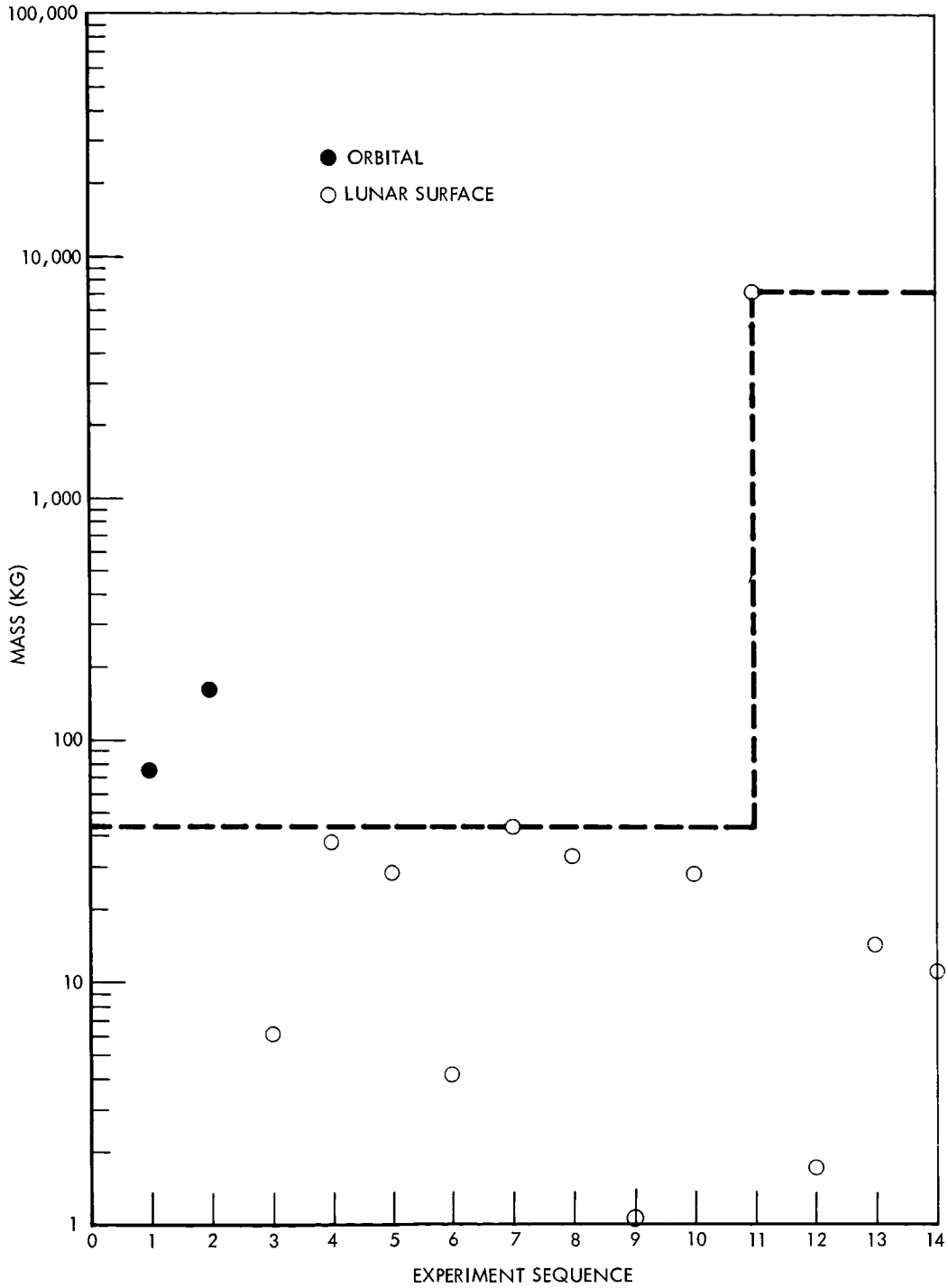


Figure 49. Mass Requirements Versus Experiment Sequence Discipline Area 2, Geology

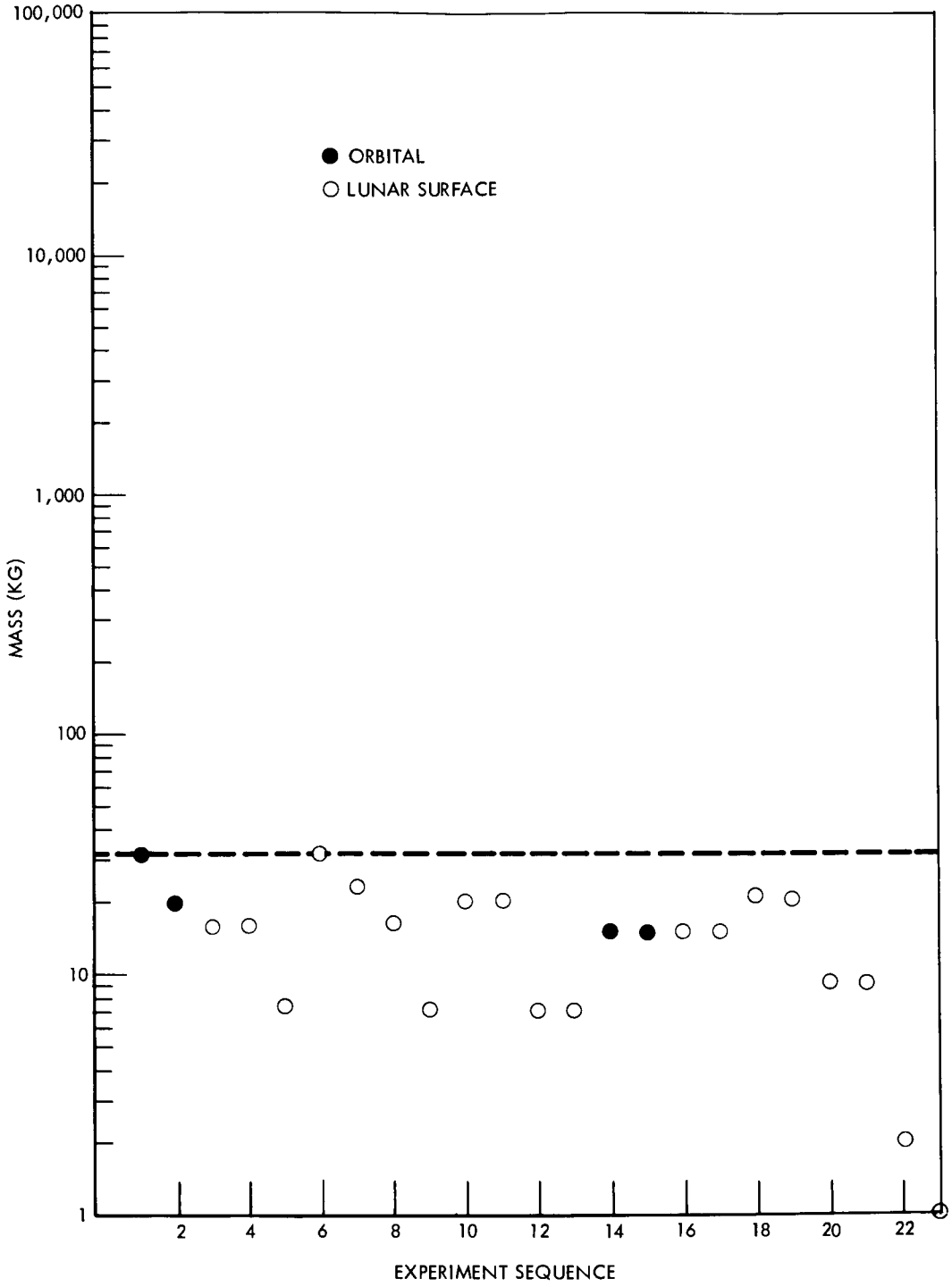


Figure 50. Mass Requirements Versus Experiment Sequence Discipline Area 3, Geochemistry

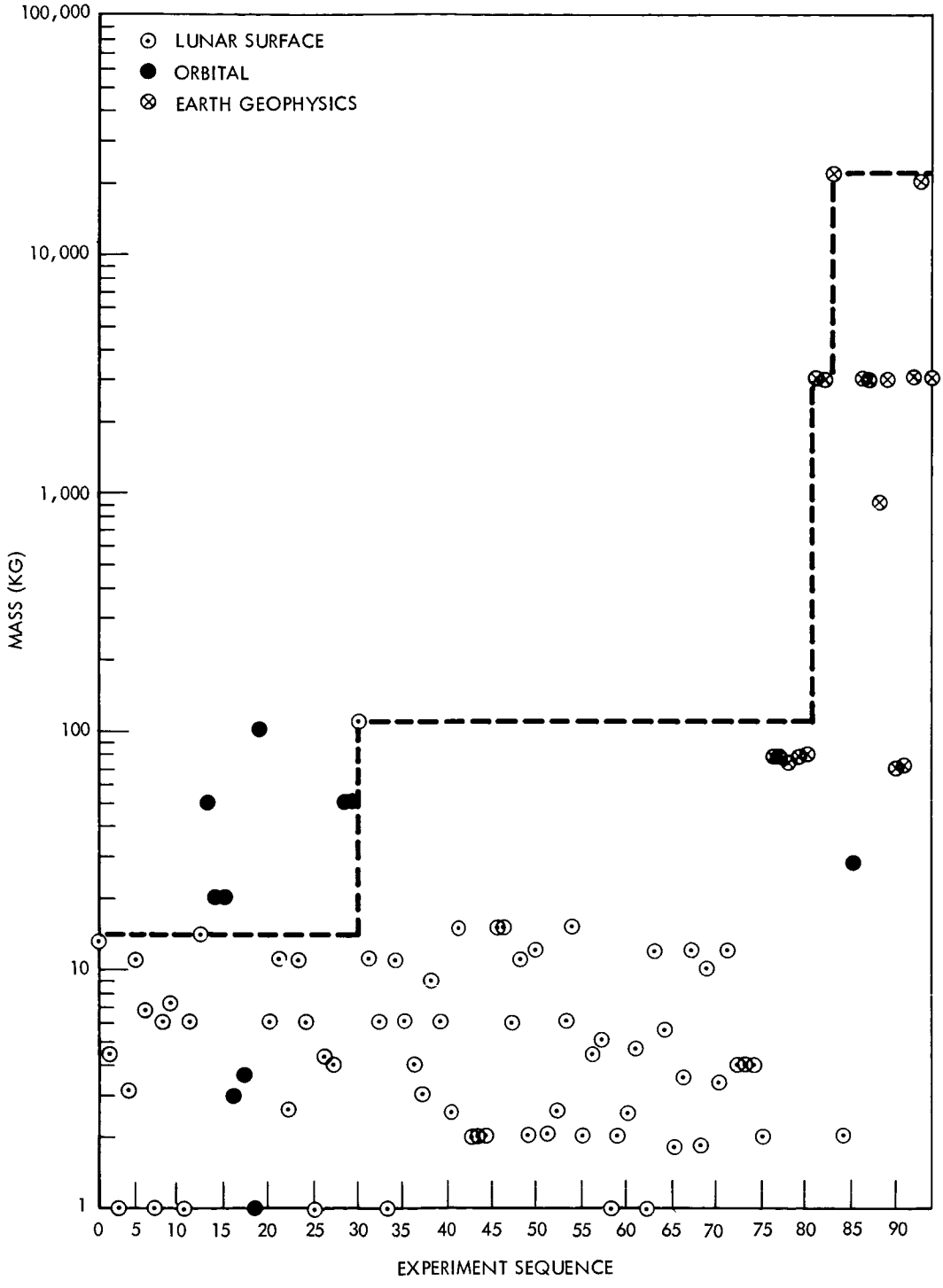


Figure 51. Mass Requirements Versus Experiment Sequence Discipline Area 4, Geophysics

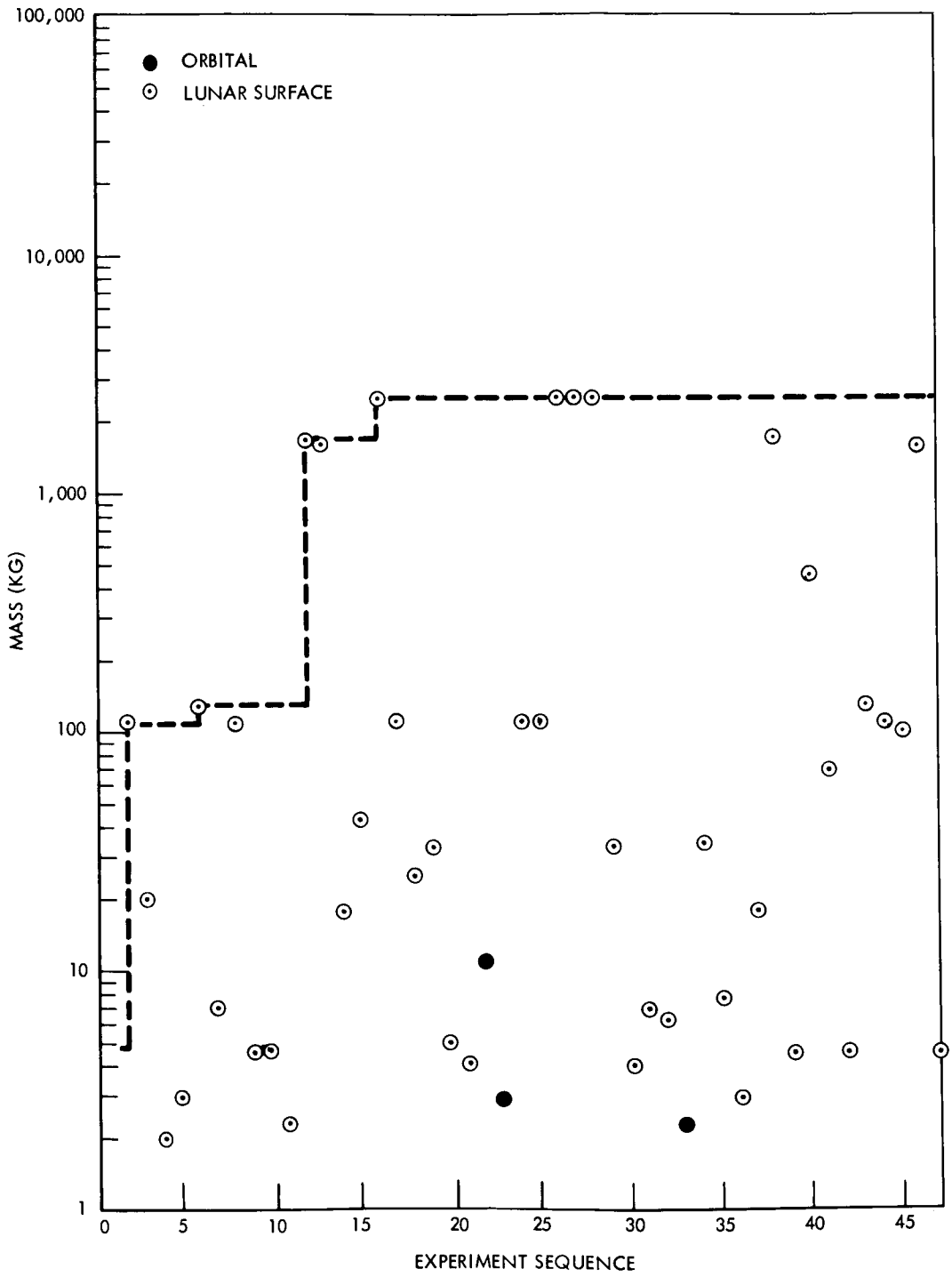


Figure 52. Mass Requirement Versus Experiment Sequence Discipline Area 5, Particles and Fields

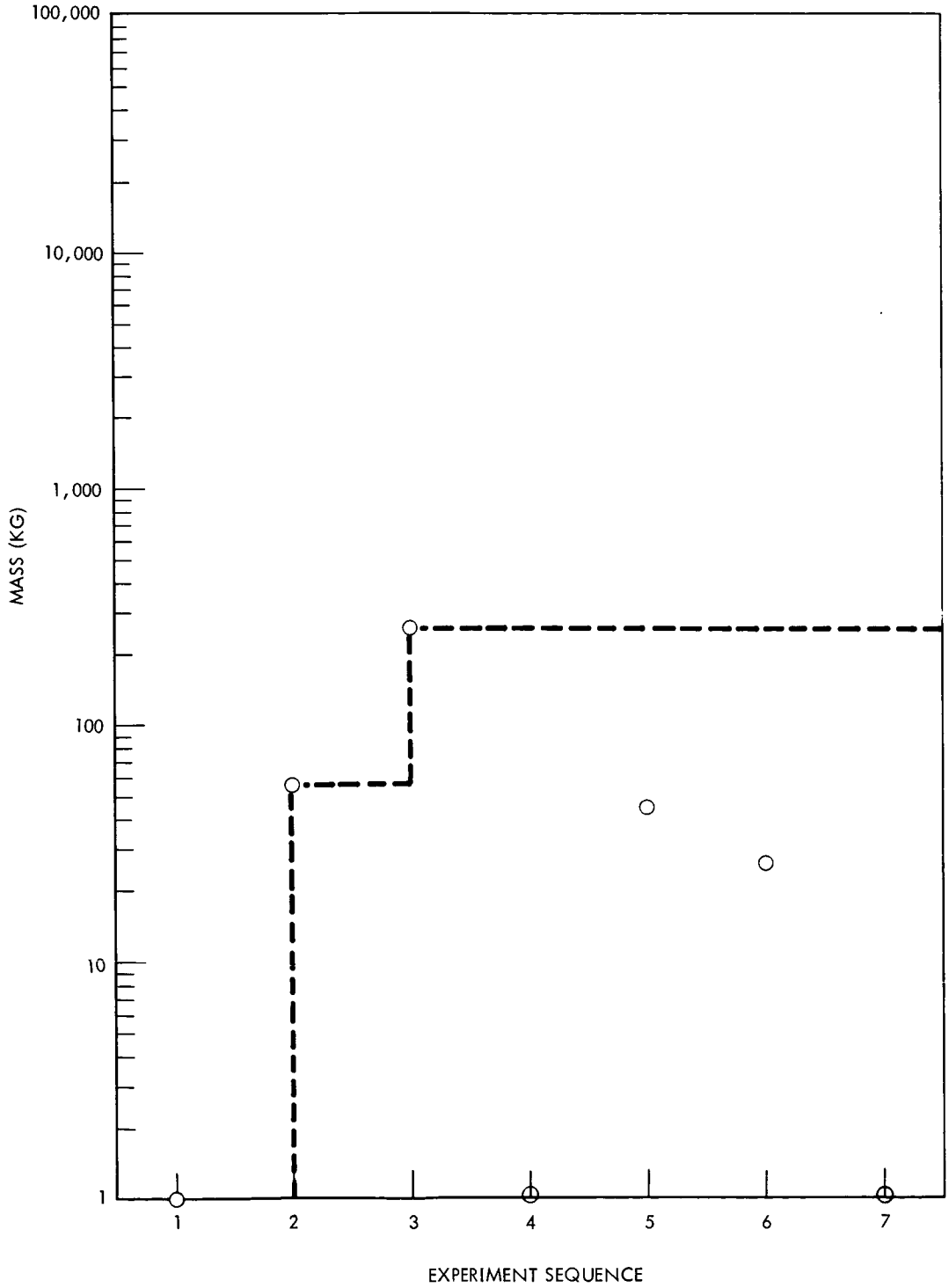


Figure 53. Mass Requirements Versus Experiment Sequence Discipline Area 6, Biology

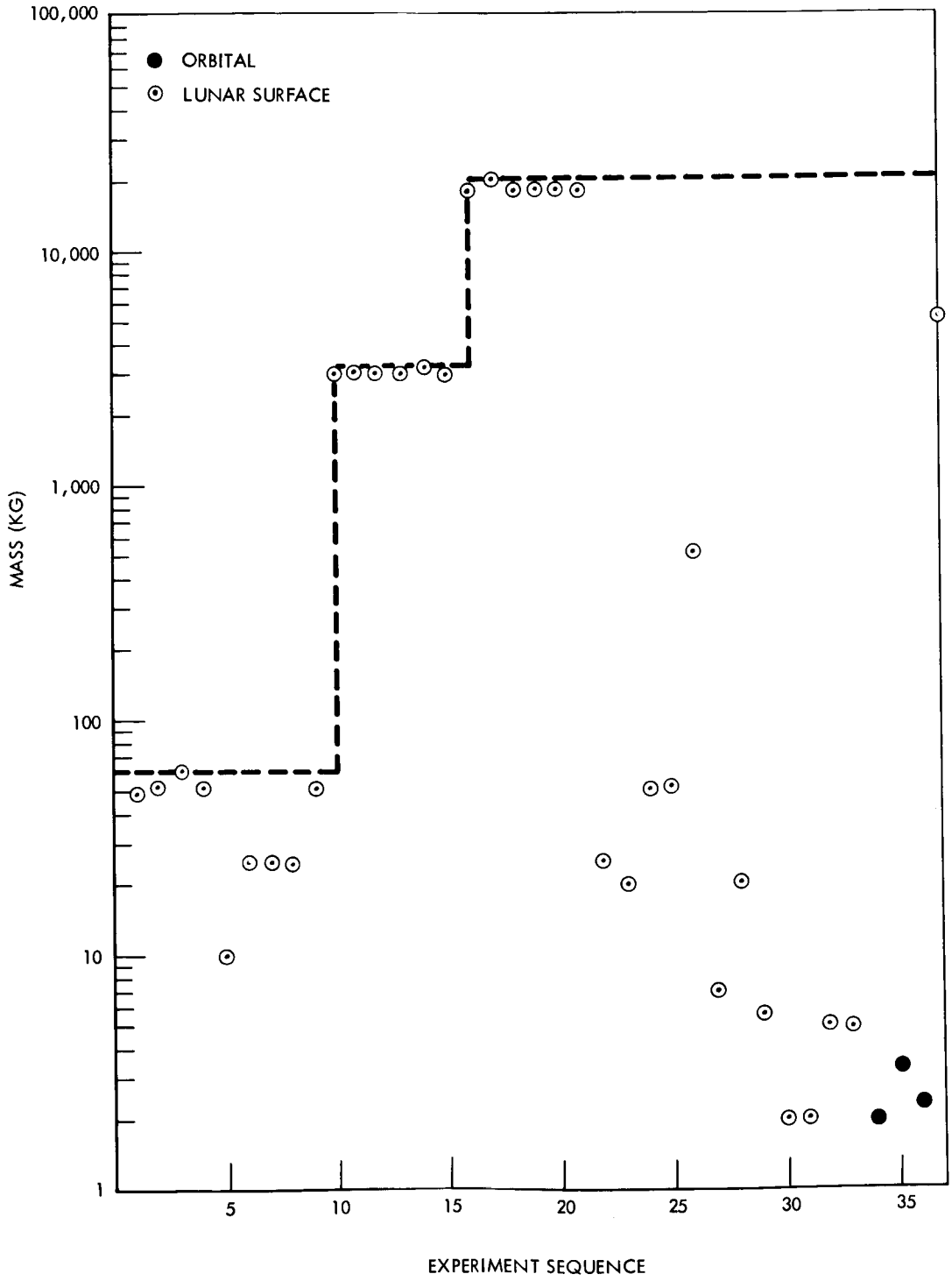


Figure 54. Mass Requirements Versus Experiment Sequence Discipline Area 7, Astronomy

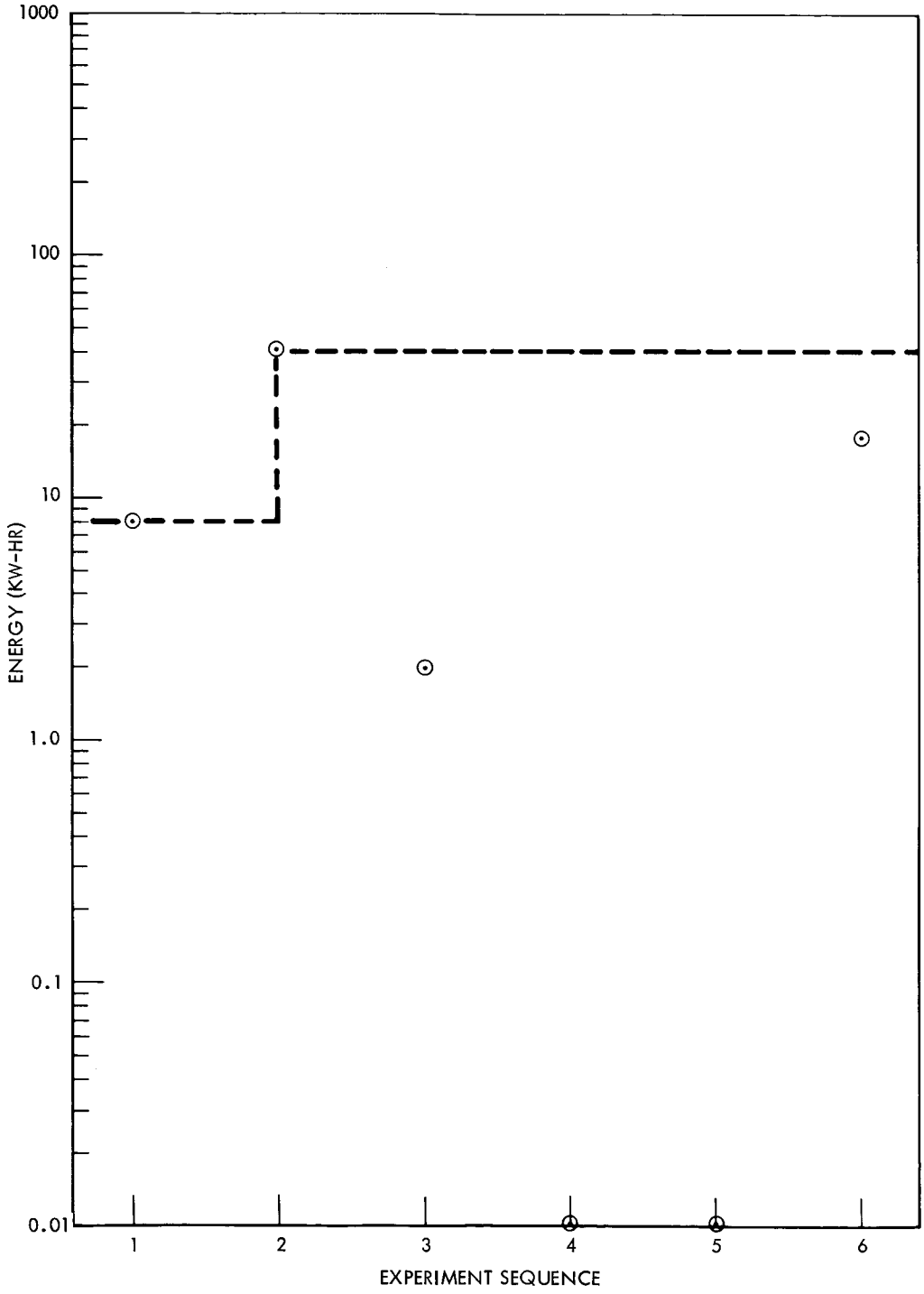


Figure 55. Energy Requirements Versus Experiment Sequence Discipline Area 0, Lunar Atmospheres

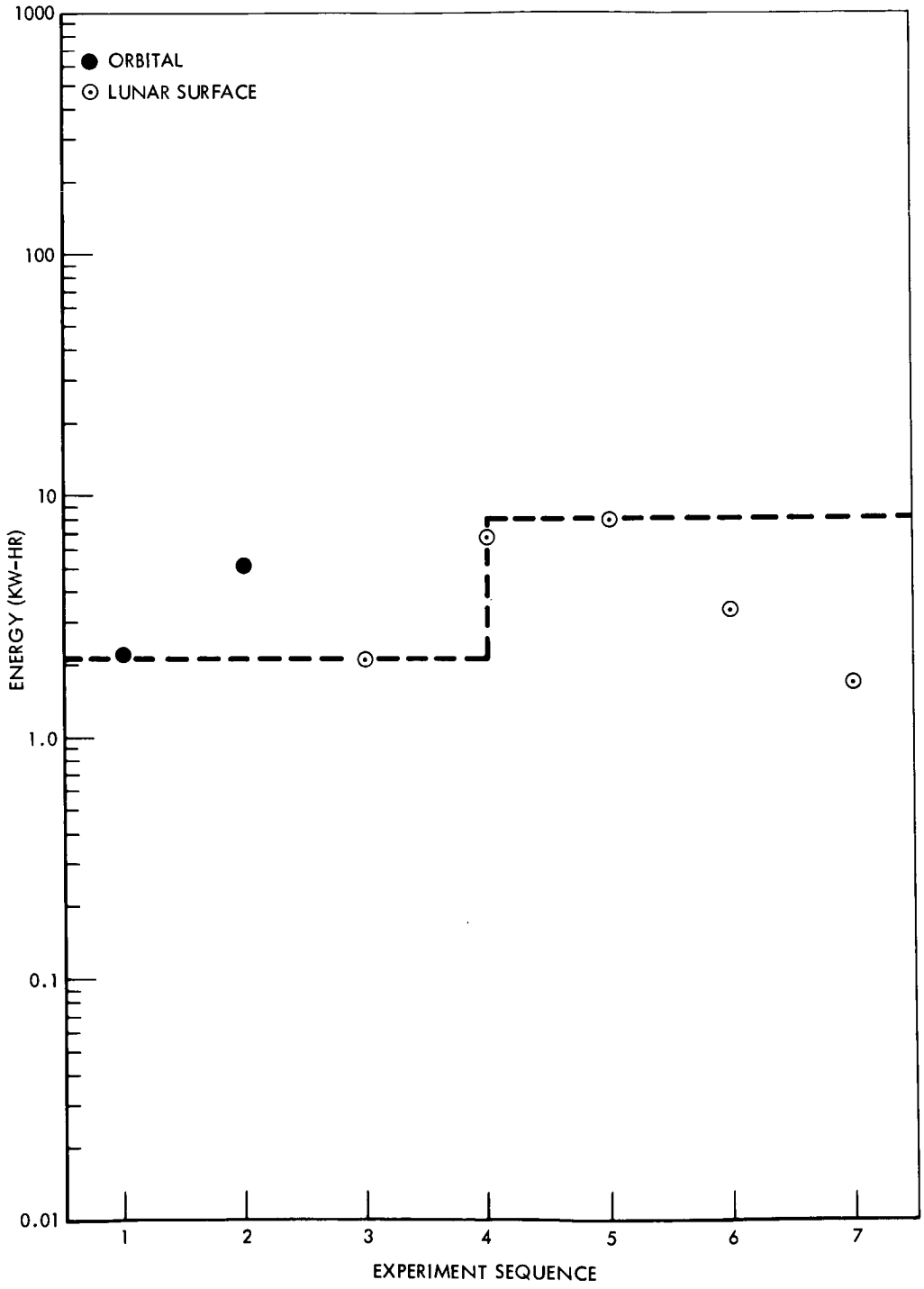


Figure 56. Energy Requirements Versus Experiment Sequence Discipline Area 1, Geodesy

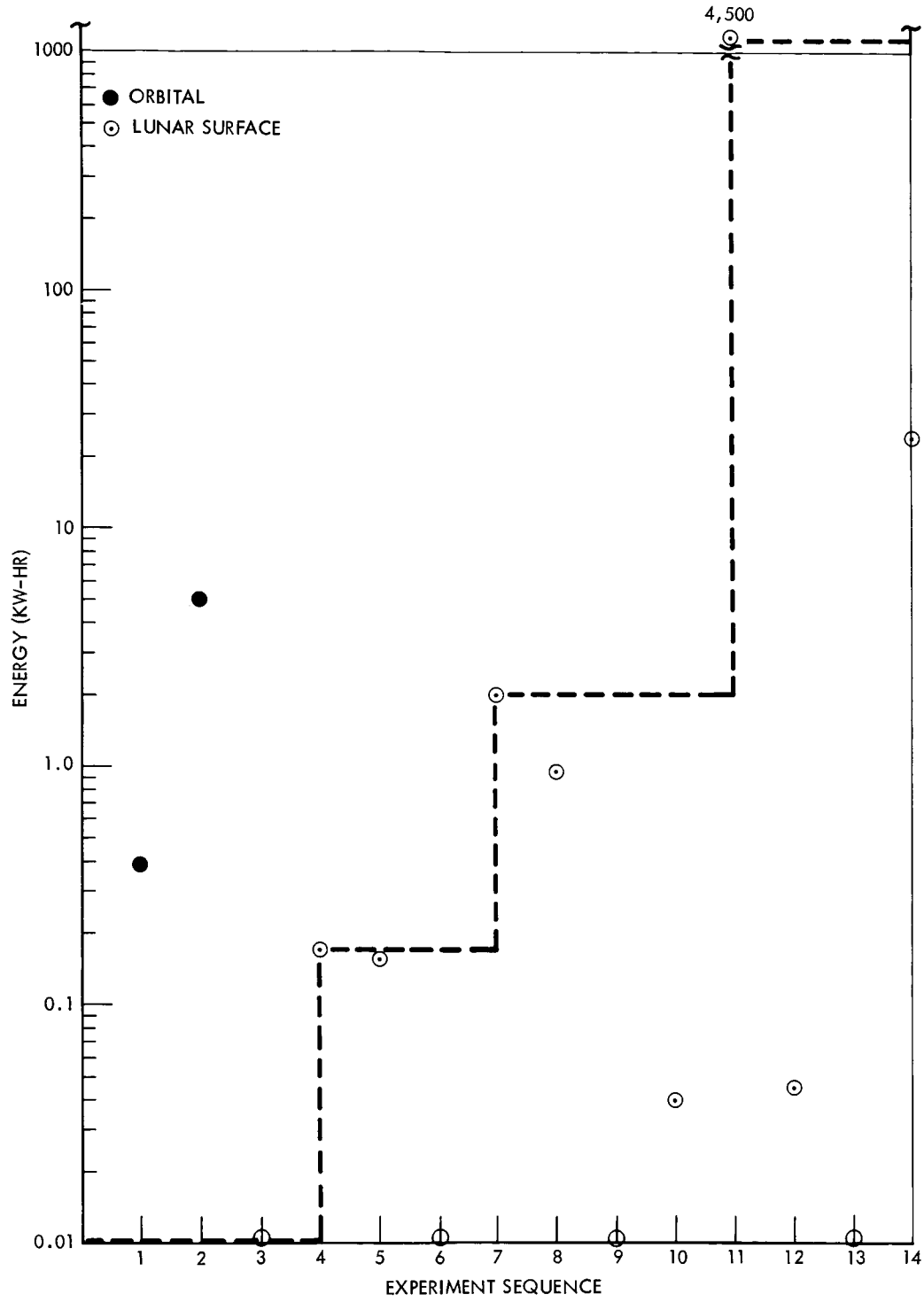


Figure 57. Energy Requirements Versus Experiment Sequence Discipline Area 2, Geology

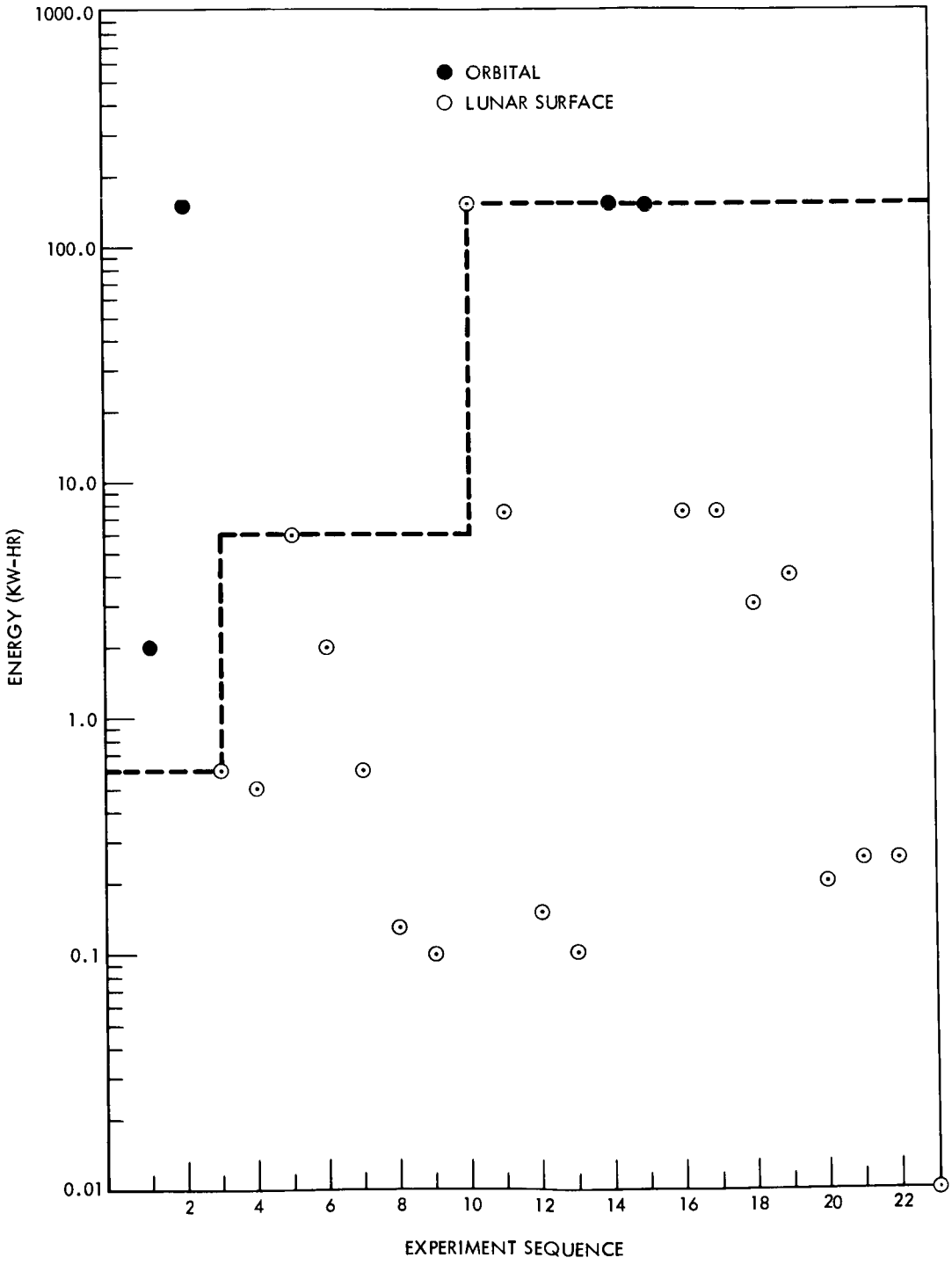


Figure 58. Energy Requirements Versus Experiment Sequence Discipline Area 3, Geochemistry

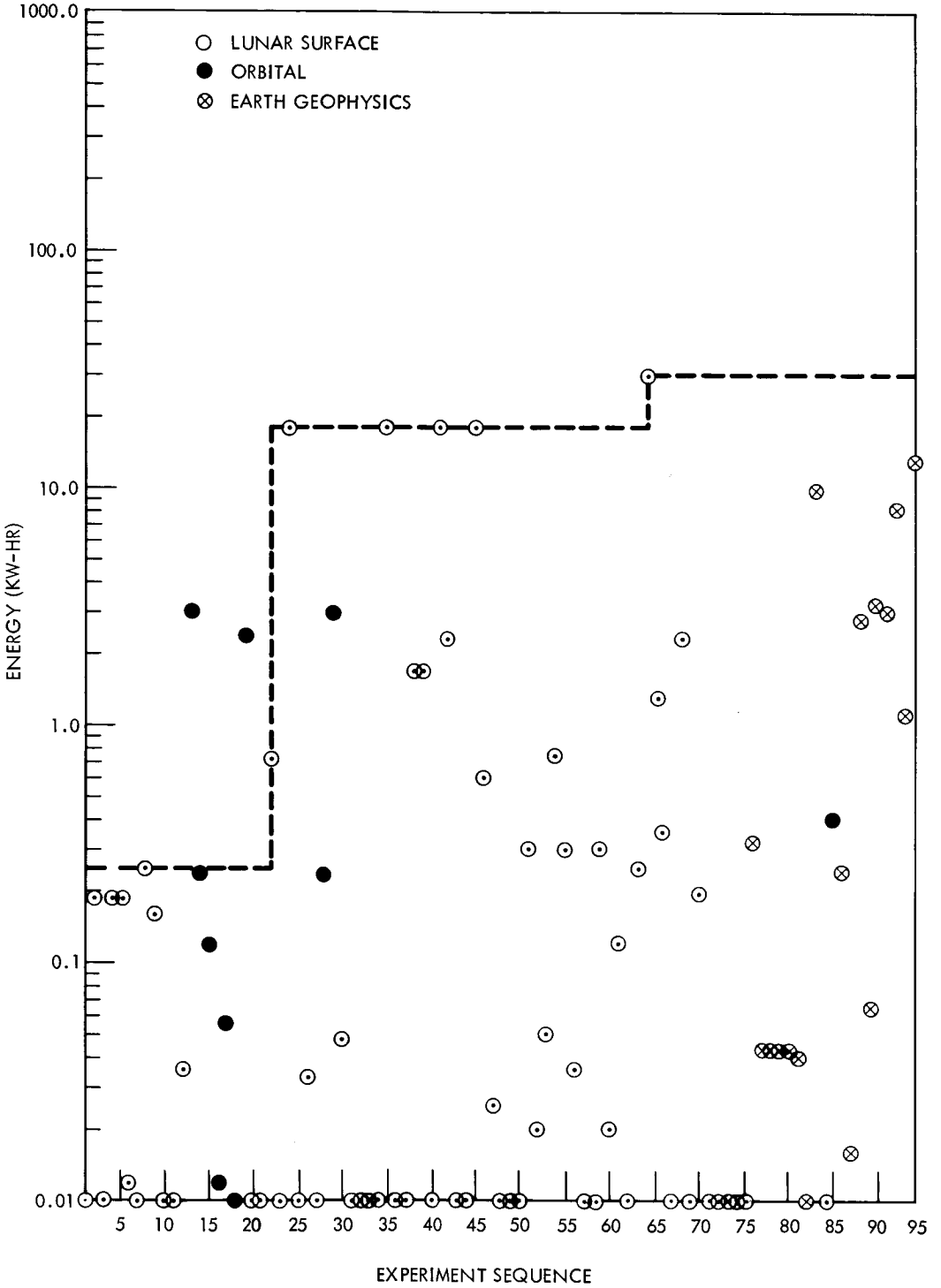


Figure 59. Energy Requirements Versus Experiment Sequence Discipline Area 4, Geophysics

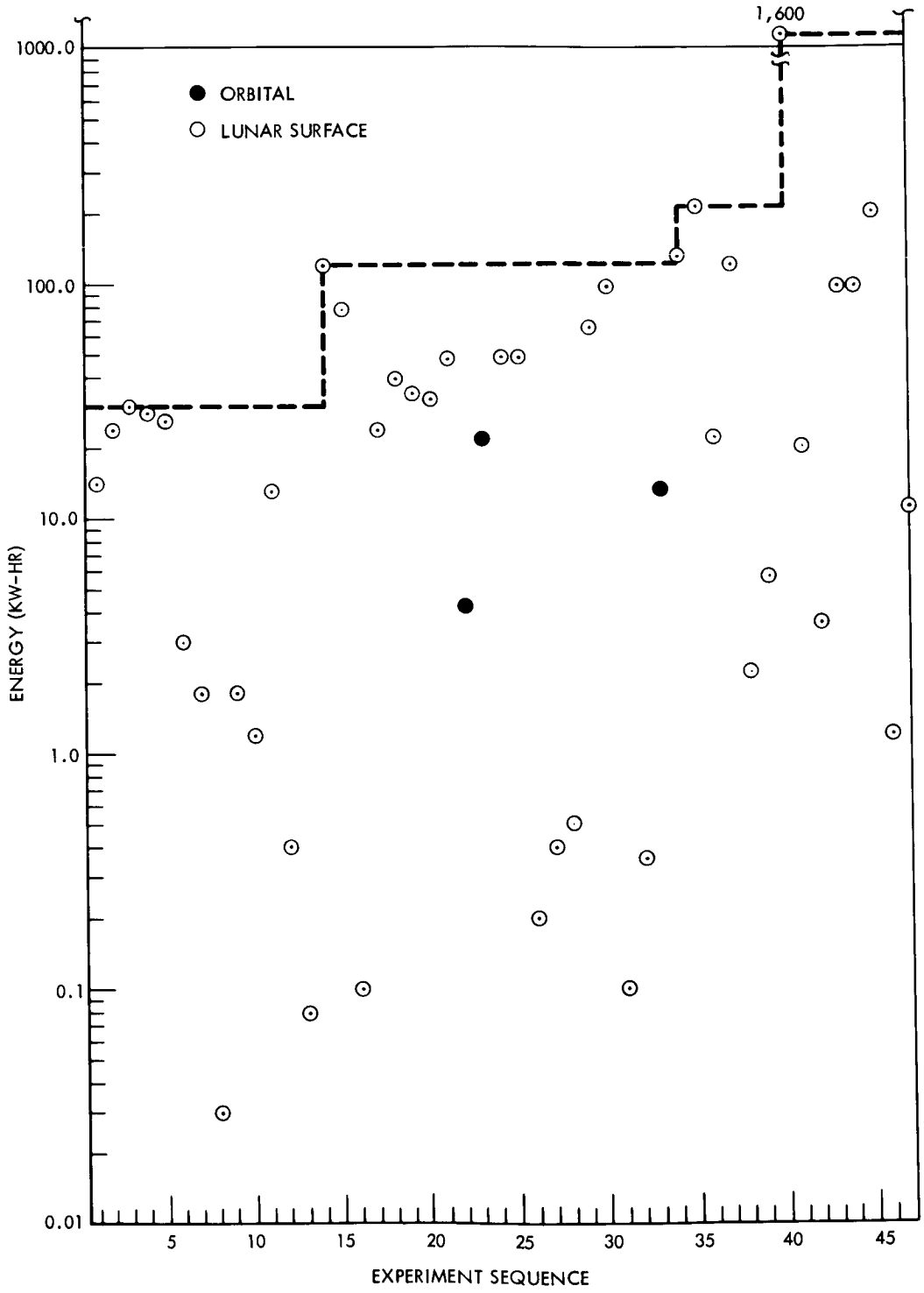


Figure 60. Energy Requirements Versus Experiment Sequence Discipline Area 5, Particles and Fields

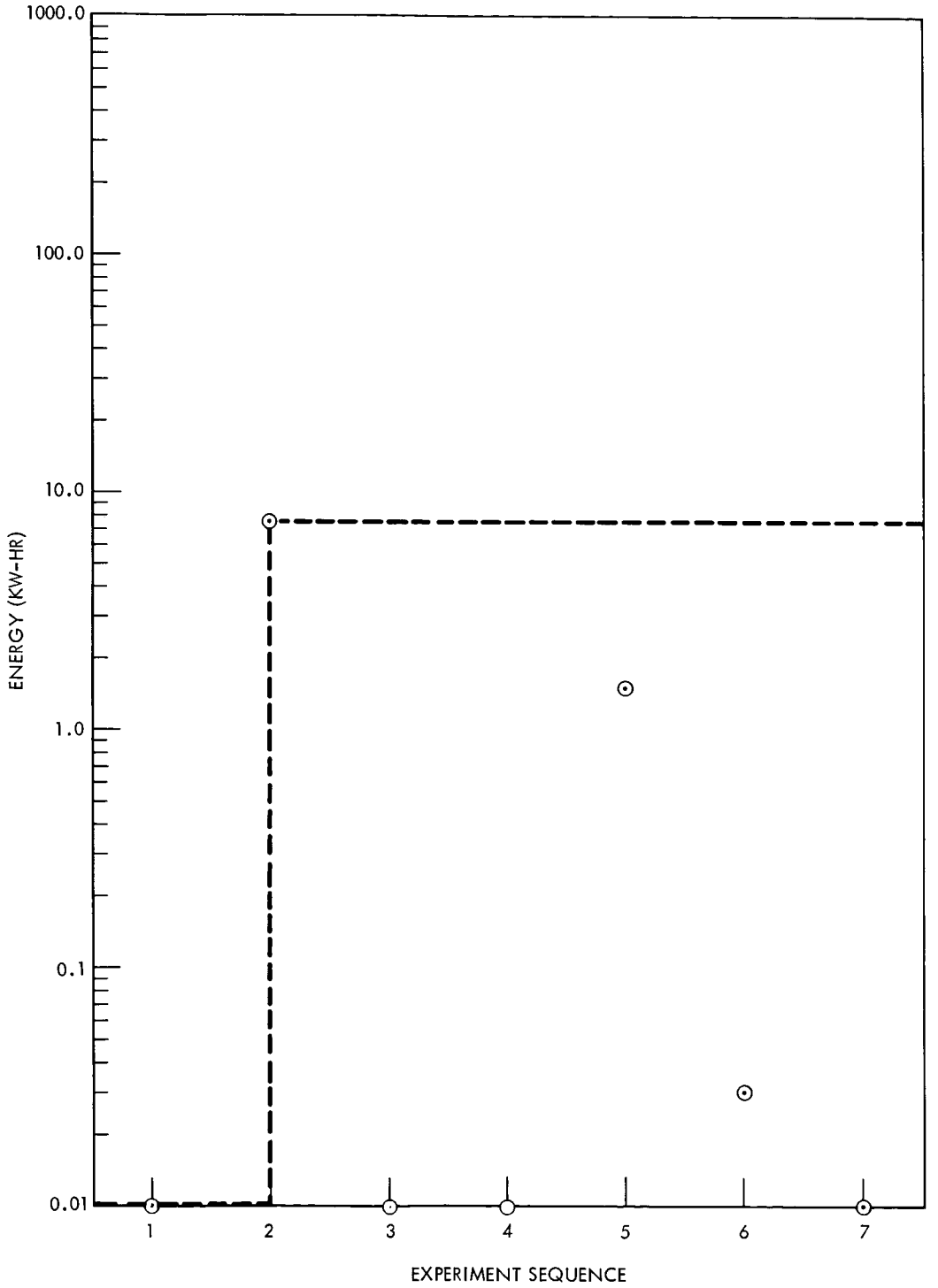


Figure 61. Energy Requirements Versus Experment Sequence Discipline Area 6, Biology

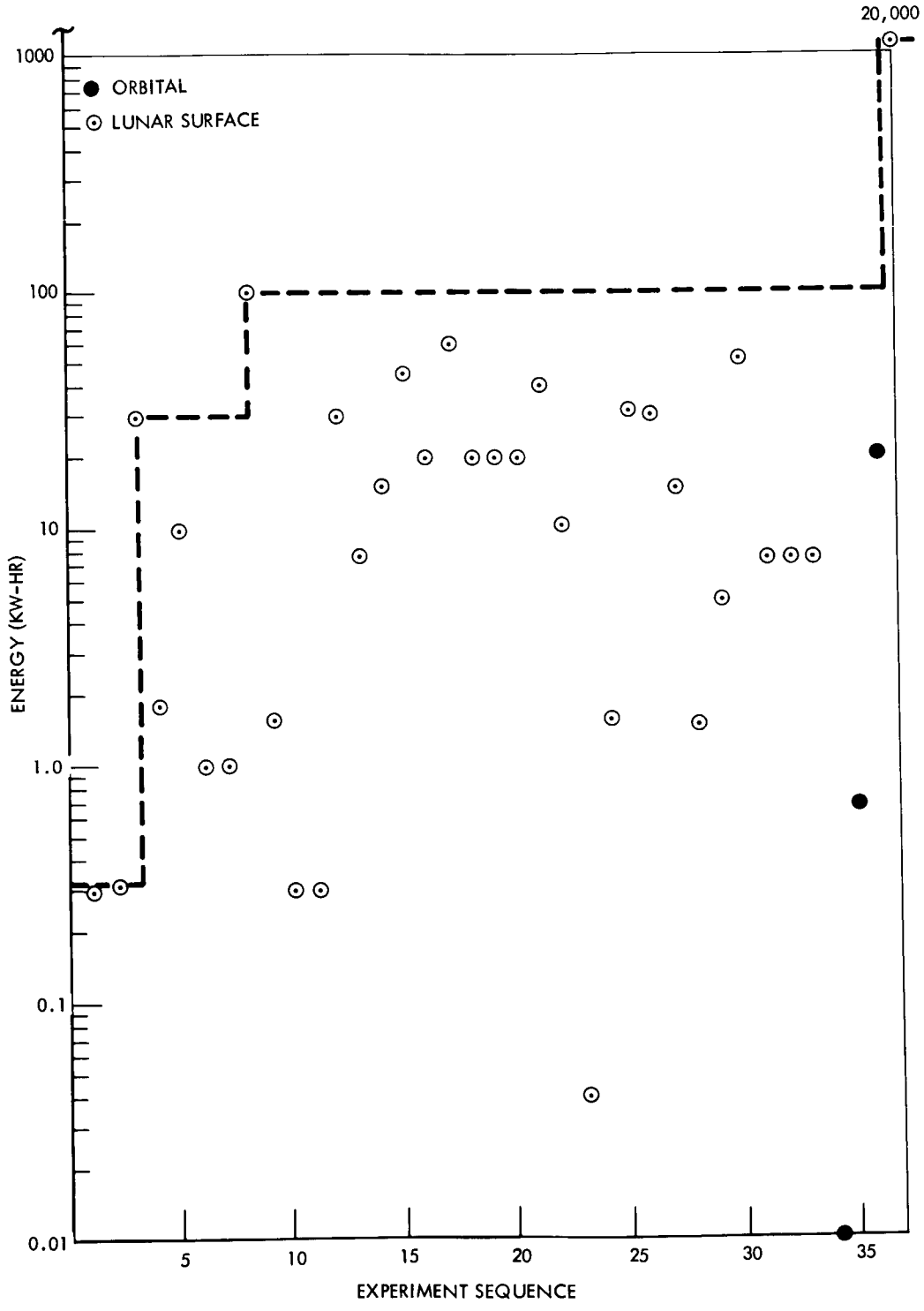


Figure 62. Energy Requirements Versus Experiment Sequence Discipline Area 7, Astronomy

7.5 COMPOSITE SEQUENCE DEVELOPMENT AND EVOLUTION OF SCIENTIFIC PROGRAMS

7.5.1 COMPOSITE SEQUENCES

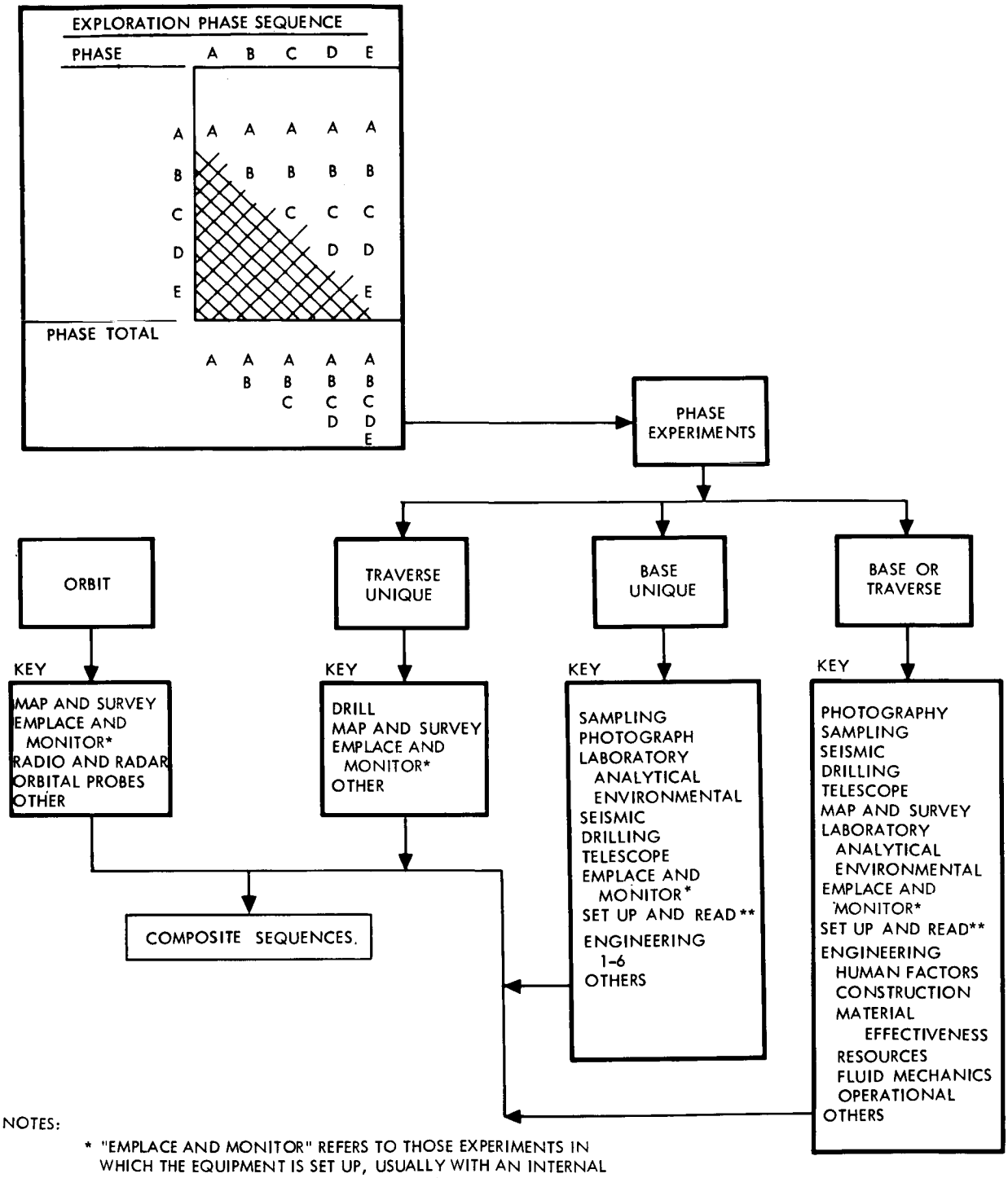
The Composite Sequences relate the experiments across various scientific areas within each of the exploration phases developed in Section 7.4. They also indicate the evolution of scientific programs of experimentation within the Discipline Areas.

Figure 63 shows a schematic flow diagram indicating the methodology adopted for the Composite Sequences. Experiments to be performed on the lunar surface within a given exploration phase were grouped according to location of possible performance. Some experiments, by their nature, are required to be performed at a lunar base, others on traverse. The majority, however, will be performed both at a lunar base and on traverse. Orbital experiments were classified as a separate and independent location category. This analysis was followed by further grouping of related experiments according to common key operational factors and key items. These common factors are shown in Figure 63 as "drilling," "sampling", "emplace and monitor," etc. Key items, are shown as "telescope" and "drill". These are items that permit the performance of experiments in more than one Discipline Area.

Most of the experiments included in the Mission Support Investigations category support the Fundamental Investigations. However, some of the experiments are designed to support engineering operations on the lunar surface as indicated in Table 28 below:

Table 28. Categories of Experiments in Support of Engineering Operations

Base Only	Traverse Only	Base and/or Traverse
Human Factors	Operational	Human factors
Construction		Construction
Material effectiveness		Material effectiveness
Resources		Resources
Fluid Mechanics		Fluid mechanics
Operational		Operational



NOTES:

* "EMPLACE AND MONITOR" REFERS TO THOSE EXPERIMENTS IN WHICH THE EQUIPMENT IS SET UP, USUALLY WITH AN INTERNAL POWER SOURCE AND TRANSMITTING DEVICE, AND MONITORED EITHER AT THE LUNAR BASE FROM ORBIT OR FROM EARTH.

** "SET UP AND READ" REFERS TO THOSE EXPERIMENTS THAT REQUIRE SETTING UP OF EQUIPMENT, TAKING DATA, AND IMMEDIATE BREAKDOWN OR ASSEMBLY.

Figure 63. Composite Sequence Development

Miscellaneous experiments not associated with a key item or with other experiments were grouped under the heading "others." Table 31 at the end of Section 7.5 contains the results of the Composite Sequence analysis.

Table 29 summarizes IBM printouts included in Volume 4 (Appendix A) showing the number of experiments within each location category for each exploration phase and for each key operational factor or item. The first column consists of the number of orbital experiments. Each phase is broken down into three columns. The first column, labeled "LCN," refers to the three operational-location modes, "uniquely base, "uniquely traverse," or "base or traverse." This is indicated by the quadrant of entry (see legend footnote). The second, or "Phase" column contains the total number of experiments per key group introduced in each exploration phase. The third, "Sigma" column contains sums of lunar surface experiments included in all previous exploration phases. The orbital experiments are not summed as they are introduced throughout all phases. Reading across the phase columns, key information can be obtained such as: (1) all sampling experiments have been introduced by the end of Phase B; (2) mapping and survey experiments are performed from orbit and introduced on the lunar surface only during Phases B and C; (3) all but three engineering experiments are introduced in Phases B and C; (4) eighty percent of the human factors experiments are uniquely base experiments and introduced in Phases B and C.

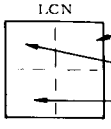
The mass requirements associated with key operations and key items can serve as a basis for scientific payload estimation. A total vehicle payload may consist of a scientific payload in various combinations with mission support payloads. Table 30 shows the total mass of all experiments associated with each key group by phase. The minimum vehicle scientific-payload capacity required for each phase can be estimated on the basis of the maximum mass associated with a key item and its related experiments for that phase. In Phase A, the "Emplace and Monitor" grouping has a mass of 56 kilograms. This requirement is well within the capability of the Apollo LEM vehicle. In Phase B, "Telescope Utilization" imposes the maximum mass requirement. There are 169 kilograms required for the key operation items and 238 kilograms required for key items, a total of 407 kilograms. In Phase C, the "Emplace and Monitor" is the critical key group with a maximum mass requirement of 920 kilograms. For Phase D, the critical key items are three telescopes with a combined mass of approximately 4700 kilograms and associated scientific activities requiring 4332 kilograms. The minimum vehicle requirement of Phase D is then approximately 9000 kilograms. In Phase E, the telescope is again the critical key item, with a mass requirement of 18,000 kilograms. Experiments associated with it require 3000 kilograms. The minimum vehicle requirement is then 21,000 kilograms. It should be noted again that an actual payload would in general, consist of some combination of groupings and would, therefore, require a mass capability exceeding these minimum estimates.

Table 29. Experiment Distribution Within Each Exploration Phase By Operational Location and Key Experiment Grouping

Phase / Key Groups	O	A			B				C				D				E			
		LCN		A	LCN		B	ΣB	LCN		C	ΣC	LCN		D	ΣD	LCN		E	ΣE
Photography	—	1	—	1	1	—	1	2	—	—	—	2	—	—	—	2	—	—	—	2
		—	—		—	—			—	—			—	—			—	—		
Sampling	—	4	—	4	3	3	6	10	—	—	—	10	—	—	—	10	—	—	—	10
		—	—		—	—			—	—			—	—			—	—		
Seismic Experimentation	—	2	—	2	2	5	7	9	—	1	1	10	—	—	—	10	—	—	—	10
		—	—		—	—			—	—			—	—			—	—		
Drilling	—	3	—	3	3	8	11	14	—	8	9	23	—	—	—	23	1	—	1	24
		—	—		—	—			1	—			—	—			—	—		
Telescope Utilization	—	—	—		16	—	16	16	7	—	7	23	22	—	22	45	8	—	8	53
		—	—		—	—			—	—			—	—			—	—		
Map & Survey	10	—	—	—	—	3	9	9	—	—	4	13	—	—	—	13	—	—	—	13
		—	—		6	—			4	—			—	—			—	—		
Laboratory Analytical	—	4	—	4	11	9	20	24	—	3	3	27	1	—	1	28	—	—	—	28
		—	—		—	—			—	—			—	—			—	—		
Laboratory Environmental	—	—	—	—	—	—	—	—	4	—	4	4	8	—	8	12	—	—	—	12
		—	—		—	—			—	—			—	—			—	—		
Emplace & Monitor	3	10	—	10	24	5	29	39	11	4	16	55	12	—	12	67	4	—	4	71
		—	—		—	—			1	—			—	—			—	—		
Set Up & Read	—	2	—	2	2	7	9	11	1	7	8	19	—	—	—	19	—	—	—	19
		—	—		—	—			—	—			—	—			—	—		
Radio & Radar	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Orbital Probes	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Engineering 1 Human Factors	—	—	—	—	4	2	6	6	5	—	5	11	—	—	—	11	—	—	—	11
		—	—		—	—			—	—			—	—			—	—		
Engineering 2 Construction	—	—	—	—	5	—	5	5	1	—	1	6	—	2	2	8	—	—	—	8
		—	—		—	—			—	—			—	—			—	—		
Engineering 3 Material Effectiveness	—	—	—	—	9	—	9	9	2	—	2	11	—	—	—	11	—	—	—	11
		—	—		—	—			—	—			—	—			—	—		
Engineering 4 Resources	—	—	—	—	2	2	4	4	5	—	5	9	—	—	—	9	—	—	—	9
		—	—		—	—			—	—			—	—			—	—		
Engineering 5 Fluid Mechanics	—	—	—	—	2	—	2	2	2	—	2	4	—	—	—	4	—	—	—	4
		—	—		—	—			—	—			—	—			—	—		
Engineering 6 Operational	—	1	—	1	—	8	10	11	1	1	2	13	—	—	—	13	—	—	—	13
		—	—		2	—			—	—			—	—			—	—		
Others	12	1	—	1	—	1	1	2	—	—	—	2	5	—	5	7	1	—	1	8
		—	—		—	—			—	—			—	—			—	—		

NOTES:

1. LCN



Experiments either at base or on traverse

Experiments performed uniquely at the base

Experiments performed uniquely on traverse

2. ΣB = A + B
3. ΣE = A + B + C + D + E
4. Orbital experiments not summed

Mission Support Experiments 81021503, 1021105 83064107 and 82053902 have no support requirements on lunar surface and are not included above.

*Equipment for this experiment is emplaced (deployed) in lunar orbit from the spacecraft.

Table 30. Lunar Surface Experiments- Evolution of Mass Requirements Associated With Key Experiment Groups

Key Operation	Exploration Phase				
	A	B	C	D	E
	Mass Requirements (kg)				
Photography	33	150			
Sampling	26	60			
Seismic experimentation	24	178	64		
Drilling	7	27	68		
Telescope utilization		169	67	4,332	3,000
Map and survey		277	26		
Laboratory analytical	21	362	24	3	
Laboratory environmental			587	2,850	
Emplace and monitor	56	354	920	1,941	5,502
Set up and read	13	61	28		
Engineering, human factors		57	113		
Engineering, construction		127	20	16	
Engineering, material effectiveness		55	85		
Engineering, resources		62	535		
Engineering, fluid mechanics		21	10		
Engineering, operational	10	85	100		
Others				160	100
Key Item	Mass Requirements (kg)				
Drill					
Drill - 1 to 3 meters		9			
Drill - 3 to 10 meters		23			
Drill - 30 meters			90		
Drill - 300 meters					7,000
Telescope					
5 inch		20			
6 inch		68		68	
8 inch		100			
12 inch		50			
36 inch grazing incidence			25		
40 inch (solar + astronomical)				4,600	
100 inch					18,000

7.5.2 EVOLUTION OF SCIENTIFIC PROGRAMS

Evolution of scientific programs can be illustrated by inspecting the Composite Sequence listings of Tables 29 and 31 of this volume or of Volume 4 (Appendix A). These are "Photography," "Sampling," "Seismic," "Drilling," "Telescope," "Map and Survey," "Laboratory Analytical," "Laboratory Environment," "Emplace and Monitor," and "Set Up and Read." In these listings, several experiments from various Discipline Areas of investigations are grouped within each key operation for each phase of exploration. An evolutionary program of experimentation is developed by following the progression of experiments by scientific discipline within a key operation through the various phases of lunar exploration.

The trend of minimum mass requirements for scientific payloads shown in Table 30 can also be used as a basis for evolutionary programs. The key item "Telescope" shows requirements of 238 kilograms in Phase B, 25 kilograms in Phase C, approximately 4700 kilograms in Phase D and 18,000 kilograms in Phase E. In arriving at these masses some minor assumptions of equipment commonality were made. This growth is based upon four small multi-use telescopes being brought to the lunar surface in Phase B. These are also used in Phase C with the addition of two small telescopic attachments. The 40-inch telescope is brought up during Phase D. Phase E shows the introduction of a 100-inch telescope and the astronomical equipment associated with a semipermanent base. The "Analytical Laboratory" grouping shows a maximum in Phase B where a substantial laboratory capability is first introduced in terms of a small work area. The environmental laboratory is introduced in Phase C but has its greatest experiment mass requirement in Phase D.

Additional information, such as number of vehicles required, logistics requirements, fuel requirements, and stay time can be estimated when the replications necessary to accomplish objectives are known per mission and on a total requirement basis. This information also allows better estimation of the vehicle experimental payload requirements in an evolutionary manner.

Table 31. Composite Sequence Summary Chart

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE A BASE - ANALYTICAL LAB												
32010111	Chemical analyses using neutron activation at lunar bases	Site	None	All phases	1	16	600	24	25	$ 5,000,000 500,000	3	0
32010301	Distillation of solids and differential thermal analysis	Site	None	Early exploration	1	7.0	150	19	100	$ 300,000 20,000	2	5.0
32010112	Chemical analysis using X-ray fluorescence at lunar base	Site	None	Early exploration	1	7.0	100	22	0.5	$ 5,000,000 500,000	2	0
32010106	Density measurements by flotation	Site	None	Early exploration	1	0.5	0	20	0.0	$ 100,000 1,000	0	0
PHASE A BASE - DRILLING												
21040411	Visual subsurface logging for fine structure	Site	Walk	Early exploration	1	1.7	45	10	100	$ 1,000,000 60,000	2	0
44070882	Temperature gradient in borehole	Site	Walk	Initial landings	1	4.4	190	0.5	9	$ 200,000 6,000	2	0
44070842	Temperature, shallow probe	Site	Walk	Initial landings	1	0.55	0	0.1	3	$ 400,000 7,000	2	0
PHASE A BASE - EMPLACE AND MONITOR												
01030159	Lunar atmospheric pressure at landing sites	Site	Walk	Initial landings	1	1.0	8,000*	0.1	20	$ 1,000,000 100,000	2	0
02030263	Charged atmospheric dust analyses with a charged dust spectrometer	Site	Walk	Initial landings	1	8.5	2,000*	1.0	0.5	$ 3,000,000 300,000	3	0
40080353	Meteorite measurements	Site	Walk	Initial landings	1	3.3	190	0.3	5	$ 900,000 100,000	0	0
44070847	Thermal Diffusivity, surface	Site	Walk	Initial landings	1	6.8	12	0.3	1,000	$ 600,000 30,000	1	0
46040616	Magnetic field, determine existence of permanent lunar magnetic field	Site	Walk	Initial landings	1	6.0	250	0.3	5	$ 800,000 100,000	1	0
46040617	Magnetic field, total	Site	Walk	Initial landings	1	7.5	160	0.5	12	$ 800,000 100,000	1	0
44070846	Heat flow, thermal blanket	Site	Walk	Initial landings	1	2.5	0	0.2	3	$ 1,000,000 100,000	3	0
45030912	Gravity, absolute, and its variations	Site	Walk	Initial landings	1	15	18,000*	0.5	15	$ 2,000,000 200,000	2	0
53010201	Solar wind particles at lunar surface	Site	Walk	Initial landings	1	2.3	13,000*	0.2	3	$ 0 200,000	0	0
53050203	Magnetic field time variation at lunar surface	Site	Walk	Initial landings	1	3.0	22,000*	0.3	5	$ 0 100,000	0	0

*Energy supplied by ALSEP RTG source

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE A BASE - ENG. 6, OPERATIONAL												
82043401	Dust removal techniques	Site	Walk	Initial landings	1	10	5.0	1.0	500	$ 500,000 100,000	1	0
PHASE A BASE - PHOTOGRAPHY												
21040205	Surface photogeology	Site	Walk	Initial Landings	1	33 [c]	960 [c]	3.0	100	$ 9,000,000 800,000	3	10
PHASE A BASE - SAMPLING												
21010309	Sample collection from all sites and traverses	Site, traverse	Combination of vehicles	All phases	1	4.1	0	5.0	0.0	$ 500,000 40,000	1	200
62030401	Soil bank, establish lunar sample depots at various locations on the moon	Emplaced points	Walk and LSSM	All early phases	2	0	0	0	0.0	0 0	0	0
82010102	Engineering properties of the lunar surface	Site	Walk	Initial landings	1	1.8	0	2.0	0.0	$ 100,000 20,000	3	0
81021104	Lunar geological-geochemical sample cassets	Site	Walk	Initial landings	1	20	0	4.0	0.0	$ 500,000 50,000	2	1.0
PHASE A BASE - SEISMIC												
40010101	Seismic velocity, surface	Site	Walk	Initial landings	1	13	1.7	0.2	20	$ 800,000 100,000	1	0
41020207	Seismic recording, passive	Site	Walk	Initial landings	1	11	190	1.0	11	$ 1,000,000 50,000	2	0
PHASE A BASE - SETUP AND READ												
44070850	Thermal emissivity, surface	Site	Walk	Initial landings	1	0.9	5.0	0.4	5	$ 300,000 10,000	2	0
40070883	Measure spectral reflectance of lunar-surface materials	Site	Walk	Early exploration	1	12	250	1.0	5	$ 3,000,000 300,000	2	0
PHASE A BASE - OTHER												
61030303	Genetic effects of lunar conditions and earth-lunar trips on microorganisms	Site	None	Early exploration	1	0	0	20	0.0	$ 0 0	0	0
PHASE B BASE - ANALYTICAL LAB												
31010108	Mineralogical and petrographic studies by use of microscope	Site	None	Early exploration	1	7.3	5,900	100	500	$ 600,000 60,000	3	0
35010110	Chemical analysis of solids using mass spectrometer	Site	None	Early exploration	1	23	600	40	30	$ 5,000,000 400,000	3	0
32010102	Chemical analysis using IR spectrometer	Site	None	Orbital Studies	1	16	130	22	1.3	$ 5,000,000 500,000	5	0
32010105	Chemical analysis at base laboratory using chemical reagents, etc.	Site	None	Extended exploration	1	21	3,000	200	100	$ 200,000 10,000	1	0

[c] Energy supplied by independent power source (Astronaut Survey Staff). Mass includes 20Kg for TV monitor located in LEM.

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
32010103	Chemical analysis using a nuclear magnetic resonance spectrometer	Site	None	Extended exploration	1	20	4,000	21	25	$ 5,000,000 500,000	4	0
32010107	Mineralogical study using an X-ray diffractometer	Site	None	Extended exploration	1	9.0	250	81	60	$ 1,000,000 100,000	4	0
40130775	Neutron activation experiment	Site	Walk	Early exploration	1	9.0	1,700	2.0	29	$ 2,000,000 500,000	3	0
40110777	Neutron flux and energy spectrum	Site	Walk	Early exploration	1	5.5	29,000**	0.2	5.4	$ 1,000,000 100,000	2	0
40130771	Alpha particle mass spectrometer	Site	Walk	Early exploration	1	12	1.4	0.1	0.3	$ 1,000,000 90,000	1	0
61040102	Evidence of existing life	Traverse	LSSM	Early exploration	2	57	7,700	270	500	$ 300,000 70,000	2	3.0
61040101	Induced prebiotic chemistry	Site	None	Early exploration	1	45	1,500	240	15	$ 300,000 50,000	1	1.0
PHASE B BASE - DRILLING												
44070845	Temperature profile in deep borehole	Site	Walk	Early exploration	1	0.55	0	0.5	3	$ 200,000 6,000	1	0
44070848	Thermal diffusivity, borehole	Site	Walk	Initial landings	1	2.6	720	1.0	10	$ 400,000 20,000	2	0
40050526	Magnetic susceptibility, subsurface	Site	Walk	Early exploration	1	2.0	300	1.0	15	$ 1,000,000 200,000	2	0
PHASE B BASE - EMPLACE AND MONITOR												
01030260	Time variations of lunar atmosphere pressure	Site	LSSM	Early exploration	1	1.0	40,000**	0.1	20	$ 1,000,000 100,000	2	0
02030361	Electric field magnitude and direction at and near lunar surface	Site	LSSM	Early exploration	1	2.0	0.016	1.0	0.4	$ 1,000,000 50,000	3	0
46040619	Magnetic field components	Emplaced points	Walk	Early exploration	1	6.0	18,000**	1.0	5	$ 400,000 80,000	1	0
46040618	Magnetic field, total, ESS	Emplaced points	Walk	Early exploration	1	6.0	18,000**	1.0	5	$ 800,000 100,000	1	0
45100601	Plasma potential variations versus height and time	Surface plus orbit	Walk	Early exploration	1	3.0	4.0	11.0	2	$ 200,000 100,000	1	0
40080352	Meteorite measurements, velocities, and momentums	Site	LSSM	Early exploration	1	3.3	190	0.4	5	$ 1,000,000 100,000	1	0
52020401	Solar and galactic radiation environment at lunar surface	Site	Walk	Initial landings	2	4.8	14,000**	39.0	1.5	$ 1,000,000 200,000	0	1.0
53050201	Monitor magnetic field strength and direction at lunar surface	Site	Walk	Initial landings	1	2.0	18,000**	2.5	2	$ 0 100,000	0	0

**Energy supplied by ESS RTG source

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
53070101	Steady and slowly varying electrostatic field near lunar surface	Site	Walk	Initial landings	1	3.0	26,000**	3.5	2	$ 800,000 100,000	1	0
52020102	Solar-charged particle environment at surface, 0.01 - 0.5 MEV, later phase	Site	Walk	Extended exploration	1	4.6	1,800	150	3	$ 500,000 100,000	1	0
52020101	Solar-charged particle environment at surface, 0.01 - 0.5 MEV	Site	Walk	Early exploration	1	4.6	1,200	100	3	$ 500,000 100,000	1	0
54080101	Galactic particle scattering and reactions	Site	Walk	Early exploration	2	6.8	100	59	30	$ 5,000,000 500,000	3	0
53070102	Vertical component of electrostatic field at and above lunar surface	Site and lunar orbit	Walk	Early exploration	2	6.6	360	9.7	1	$ 500,000 70,000	1	0
53040101	Electrons escaping earth auroral zones during geomagnetic storms	Site	Walk	Extended exploration	1	4.5	5,600	220	4	$ 80,000 200,000	1	0
52020103	Solar-charged particle environment at surface, 0.01 - 0.5 MEV, later activity	Site	Walk	Extended exploration	1	4.6	3,600	270	3	$ 500,000 100,000	1	0
78070101	Cislunar wave propagation, study of medium	Site	Walk	Early exploration	1	20	1,500	8.0	5	$ 300,000 50,000	1	0
77070101	Lunar ambient vector magnetic field measurements	Site	Walk	Early exploration	1	5.5	5,000	57	5	$ 100,000 20,000	1	0
78070102	Cislunar wave propagation advanced central station	Lunar site and earth	Walk	Extended exploration	1	20	7,500	8.0	5	$ 400,000 70,000	1	0
82010109	Lunar surface and subsurface electrical parameters	Geological area	LSSM	Early exploration	2	35	200	14	5	$ 300,000 40,000	2	0
82043501	Dynamics and surface environment effects on long antenna structures	Site	Walk	Early exploration	2	8.0	0	2.0	0.0	$ 300,000 50,000	1	0
82010202	Lunar RF noise, Part 1, low-frequencies	Geological area	LSSM	Early exploration	2	70	4,000	10	20	$ 400,000 70,000	1	0
82010203	Lunar RF noise, Part 2	Site	LSSM	Early exploration	1	6.0	2,000	6.5	10	$ 2,000,000 300,000	3	0
82010204	Antenna dust accumulation	Site	Walk	Early exploration	1	2.0	200	2.0	3	$ 300,000 50,000	1	0
82043203	RF ground wave propagation	Geological area	LSSM	Early exploration	2	7.5	260	8.0	100	$ 1,000,000 200,000	3	0
	PHASE B BASE - ENG. 1, HUMAN FACT											
82032001	Clinical monitoring	Site	None	Early exploration	2	14	70	14	5	$ 0 20,000	-	1.0
82032002	Mechanical efficiency of man at reduced gravity	Site	None	Early exploration	2	18	16	4.0	4	$ 0 50,000	-	0
82032003	Work capability determinations on lunar surface	Site	None	Early exploration	2	18	2.1	2.0	10	$ 200,000 30,000	2	0

**Energy Supplied by ESS RTG source

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82032005	Vision studies	Site	None	Early exploration	1	2.3	20	0.5	40	$ 100,000 20,000	1	0.1
PHASE B BASE - ENG. 2, CONSTRUCTION												
82043101	Simulated personnel shielding from solar event protons	Site	None	Early exploration	1	0.3	0	0.2	0.0	$ 0 2,000	0	0.3
82043502	Repair techniques for major structural damage	Site	Walk	Early exploration	2	10	1,000	3.0	1,000	$ 400,000 70,000	2	0
82053901	Explosive techniques for surface modification	Geological area	LSSM	Early exploration	1	100	0	10	0.0	$ 500,000 50,000	2	0
82010105	Radiation shielding effectiveness of lunar soil	Site	Walk	Early exploration	2	10	0.2	13	1	$ 1,000,000 300,000	2	0
82010108	Shelter shielding and construction support properties of lunar soil	Geological area	LSSM	Early exploration	2	6.5	2.0	5.0	2	$ 800,000 200,000	2	0
PHASE B BASE - ENG. 3, MAT EFFECTS												
82043414	Elastomer and polymer behavior	Site	Walk	Early exploration	1	2.5	0	2.0	0.0	$ 500,000 100,000	2	1.0
82043403	Static exposure effects on materials	Site	Walk	Early exploration	1	2.0	0	0.5	0.0	$ 200,000 40,000	1	1.0
82043404	Exposure effects on radiator materials	Site	Walk	Early exploration	1	5.0	100	1.5	100	$ 200,000 40,000	1	0.0
82010104	Corrosive action of lunar surface material	Site	Walk	Early exploration	1	1.0	0	1.0	0.0	$ 0 0	0	1.0
82043406	Early materials dynamic tests machine elements	Site	Walk	Early exploration	1	20	5,000	2.0	500	$ 1,000,000 300,000	2	1.0
82043407	Early materials dynamic tests - thin film bearings	Site	Walk	Early exploration	1	10	2,000	2.0	200	$ 500,000 100,000	2	1.0
82043408	Early materials dynamic test - electrical components	Site	Walk	Early exploration	1	5.0	1,000	1.0	100	$ 500,000 100,000	2	1.0
82043415	Static and dynamic seals	Site	Walk	Early exploration	1	5.0	0	1.5	0.0	$ 300,000 80,000	2	2.5
82023413	Solid state materials, effect of lunar environment	Site	Walk	Early exploration	1	4.0	1,000	0.2	20	$ 700,000 100,000	2	2.0
PHASE B BASE - ENG. 4, RESOURCES												
83064105	Quantitative analysis of hydrogen in lunar material	Site	None	Early exploration	1	20	40	4.0	25	$ 0 0	4	2.0
83064104	Detection of hydrogen with a phosphorus pentoxide conductance cell	Site	None	Early exploration	1	10	40	4.0	10	$ 300,000 70,000	4	2.0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE B BASE - ENG. 5, FLUID MECH												
90030301	Heat convection and flow of gases in enclosed spaces	Site	Walk	Early exploration	1	20	100	3.0	20	$ 500,000 100,000	2	0
82045003	Temperature/density stratification of cryogenic liquids	Site	None	Early exploration	1	1.0	0.01	0	0.001	$ 200,000 50,000	1	0
PHASE B BASE - PHOTOGRAPHY												
11010101	Selenodetic astronomy observations for improving map accuracy	Site, traverse	Combinations of vehicles	All phases	1	150	6,800	73	25.0	$ 1,000,000 100,000	5	60
PHASE B BASE - SAMPLING												
81021301	Biological contamination of lunar soil	Site	Walk	Early exploration	1	15	600	2.2	80	$ 2,000,000 200,000	2	1.0
82010208	Effects of leakage from vehicles, shelters and space suits	Site	Walk	Early exploration	1	4.6	0.003	0.8	0.003	$ 500,000 100,000	1	0
82010205	Lunar atmosphere contamination effects of rocket exhaust	Site	Walk	Early exploration	1	4.6	0.003	0.8	0.003	$ 500,000 100,000	1	0
PHASE B BASE - SEISMIC												
41020208	Seismic recording, passive, (long period, short period)	Site	LSSM	Early exploration	2	14	36	6.0	3	$ 1,000,000 90,000	2	0
40010102	Seismic velocity, subsurface logging	Site	Combination of vehicles‡	Early exploration	1	11	4.6	0.3	20	$ 800,000 100,000	1	0
PHASE B BASE - SETUP AND READ												
40120778	Surface and subsurface gamma ray spectroscopy	Site	Walk	Early exploration	1	6.0	4.5	0.5	1	$ 1,000,000 100,000	1	0
40130773	Normal radioactivity at different lunar locations	Site	Walk	Early exploration	1	1.8	1,300	1.0	8	$ 800,000 80,000	0	0
PHASE B BASE - TELESCOPE												
47011101	Study of earth atmosphere heat balance from lunar site	Site	Walk	Early exploration	1	78	320	27	15	$ 400,000 90,000	2	2.0
47021202	Study of earth reflectivity and albedo	Site	Walk	Early exploration	1	78	44	25	2	$ 400,000 100,000	2	2.0
47031303	Study of earth auroral and airglow emission	Site	Walk	Early exploration	1	74	44	20	2	$ 300,000 80,000	2	2.0
47041404	Ultraviolet scattering in earth atmosphere	Site	Walk	Early exploration	1	78	44	20	1.5	$ 400,000 90,000	2	2.0
47051505	Earth atmosphere sounding by passive infrared scanning	Site	Walk	Early exploration	1	80	44	20	2	$ 400,000 90,000	2	4.0
49013101	Earth ocean heat balance study	Site	Walk	Early exploration	1	69	3,200	33	15	$ 7,000,000 700,000	3	0

‡Experiment primarily recommended for early exploration phase, may be desirable for later phases. Combination of vehicles identifies requirement for using the most advanced vehicles available in each exploration phase.

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
49023201	Sequential multiband ocean photography	Site	Walk	Early exploration	1	73	3,000	31	15	$ 2,000,000 200,000	1	2.0
55220201	Measure UV spectrum of solar flares	Site	Walk	Early exploration	1	130	3,000	7.0	10	$ 1,000,000 200,000	3	0
55220101	Observe spectrum of outer solar corona	Site	Walk	Early exploration	1	110	30	12	12	$ 5,000,000 1,000,000	3	0
71010101	Test the influence of lunar environment on optical telescope installation	Site	Walk	Early exploration	1	50.0	300	310	20	$ 200,000 50,000	2	1.0
72010102	High-resolution astronomical photos with 12-inch telescope	Site	Walk	Early exploration	1	52	320	320	20	$ 200,000 50,000	2	21.
72010104	Medium and low-dispersion spectroscopy of stars, planets, galaxies, etc.	Site	Walk	Early exploration	1	52	1,800	310	20	$ 300,000 70,000	2	2.0
72010205	Photo survey of sky, 1000 - 3000 angstroms, with 12-inch wide field telescope	Site	Walk	Early exploration	1	51	1,600	920	20	$ 200,000 60,000	2	5.0
74010520	Einstein eclipse problem	Site	Walk	Early exploration	1	20	40	62	20	$ 200,000 30,000	1	20
72010206	Investigation of variable brightness extended surface phenomena	Site	Walk	Early exploration	1	50	1,600	500	20	$ 300,000 60,000	2	5.0
81021801	Lunar optical astronomy test program	Site	Walk	Early exploration	2	120	1,000	20	20	$ 9,000,000 3,000,000	4	5.0
PHASE B BASE OR TRAVERSE - ANALYTICAL LAB												
32010101	Chemical analyses using neutron activation	Traverse	Combination of vehicles	Early exploration	1	16	500	22	25	$ 5,000,000 800,000	3	0
33010101	Gamma ray spectrometry on traverse	Traverse	‡Combination of vehicles	Early exploration	1	32	2,000	20	1	$ 5,000,000 200,000	2	0
32010104	Chemical analysis using X-ray fluorescence	Traverse	Rover	Extended exploration	1	7.0	100	22	0.5	$ 5,000,000 500,000	2	0
34010403	Mass spectrometry near emission source	Emplaced points	From orbit and LSSM	Early exploration	0	20	150,000	0	30	$ 5,000,000 200,000	3	0
34010402	Mass spectrometric analysis of gasses on lunar surface	Traverse	Combination of vehicles	Early exploration	1	20	7,500	4.5	30	$ 5,000,000 200,000	3	0
32010118	IR reflectance and emissivity in situ	Traverse	‡Combination of vehicles	Early exploration	1	15	7,500	7	30	$ 1,000,000 100,000	2	500
32010115	UV and visible reflectance spectra in situ	Traverse	‡Combination of vehicles	Early exploration	1	15	7,500	7	30	$ 2,000,000 200,000	2	500
32010114	Mineralogical study with X-ray diffractometer in situ	Traverse	Combination of vehicles	Extended exploration	1	9.0	200	10	60	$ 1,000,000 100,000	2	0
32010113	Density measurements by gamma scattering in situ	Traverse	Combination of Vehicles	Extended exploration	1	2.0	250	10	25	$ 5,000,000 500,000	1	0

•Energy supplied by independent power source (emplaced package)
‡Experiment primarily recommended for early exploration phase may be desirable for later phases. Combination of Vehicles identifies requirement for using the most advanced vehicles available in each exploration phase.

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE B BASE OR TRAVERSE - DRILLING												
21020307	Shallow drilling for subsurface structure and sampling	Site, traverse	LSSM	Early exploration	1	44	2,000	2.4	1,200	$ 5,000,000 100,000	3	42
24030413	Paleomagnetism of the moon	Traverse	LSSM	Early exploration	1	1.0	1.0	0.2	5	$ 400,000 80,000	1	0
44070843	Temperature, borehole logging	Geological area	LSSM	Early exploration	1	0.55	0	0.2	3	$ 200,000 6,000	1	0
40060534	Resistivity, subsurface	Geological area	LSSM	Early exploration	1	2.0	0.001	0.2	5	$ 1,000,000 200,000	2	0
40060628	Self potential, subsurface	Traverse	LSSM	Early exploration	1	2.5	20	2.0	1	$ 1,000,000 20,000	1	0
40050538	Electrical permittivity, subsurface	Geological area	LSSM	Early exploration	1	4.0	0.02	0.1	5	$ 500,000 20,000	1	0
81021102	Lunar drill bit technology	Selected drilling sites	LSSM	Early exploration	1	0.5	0	0	0.0	$ 0 0	0	0
81021101	Gas requirements for lunar core drilling	Selected drilling sites	LSSM	Early exploration	1	0.1	0	1.0	0.0	$ 0 0	0	0
PHASE B BASE OR TRAVERSE - EMPLACE AND MONITOR												
53010101	Solar wind interaction with moon and geomagnetosphere	Geological area	LSSM	Early exploration	2	7.0	1,800	20	6.5	$ 2,000,000 700,000	1	0
78070103	Cislunar wave propagation, advanced outlying station A	Emplaced points	Flying vehicle or Rover	Extended exploration	1	50	7,500	8.0	5	$ 400,000 70,000	1	0
78070104	Cislunar wave propagation advanced outlying station B	Emplaced points	Flying vehicle or Rover	Extended exploration	1	50	7,500	8.0	5	$ 400,000 70,000	1	0
82043201	Lunar environment effects on antenna systems	Geological area	LSSM	Early exploration	1	7.0	100	3.0	2	$ 400,000 80,000	2	0
82043206	Retrodirective optical system techniques	Geological area	LSSM	Early exploration	2	3.0	50	1.0	5	$ 300,000 50,000	1	0
PHASE B BASE OR TRAVERSE - ENG. 1, HUMAN FACT												
82053701	Visual techniques in land navigation - astronaut vision	Geological area	LSSM	Early exploration	2	4.0	0	4.3	0.0	$ 200,000 40,000	1	0
82053702	Visual techniques in land navigation - land recognition	Geological area	LSSM	Early exploration	2	1.0	0	3.3	0.0	$ 200,000 50,000	3	0
PHASE B BASE OR TRAVERSE - ENG. 4, RESOURCES												
83064106	Detection of hydrogen in lunar materials using infrared spectrometer	Site	None	Early exploration	1	16	600	40	30	$ 200,000 100,000	5	0
83064101	Detection of hydrogen in lunar materials using neutron activation	Geological area	LSSM	Early exploration	1	16	250	5.0	25	$ 0 0	3	2.0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE B BASE OR TRAVERSE - ENG. 6, OPERATIONAL												
82010201	Lunar surface dust environment	Various locations	Walk	Early exploration	1	2.0	0	2.0	0.0	$ 100,000 10,000 50,000	1	1.0
82043310	Electrical systems grounding	Site	LSSM	Early exploration	1	3.0	0.2	2.0	1	$ 300,000 50,000	1	0
82023202	RF forward scatter techniques	Geological area	LSSM	Early exploration	2	10	150	5.0	3	$ 500,000 100,000	3	0
82043301	Lunar surface transmission line interactions	Site	Walk	Early exploration	1	2.0	0	2.0	0.0	$ 200,000 50,000	1	2.0
82043402	Damage to lunar equipment	Site	Walk	Early exploration	1	0	0	3.0	0.0	$ 0 0	2	0
82010206	Thermal radiation intensities and surface temperature gradients	Geological area	LSSM	Early exploration	1	10	100	2.0	50	$ 200,000 50,000	1	0
82010122	Lunar strata electromagnetic propagation parameters	Geological area	LSSM	Early exploration	2	3.0	250	7.5	100	$ 1,000,000 200,000	2	0
82043204	RF subsurface propagation	Geological area	Rover	Extended exploration	3	20	350	11	100	$ 800,000 200,000	3	0
PHASE B BASE OR TRAVERSE - MAPPING AND SURVEY												
21010203	Detailed mapping of lunar surface geologic fine structure	Site, traverse	Combination of vehicles	All phases	1	38	170	5.0	100	$ 10,000,000 800,000	3	.1
21010204	Geologic mapping, general, including on-site verification of features identified from orbital experiments	Site, traverse	Combination of vehicles	All phases	1	28	160	8.0	25	$ 7,000,000 600,000	3	.1
90050201	Corner reflectors for laser beams	Emplaced points	LSSM	Early exploration	1	30	0	0.4	0.0	$ 200,000 50,000	1	0
PHASE B BASE OR TRAVERSE - OTHERS												
81021103	Calibration of remote sensing techniques	Selected geophysics sites	LSSM	Early exploration	1	0	0	1.0	0.0	$ 0 0	0	0
PHASE B BASE OR TRAVERSE - SAMPLING												
24030310	Age dating of lunar rocks and formations	Traverse	Combination of vehicles	All phases	1	28	40	2.0	25	$ 9,000,000 900,000	3	10
23010320	Sample collection	Traverse	Walk	All phases	1	6.0	0	0.1	0.0	$ 300,000 1,000	2	100
41050622	Magnetism, remnant	Geologic area	LSSM	Early exploration	1	2.0	0	2.0	0	$ 40,000 800	1	2.0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE B BASE OR TRAVERSE - SEISMIC												
40010103	Seismic profiling, shallow reflection	Geological area	Walk	Early exploration	1	11	4.6	0.3	20	$ 800,000 100,000	1	0
41020211	Seismic recording, large array	Emplaced points	LSSM	Extended exploration	2	110	48	2.0	140	$ 1,000,000 50,000	2	0
41010206	Seismic profiling, deep refraction	Traverse	Rover	Extended exploration	0	11	0.05	0	3	$ 1,000,000 50,000	2	0
40010104	Seismic profiling, shallow refraction	Geological area	LSSM	Early exploration	1	11	4.5	0.6	20	$ 800,000 100,000	1	0
81021203	Explosive energy coupling in lunar materials	Geological area	LSSM	Early exploration	1	10	2.7	8.0	30	$ 1,000,000 100,000	1	0
PHASE B BASE OR TRAVERSE - SETUP AND READ												
13030303	Gravity measurements at lunar surface to supplement surveying observations	Site, traverse	Combination of vehicles	All phases	1	27	2,100	17	10	$ 1,000,000 100,000	5	0
40060532	Resistivity of lunar surface materials in situ	Geological area	LSSM	Early exploration	1	4.0	0.001	0.2	5	$ 800,000 60,000	1	0
41050541	Electrical surveying, subsurface	Geological area	LSSM	Early exploration	0	4.0	0	0	10	$ 1,000,000 100,000	1	0
40050524	Magnetic susceptibility, surface, in situ	Traverse	LSSM	Early exploration	1	2.0	2,300	1.0	15	$ 500,000 50,000	2	0
41040681	Electrical surveying, earth current	Geological area	LSSM	Early exploration	2	4.6	120	3.0	5	$ 1,000,000 30,000	2	0
41090487	Subsurface hardness	Traverse	LSSM	Early exploration	1	10	2.0	.2	20	$ 1,000,000 100,000	4	0
81021201	Electrode electrical coupling properties in lunar surface	Geological area	LSSM	Early exploration	1	2.0	0.02	4.0	5	$ 400,000 50,000	3	0
PHASE B TRAVERSE ONLY - ENG. 6, OPERATIONAL												
82053602	Dangerous terrain warning techniques	Geological area	LSSM	Early exploration	1	20	2,000	2.0	20	$ 800,000 200,000	2	0
82053601	Soil value variations in lunar terrain	Geological area	LSSM	Early exploration	2	15	0	6.2	0.0	$ 600,000 100,000	2	0
PHASE B TRAVERSE ONLY - MAPPING AND SURVEY												
12010202	Selenodetic surveying to establish ground control for satellite mapping	Site, traverse	Combinations of vehicles	All phases	1	140	4,000	55	1,000	$ 2,000,000 200,000	5	60
40060630	Electrical survey, surface	Geological area	LSSM	Early exploration	1	4.3	33	1.0	500	$ 1,000,000 40,000	2	0
45030913	Gravity absolute (ESS)	Emplaced site	Walk	Early exploration	1	15.0	18,000 **	1.2	15	$ 2,000,000 200,000	2	0

**Energy Supplied by ESS RTG source

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
45030914	Gravity survey on traverses	Traverse	LSSM	Early exploration	1	15	600	2.5	15	$ 2,000,000 200,000	2	0
46040620	Magnetic field, total field surveying	Traverse	LSSM	Early exploration	1	6.0	25	2.5	5	$ 800,000 100,000	1	0
40050536	Electrical permittivity, surface	Geological area	LSSM	Early exploration	1	0.6	0	1.0	0.0	$ 100,000 200	1	2
PHASE C BASE -EMPLACE AND MONITOR												
11010505	Earth-moon distance observations for determining librations, etc.	Site, traverse	Combinations of vehicles	All phases	1	300	8,000	73	1,000	$ 2,000,000 200,000	5	60
52030101	Galactic nuclei environment at surface, 100 MEV - 100+ BEV	Site	Walk	Early exploration	1	110	24,000	55	4	$ 2,000,000 400,000	1	10
52020201	Solar-charged particle environment at surface 0.04 - 1000 MEV	Site	Walk	Early exploration	1	20	20,000	54	4	$ 1,000,000 300,000	2	4.0
52030201	Galactic electron environment at surface, 100 - 1000 MEV	Site	Walk	Early exploration	1	110	24,000	21	4	$ 2,000,000 400,000	1	10
52020202	Solar-charged particle environment at surface, 0.04 - 1000 MEV, later activity	Site	Walk	Extended exploration	1	25	39,000	160	4	$ 1,000,000 300,000	3	6.0
53050101	Interplanetary magnetic field and distant geomagnetic field	Site	Walk	Early exploration	2	5.0	32,000	21	11	$ 2,000,000 400,000	1	0
52030102	Galactic nuclei environment at surface, 100 MEV - 100+ BEV, later solar activity	Site	Walk	Extended exploration	1	110	48,000	210	4	$ 2,000,000 400,000	3	10
52030202	Galactic electron environment at surface, 100 - 1000 MEV, later solar activity	Site	Walk	Extended exploration	1	110	48,000	77	4	$ 2,000,000 400,000	1	10
54080102	Galactic particle scattering and reactions, advanced	Site	LSSM	Extended exploration	2	70	20,000	97.0	200	$ 10,000,000 1,000,000	6	2.0
53040102	Electrons escaping earth auroral zones during geomagnetic storms, later solar activity	Site	Walk	Extended exploration	1	4.5	11,000	420	4	$ 80,000 200,000	1	0
75040101	Nondirectional radio astronomy	Site	Walk	Early exploration	1	7.0	15,000	6.0	3	$ 500,000 90,000	2	0
PHASE C BASE - ENG. 1, HUMAN FACT												
82032011	Bone demineralization studies	Site	None	Extended exploration	2	65	10,000	55	1,000	$ 0 50,000	0	1.0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82033004	Effects of breathing various gas mixtures	Site	None	Extended exploration	2	30	0	23	0.0	$ 50,000	2	0
82032006	Psychological studies	Site	None	Extended exploration	2	7.0	0	20	0.0	$ 100,000 1,000	1	0
82032004	Bioassays of body fluids	Site	None	Extended exploration	2	3.5	0	21	0.0	$ 0 5,000	0	0
82032010	Cardiovascular phenomena	Site	None	Extended exploration	2	7.3	900	55	20	$ 100,000 20,000	1	0.5
PHASE C BASE - ENG. 2, CONSTRUCTION												
82054001	Metals joining techniques in lunar surface construction and repair	Site	Walk	Extended exploration	2	20	10,000	18	10,000	$ 300,000 80,000	3	0
PHASE C BASE - ENG. 3, MAT. EFFECTS												
82043405	Materials dynamic test program	Site	LSSM	Extended exploration	1	80	20,000	20	800	$ 1,000,000 400,000	2	3
82043409	Long-term static exposure effects on materials	Site	Walk	Extended exploration	1	5.0	40	3.0	40	$ 400,000 100,000	1	2.0
PHASE C BASE - ENG. 4, RESOURCES												
83064201	Characteristics of lunar ores - self welding	Geological area	LSSM	Extended exploration	1	5.0	0	4.5	0.0	$ 200,000 50,000	2	0.5
83064303	Particle adhesion in mechanical processing	Geological area	LSSM	Extended exploration	1	400	10,000	24	1,500	$ 1,000,000 300,000	3	4.0
83064501	Lunar dry cement and concrete applications	Geological area	Rover	Extended exploration	2	110	7,000	51	1,500	$ 500,000 100,000	4	5.0
83064102	Chemical and differential thermal analysis for oxygen and CO_2 sources	Site	None	Extended exploration	1	15	320	10	100	$ 0 0	2	1.0
83064103	Differential thermal analysis of potentially castable materials	Site	None	Extended exploration	1	5.0	15	10	100	$ 0 0	2	1.0
PHASE C BASE - ENG. 5, FLUID MECH.												
82045001	Heat transfer in liquids through natural convection	Site	None	Extended exploration	1	7.0	5.0	10	300	$ 200,000 40,000	2	0
82045002	Heat transfer in film and drop condensation processes	Site	None	Extended exploration	1	3.0	2.0	10	100	$ 200,000 50,000	2	0
PHASE C BASE - ENG. 6, OPERATIONAL												
82010207	Lunar impact sferics	Site	Walk	Extended exploration	1	20	1,000	2.4	1	$ 600,000 100,000	1	0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE C - BASE - ENVIRONMENTAL LAB												
61010301	Genetic effects of lunar conditions and earth-lunar trips on plants	Site	None	Early exploration	1	260	0	170	0.0	$ 200,000 30,000	1	0
61010201	Behavior and rhythms of plants under the lunar day-night cycle	Site	None	Extended exploration	1	26	30	800	0.1	$ 70,000 10,000	2	2.0
61020202	Behavior and rhythms of animals under the lunar light/dark cycle	Site	None	Extended exploration	1	1.0	0	2,400	0.0	$ 10,000 1,000	1	1.0
82033002	Use of lunar soil for microorganisms and higher plants	Site	LSSM	Extended exploration	1	300	34,000	140	1,700	$ 2,000,000 300,000	3	0
PHASE C - BASE - SETUP AND READ												
81021207	Earth reference gravimeter	Site	Walk	Extended exploration	2	5.0	8,000	16	1	$ 2,000,000 200,000	2	5.0
PHASE C - BASE - TELESCOPE												
72010103	Photoelectric observations with the 12-inch telescope	Site	Walk	Early exploration	1	60	30,000	250	100	$ 200,000 50,000	2	1.0
73020622	Investigations of the X-ray radiation from sun, stars, galaxies and X-ray sources	Site	Walk	Early exploration	1	10	10,000	980	200	$ 500,000 100,000	2	0
73020623	High resolution study of X-ray sources	Site	Walk	Early exploration	1	25	1,000	590	200	$ 500,000 100,000	2	0
73020624	Interstellar medium distribution investigation	Site	Walk	Early exploration	1	25	1,000	390	200	$ 500,000 100,000	2	0
72010521	Lyman-alpha survey of the sky	Site	Walk	Early exploration	1	25	10,000	610	20	$ 100,000 50,000	2	0
72010207	Photoelectric scanning data on extended objects	Site	Walk	Early exploration	1	52	32,000	280	20	$ 400,000 70,000	2	5.0
81021802	Remote occulting disk as solar coronagraph	Geological area	LSSM	Extended exploration	2	20	0	6.7	0.0	$ 300,000 50,000	1	0.2
PHASE C - BASE OR TRAVERSE - ANALYTICAL LAB												
40120779	Surface and subsurface gamma ray spectroscopy	Traverse	Rover	Extended exploration	1	6.0	7.0	1.0	1	$ 1,000,000 100,000	1	0
40130776	Neutron activation experiment on traverse	Traverse	Rover	Extended exploration	1	6.0	1,700	0	29	$ 2,000,000 500,000	3	0
40130772	Alpha particle mass spectrometer on traverse	Traverse	Rover	Extended exploration	1	12	2.8	0	0.3	$ 1,000,000 90,000	1	0
PHASE C - BASE OR TRAVERSE - DRILLING												
21010330	Subsurface sampling	Traverse	Rover	Extended exploration	1	14	0	0.2	0.0	$ 300,000 5,000	2	200
22010412	Formation stratigraphic correlation over large distances by coring, etc.	Site, traverse	Rover	Extended exploration		110	24,000	14.0	5,000	$ 20,000,000 1,000,000	3	10

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
44070844	Temperature and emissivity of borehole walls	Traverse	Rover	Extended exploration	1	0.55	0	0.3	3	$ 200,000 6,000	1	0
44070849	Thermal diffusivity, borehole	Traverse	Rover	Extended exploration	1	11	0.03	0.2	10	$ 500,000 20,000	3	0
41010205	Seismic profiling, deep reflection	Geologic area	Rover	Extended exploration	2	12	4.2	2.1	20	$ 800,000 100,000	0	0
40050527	Magnetic susceptibility, subsurface	Traverse	Rover	Extended exploration	1	2.0	300	2.0	15	$ 1,000,000 100,000	2	0
40060629	Self potential, subsurface	Traverse	Rover	Extended exploration	1	2.5	20	3.0	1	$ 1,000,000 20,000	1	0
40050539	Electrical permittivity, subsurface	Traverse	Rover	Extended exploration	1	4.0	0.02	0.1	10	$ 500,000 20,000	1	0
PHASE C - BASE OR TRAVERSE - EMPLACE AND MONITOR												
41050623	Magnetism, remnant, late exploration	Traverse	Rover	Extended exploration	1	2.0	0	3.0	0	$ 40,000 800	1	5.0
40080354	Meteorite measurements on traverse	Traverse	Rover	Extended exploration	0	3.5	360	0	10	$ 600,000 50,000	2	0
53010102	Solar wind interaction with moon and geomagnetosphere including lunar limb measurements	Traverse	Rover	Extended exploration	3	33	34,000	39	4	$ 2,000,000 400,000	2	0
53050102	Interplanetary magnetic field and distant geomagnetic field, including lunar limb measurements	Traverse	Rover	Extended exploration	2	4.1	48,000	37	7	$ 2,000,000 400,000		0
PHASE C - BASE OR TRAVERSE - ENG. 6, OPERATIONAL												
82043205	Laser scatter propagation	Traverse	Rover	Extended exploration	3	80	100	4.0	50	$ .500,000 200,000	2	0
PHASE C - BASE OR TRAVERSE - SEISMIC												
13040404	Seismic measurements to supplement gravity observations	Site, traverse	Combination of vehicles	All phases	1	64	1,700	14	5	$ 200,000 20,000	3	0
PHASE C - BASE OR TRAVERSE - SETUP AND READ												
02030362	Electric field magnetic and direction at different lunar positions	Traverse	Rover	Extended exploration	1	2.0	0.016	0.1	0.4	$ 1,000,000 50,000	3	0
41060540	Electrical surveying, deep formations	Traverse	Rover	Extended exploration	0	6.0	0	0	10	$ 1,000,000 100,000	3	0
40050525	Magnetic susceptibility surface	Traverse	Rover	Extended exploration	1	2.0	300	2.0	15	$ 500,000 50,000	2	0
40060533	Resitivity of lunar-surface materials on traverses	Traverse	Rover	Extended exploration	1	5.0	0.001	0.1	10	$ 800,000 60,000	1	0

*Experiment primarily recommended for early exploration phase, may be desirable for later phases. Combination of Vehicles identifies requirement for using the most advanced vehicles in each exploration phase

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
40130774	Natural radioactivity on traverse	Traverse	Rover	Extended exploration	1	1.8	2,600	1.0	8	$ 800,000 60,000	0	0
40050537	Electrical permittivity, surface	Traverse	Rover	Extended exploration	1	4.0	0.02	0.1	5	$ 500,000 60,000	1	0
40090456	Determine hardness of subsurface lunar material	Traverse	Rover	Extended exploration	0	2.0	0	0	5	$ 500,000 50,000	1	0
PHASE C - TRAVERSE ONLY - DRILLING												
40060535	Resistivity of near-subsurface materials in boreholes	Traverse	Rover	Extended exploration	1	2.0	0.001	1.0	10	$ 700,000 60,000	2	0
PHASE C - TRAVERSE ONLY - EMPLACE AND MONITOR												
01030464	Gas chromatography for identification of heavy gases	Traverse	Rover	Extended exploration	1	6.3	18,000	20	30	$ 2,000,000 200,000	3	0
PHASE C - TRAVERSE ONLY - MAPPING AND SURVEY												
46040621	Magnetic field survey for determining models of lunar structure	Traverse	Rover	Extended exploration	1	6.0	50	11.0	5	$ 800,000 100,000	1	0
45030915	Gravity survey, regional anomalies	Traverse	Rover	Extended exploration	1	15	750	11.0	15	$ 2,000,000 200,000	2	0
40060631	Electrical surveying, surface	Traverse	Rover	Extended exploration	2	4.3	36	0.5	500	$ 1,000,000 40,000	2	0
44070851	Temperature, surface profile	Traverse	Rover	Extended exploration	0	1.0	0	0	5	$ 800,000 60,000	2	0
PHASE D - BASE - ANALYTICAL LAB												
90020101	Field emission optics	Site	Walk	Extended exploration	1	3.0	1,000	15	100	$ 800,000 200,000	2	0.5
PHASE D - BASE - EMPLACE AND MONITOR												
47081808	Passive probe of earth atmospheric by microwave scan	Site	Walk	Extended exploration	2	930	2,800	14	50	$ 6,000,000 1,000,000	9	0
52020402	Solar energetic electrons associated with solar flares	Emplaced points	Rover	Extended exploration	2	18	120,000	91	10	$ 1,000,000 400,000	2	0
52020203	Solar-charged particle environment at surface, 0.5 - 1000 MEV, later activity	Site	Walk	Extended exploration	1	43	78,000	310	4	$ 1,000,000 400,000	3	10
53010103	Solar wind interaction with moon and geomagnetosphere, several stations and solar eclipse event	Emplaced points	Rover	Extended exploration	4	33	64,000	61	4	$ 2,000,000 400,000	2	0
53050103	Interplanetary magnetic field and distant geomagnetic field, several stations	Emplaced points	Rover	Extended exploration	2	4.1	96,000	65	7	$ 0 400,000	2	0
52020403	Solar energetic electrons associated with solar flares, lunar limb stations	Emplaced points	Rover	Extended exploration	2	18	120,000	91	10	$ 0 500,000	2	0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
52030103	Galactic nuclei environment at surface 100 MEV - 100+ BEV, later solar activity	Site	Walk	Extended exploration	1	130	96,000	400	4	$ 0 1,000,000	3	20
52030203	Galactic electron environment at lunar surface, 100 - 1000 MEV, later solar activity	Site	Walk	Extended exploration	1	110	96,000	77	4	$ 2,000,000 400,000	3	10
54080103	Galactic particle scattering and reactions, detailed studies	Site	Walk	Extended exploration	2	100	200,000	88	1,500	$100,000,000 20,000,000	9	4.0
73030725	Detection of high-energy gamma rays	Site	Walk	Early exploration	1	25	100,000	610	200	$ 500,000 100,000	2	0
75050102	Directional radio astronomy using interferometer	Geological area	Rover	Extended exploration	2	510	30,000	23	3	$ 500,000 100,000	1	0
76070102	Lunar wave propagation experiment	Geological area	LSSM	Early exploration	2	20	51,000	19	40	$ 400,000 80,000	1	0
PHASE D - BASE - ENVIRONMENTAL LAB												
82033001	Evaluation of algae strains	Site	None	Extended exploration	1	320	14,000	210	1,700	$ 2,000,000 300,000	3	4.5
82033003	Evaluation of hydrogenomonas strains	Site	None	Extended exploration	1	320	2,000	210	120	$ 2,000,000 300,000	2	15
82033006	Evaluation of hydrocarbon utilizing organisms	Site	None	Extended exploration	1	320	14,000	110	1,700	$ 2,000,000 300,000	2	0.2
82033005	Biological monitor and eco-system prototype	Site	None	Extended exploration	1	10	12,000	10	50	$ 200,000 50,000	3	0.01
82033007	Effects of lunar conditions on plants	Site	None	Extended exploration	1	470	500	85	10	$ 2,000,000 400,000	2	10
82033008	Growth, development, reproduction and survival of plants	Site	None	Extended exploration	2	470	6,000	500	60	$ 2,000,000 400,000	2	200
82033009	Genetic effects of lunar conditions and earth-lunar trips on animals	Site	None	Extended exploration	1	470	0	100	0.0	$ 2,000,000 400,000	2	0
82033010	Growth development reproduction and survival of animals	Site	None	Extended exploration	2	470	0	500	0.0	$ 2,000,000 400,000	2	68
PHASE D - BASE - TELESCOPE												
47061606	Earth atmosphere density measurements by stellar refraction	Site	Walk	Extended exploration	2	3,100	40	120	20	$ 9,000,000 2,000,000	4	4.0
48092109	Study of nonterrestrial planetary atmosphere circulations	Site	Walk	Extended exploration	1	3,000	5.0	33	20	$ 10,000,000 3,000,000	4	9.0
48112311	Determination of planetary albedoes and reflectivities	Site	Walk	Extended exploration	1	3,000	240	180	20	$ 9,000,000 2,000,000	4	6.0
47071707	Study of earth atmosphere during terrestrial eclipse of sun	Site	Walk	Extended exploration	1	3,000	16	2.3	20	$ 9,000,000 2,000,000	4	4.0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
47051512	Observations and analyses of earth atmosphere circulation	Site	Walk	Extended exploration	1	3,000	65	52	20	$ 2,000,000	4	6.0
49013102	Ocean heat balance study, later phase	Site	Walk	Extended exploration	1	3,100	8,100	1,000	20	$ 9,000,000 2,000,000	6	0
49033301	Sea surface height measurements by use of lunar-based sensor	Site	Walk	Extended exploration	1	3,100	13,000	940	50	$ 10,000,000 2,000,000	8	10
55220301	Measure size distribution versus time of solar photospheric granulations	Site	Walk	Extended exploration	2	1,700	400	54	100	$ 9,000,000 2,000,000	5	0
55220601	Observe motion of solar chromospheric and coronal material and above solar flares	Site	Walk	Extended exploration	2	1,600	80	17	25	$ 9,000,000 2,000,000	5	10
55230101	Measure UV spectrum over solar disk	Site	Walk	Extended exploration	2	2,500	100	8.0	30	$ 10,000,000 2,000,000	5	0
55230102	Measure UV and visible spectrum from point to point over solar disk; determine chemical composition	Site	Walk	Extended exploration	2	2,500	200	11	30	$ 10,000,000 2,000,000	5	0
55220302	Measure velocity of photospheric material in granulations	Site	Walk	Extended exploration	2	2,500	400	31	25	$ 9,000,000 2,000,000	5	0
55230201	Measure UV spectrum of solar flares, advanced	Site	Walk	Extended exploration	2	2,500	500	21	30	$ 10,000,000 2,000,000	5	0
55220401	Observe size and magnetic field of sunspots versus time	Site	Walk	Extended exploration	2	1,700	2,200	16	100	$ 9,000,000 2,000,000	5	0
55220501	Observe structure and sudden disappearances of quiescent solar prominences	Site	Walk	Extended exploration	2	1,600	1,200	220	25	$ 9,000,000 2,000,000	5	1.0
72010308	Photographic studies of faint and bright objects at high resolution, 40-inch telescope	Site	Walk	Extended exploration	2	3,000	300	540	20	$ 9,000,000 2,000,000	4	50
72010309	Wide-band photographic photometry at very faint limits	Site	Walk	Extended exploration	2	3,000	300	240	20	$ 9,000,000 2,000,000	4	50
72010310	Photoelectric photometry of selected objects	Site	Walk	Extended exploration	2	3,000	30,000	480	200	$ 9,000,000 2,000,000	4	50
72010311	Medium- and low-dispersion spectroscopy of faint stars	Site	Walk	Extended exploration	2	3,000	7,800	910	20	$ 9,000,000 2,000,000	4	55
72010312	High-dispersion spectroscopy of bright stars, nebulae, etc.	Site	Walk	Extended exploration	2	3,200	15,000	940	20	$ 10,000,000 2,000,000	4	100
72010313	Spectral scans of various objects	Site	Walk	Extended exploration	2	3,000	45,000	910	200	$ 9,000,000 2,000,000	4	50
82010107	Lunar seismic environment	Site	LSSM	Extended exploration	1	10	20,000	1.0	5	$ 200,000 40,000	3	0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
PHASE D - BASE - OTHER												
90010101	Generation of high-intensity electron beams	Site	Walk	Extended exploration	1	15	10,000	20	50,000	$ 1,000,000 200,000	2	0
90030201	Solar furnace with controllable focal energy flux	Site	Walk	Extended exploration	1	100	1,000	15	50	$ 800,000 200,000	2	0
90010201	High-intensity arc generation in lunar environment	Site	Walk	Extended exploration	1	25	3,000	15	10,000	$ 1,000,000 300,000	2	0
90030101	Radiation cryostat	Site	Walk	Extended exploration	1	10	100	20	1	$ 500,000 100,000	2	0
90050101	Lorentzian plasma environmental physics	Site	Walk	Extended exploration	2	10	40	4.0	20	$ 400,000 100,000	2	0
PHASE D - BASE OR TRAVERSE - ENG. 2, CONSTRUCTION												
82010106	Nuclear reactor emplacement assessment	Site	LSSM	Extended exploration	2	16	0.47	10	0.49	Common usage equipment	2	0
82043302	Electrical transmission line routes	Site	LSSM	Extended exploration	2	0	1,000	6.0	100	$ 0 200,000	0	1.0
PHASE E - BASE - DRILLING												
21020308	Deep-drilling for sub-surface structure and sampling	Site	Walk	Extended exploration	4	7,000	4,200,000	1,200	12,000	$ 50,000,000 5,000,000	1	2,000
PHASE E - BASE - EMPLACE AND MONITOR												
53010104	Magnetohydrodynamics of solar wind flow past earth and moon	Lunar surface and in lunar polar orbit	Rover	Extended exploration	4	34	130,000	140	4	$ 2,000,000 500,000	2	0
53050104	Interplanetary magnetic field and distant geomagnetic field with added measurements from lunar orbiter	Surface and orbit	Rover	Extended exploration	2	7.6	210,000	110	9	$ 2,000,000 800,000	2	0
52090101	Solar and galactic neutrino sources	Site	Rover	Extended exploration	3	460	1,600,000	520	110	$ 30,000,000 5,000,000	9	0
75060101	Submillimeter radio astronomy experiments	Lunar limb, emplaced points	Rover	Extended exploration	3	5,000	20,000,000	1,000	1,000	$100,000,000 20,000,000	5	200
PHASE E - BASE - TELESCOPE												
48102210	Measurements of temperature and composition of planetary atmosphere	Site	Walk	Extended exploration	2	22,000	9,700	43	50	$100,000,000 20,000,000	9	10
49023202	Sequential multiband ocean photography, later phase	Site	Walk	Extended exploration	1	21,000	1,100	820	50	$100,000,000 20,000,000	8	10
72010414	High-resolution photographic studies with diffraction-limited 100-inch telescope	Site	Walk	Extended exploration	2	18,000	20,000	1,100	50	$100,000,000 20,000,000	6	50

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight *(kg)
72010415	High-dispersion spectroscopy of stars, planets, nebulae, comets, etc.	Site	Walk	Extended exploration	2	20,000	60,000	1,100	50	$100,000,000 20,000,000	6	100
72010416	Systematic observations of high-energy stellar phenomena	Site	Walk	Extended exploration	2	18,000	20,000	690	50	$100,000,000 20,000,000	6	50
72010417	Determination of nature and extent of stellar outer envelope	Site	Walk	Extended exploration	2	18,000	20,000	730	50	$100,000,000 20,000,000	6	50
72010418	Photo survey for planet-like companions of stars	Site	Walk	Extended exploration	2	18,000	20,000	430	50	$100,000,000 20,000,000	6	50
72010419	Photoelectric magnitude and color index measurements of stars	Site	Walk	Extended exploration	2	18,000	40,000	1,000	200	$100,000,000 20,000,000	6	50
PHASE E - BASE - OTHER												
90040101	Lifetimes of atomic species	Geological area	Rover	Extended exploration	2	100	2,000	70	200	$ 1,000,000 300,000	4	0
ORBITAL - ORBIT - EMPLACE AND MONITOR												
81021701	Earth RFI and background radio noise	Orbit	None	Orbital studies	1	15	40,000	0	10	$ 1,000,000 100,000	2	0
81021702	Dielectric properties of the lunar sphere	Orbit	None	Orbital studies	1	30	40,000	0	10	$ 1,000,000 100,000	2	0
81021703	Critical plasma frequencies of orbit-to-moon transmissions	Orbit	None	Orbital studies	1	12	300	5	25	$ 2,000,000 100,000	1	0
ORBITAL - ORBIT - MAPPING AND SURVEY												
12020606	Selenodetic mapping to establish detailed topographic lunar maps	Orbit	None	Orbital studies	1	530	5,100	0	1,000	$ 10,000,000 1,000,000	5	100
21040102	Photogeologic mapping from lunar orbit	Orbit	None	Orbital studies	0	75	380	0	25	$ 3,000,000 500,000	2	80
21040101	Geologic base maps from unmanned lunar orbiters	Orbit	None	Orbital studies	0	160	5,000	0	10,000	$ 10,000,000 1,000,000	4	0
33010102	Gamma ray spectrometry from lunar orbit	Orbit	None	Orbital studies	0	32	2,000	0	1	$ 10,000,000 1,000,000	3	0
32010117	IR reflectance and emissivity from orbit	Orbit	None	Orbital studies	0	15	150,000	0	1,000	$ 10,000,000 1,000,000	3	0
32010116	UV and visible reflectance spectra from orbit	Orbit	None	Orbital studies	0	15	150,000	0	1,000	$ 20,000,000 2,000,000	3	0
40070869	Spectrazonal photography to determine lunar-surface temperature and geologic formations	Orbit	None	Orbital studies	1	1.0	0	0	0.0	$ 2,000,000 200,000	2	5.0
40120780	Orbital gamma ray spectroscopy	Orbit	None	Orbital studies	1	28	400	0	2	$ 1,000,000 100,000	1	0

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
82010101	Topography of proposed AAP LEM landing sites	Orbit	None	Orbital studies	1	18	5.0	0	10	X$^{\Delta}$	X$^{\Delta}$	100
81021205	Sterophotogrammetry	Orbit	None	Orbital studies	2	700	2,000	8	25	$ 2,000,000 300,000	2	180
	ORBITAL - ORBIT - ORBITAL PROBE											
44070886	Temperature probes emplaced from lunar orbit	Emplaced points	None	Orbital studies	0	20	120	0	10	$ 1,000,000 100,000	4	0
42020284	Remote seismic station	Emplaced points from orbit	None	Orbital studies	0	3.0	12	0	1	$ 200,000 10,000	1	0
82010103	Soil bearing strength of proposed LEM landing sites	Orbit	None	Orbital studies	1	45	93	1.0	250	$ 4,000,000 200,000	2	0
	ORBITAL - ORBIT - RADIO AND RADAR											
40060565	Determination of surface and subsurface structure and formations by use of high resolution radar	Orbit	None	Orbital studies	0	100	2,400	0	10,000	$ 5,000,000 1,000,000	5	0
44070866	Passive microwave determination of surface temp, and formations	Orbit	None	Orbital studies	0	50	240	0	10	$ 1,000,000 200,000	5	0
	ORBITAL - ORBIT - OTHER											
13030707	Gravity observations from lunar orbit to supplement surface observations	Orbit	None	Orbital studies	1	140	2,200	0	10	$ 10,000,000 1,000,000	5	0
34010401	Mass spectrometric analyses from lunar orbit	Orbit	None	Orbital studies	0	20	150,000	0	30	$ 10,000,000 500,000	3	0
43030985	Orbital gravity gradient for moment-of-inertia calculations	Orbit	None	Orbital studies	0	50	3,000	0	10	$ 2,000,000 200,000	5	0
46040667	Magnetic field mapping from orbit	Orbit	None	Orbital studies	0	20	240	0	10	$ 800,000 100,000	1	0
40080370	Meteorite counter in orbit	Orbit	None	Orbital studies	1	3.7	56	0	0.2	$ 1,000,000 200,000	1	0
45030968	Gravity gradient from orbit	Orbit	None	Orbital studies	0	50	3,000	0	10	$ 2,000,000 200,000	5	0
52020301	Anistropy versus charge and energy of solar and galactic particles	Orbit	None	Orbital studies	1	11	4,300	3.3	6	$ 1,000,000 200,000	1	3.0
53050202	Magnetic field in solar wind shock front near moon	Orbit	None	Orbital studies	0	3.0	22,000	0	5	$ 0 100,000	0	0
53010202	Solar wind particles in shock front near moon	Orbit	None	Orbital studies	0	2.3	13,000	0	3	$ 0 200,000	0	0
79070101	Electric field measurement from lunar orbit	Orbit	None	Orbital studies	1	2.0	2.0	0	0.4	$ 100,000 20,000	1	0

$^{\Delta}$"X" Indicates classified information

Table 31. Composite Sequence Summary Chart (Cont)

Experiment No.	Experiment Title	Experiment Location	Mobility Requirement	Exploration Phase	Men Req'd	Equip. Mass (kg)	Energy (watt-hr)	Total Man-hours	Peak Power (watts)	Nonrecurring and First Item Costs	Development Time (years)	Earth Return Weight (kg)
79070102	Magnetic field measurement from lunar orbit	Orbit	None	Orbital studies	1	3.3	700	0	7	$ 100,000 20,000	1	0
79070103	Particle flux measurements from lunar orbit	Orbit	None	Orbital studies	1	2.3	21,000	0	2	$ 200,000 60,000	1	0
81021503	Lunar plasma properties near surface	—	—	Early exploration	These experiments have no Lunar surface support requirements. The information from other experiments is correlated on Earth to obtain other desired information, see Type-0 card.							
81021104	Sampling survey techniques	—	—	Early exploration								
83064105	Hydrogen detection and analysis techniques	—	—	Early exploration								
82053902	Digging and cutting tool assessment	—	—	Early exploration								

7.6 SUMMARY

The objectives of ordering the compiled experiments into Discipline Sequences, Mission Support Sequences, Exploration Phase Sequences, and Composite Sequences were to allow identification of logical phases of lunar exploration and the evolutionary programs and experiments within the capability of each phase. Such a systematic approach provides tools for mission planning, equipment planning, and alternate program evaluations, and demonstrates a method of analysis applicable to evaluation of lunar exploration systems based on scientific experiments requirements.

All work is evolved from the Discipline Sequences, which group the experiments according to the desires of the scientific community to allow an orderly progress of scientific knowledge and achievement. The Discipline Sequences are shown in Volume 4 (Appendix A) in the form of sequential printouts of the Type-1 cards for each discipline area.

The Mission Support Sequences evolved by ordering the experiments within each discipline area according to increasing values of mass, energy, and man-power. A printout of these sequences by discipline is given in Volume 4 (Appendix A). Histograms of Experiment Distribution according to Mass Requirements indicate that the mass requirements range from zero to 22,000 kilograms, with a median of 14 kilograms and with 67 percent of all experiments requiring less than 30 kilograms. Similar histograms indicate that energy requirements range from zero kilowatt-hours to 20,000 kilowatt-hours, with a median of 0.36 kilowatt-hours and with 4 percent of all experiments requiring over 100 kilowatt-hours.

Exploration Phase Sequences were developed from the Discipline Sequences and associated mission support analysis. Initially, mass and energy requirements associated with the experiments in each of the scientific disciplines were plotted versus experiment order, as defined in the Discipline Sequences. These initial diagrams contained isolated singularities resulting from mission support requirements that were grossly out of range with respect to those corresponding to experiments of adjacent order. The singularities were examined, and, where found to be relocatable without disrupting the overall continuity of the investigation program, the singularities were removed by reordering the corresponding experiments and their logical corollaries. The diagrams generated indicate gradually increasing mass and energy requirements bound by enveloping plateaus, which can be considered to be logical exploration-phase levels. Such potential phase breaks were indicated respectively at 20, 150, 500 and 4000 kilograms,

and at 0.6, 8.0, 50, and 200 kilowatt-hours. Further phasing criteria based on man-hours, mobility, and stay-time requirements were then applied to this preliminary phasing definition. The latter iteration procedure resulted in the final definition of exploration phases and ranges of mission-support requirements for each exploration phase.

The Composite Sequences were evolved from the Exploration Phase Sequences. The Composite Sequences identify groups of experiments within a given exploration phase by key experimental or operational items from which evolutionary lunar scientific programs can be formulated. Nineteen key operation groupings (Table 29) were identified, as well as ten evolutionary programs of investigations based on the key items. The Type-1 cards for these sequences are printed out in Volume 4 (Appendix A). From these printouts, the characteristics of each exploration phase were identified, including minimum vehicle requirements. The phases were designated alphabetically for ease of reference.

The sequences evolved in this section constitute a base for planning lunar and space systems, developing scientific equipment, training astronauts, and coordinating efforts of the principal investigators.

8.0 EARTH-BASED SUPPORT REQUIREMENTS

8.1 REQUIREMENT SCOPE

The objective of this task is to estimate the requirements for Earth-based scientific support for lunar mission operations and for the analysis of returned scientific data. This effort is intended to aid in the planning for scientific training requirements, facilities, and laboratory development. Extended lunar exploration will require the most sustained and prolonged technical and scientific interest of any ground support operation yet attempted.

Scientific operations on the lunar surface require the following earth support:

1. Experiment design, fabrication, qualification, checkout, and installation

2. Personnel training and scientific experiment organization

3. Launch control

4. Flight control

5. Logistics support

6. Prolonged manning of Manned Space Flight Network for reception of operational engineering data and experimental data and the extended operation of the NASA Communications System

7. Real time support of scientific experiments by principal experimenters

8. Real time engineering support of exploration vehicles and equipment

9. Scientific analyses of telemetered data, television, and transmitted photographic data.

10. Recovery of returned vehicles with experimental samples and equipment

11. Debriefing of returned scientists and astronauts

12. Analysis of returned samples, films, and emulsions.

Most of these tasks will be accomplished to various degrees during the first lunar landing missions of Project Apollo. However, the emphasis will change after the initial manned landing. Immediately following the initial landing, the primary mission objectives will no longer be the operational capability of landing a man on the moon and safe return, but will be the advancement of scientific knowledge of the Moon, Earth, space phenomena, and the universe. This change of objective will result in greater attention to the design, manufacture, checkout, installation, and operation of the scientific equipment and analysis of return data, due to increased mission emphasis on scientific investigations.

To phase operations smoothly into the lunar exploration program after the initial Apollo landings, the concept, design, fabrication, and qualification of the scientific equipment must, for purposes of scientific equipment and systems integration, be completed at approximately the same time the initial manned landings are accomplished. This task is anticipated to require scientists and engineers to work closely together.

Scientists will be responsible for the concept, establishment of scientific requirements, and for qualification of the instruments to assure that the data obtained can be reduced in a meaningful manner. The requirements for scientific support during this phase would not be expected to be great. The major scientific effort will be monitoring the progress of the design, fabrication, and qualification of the experiment hardware to ensure that scientific requirements are maintained and met. The scientists will also be required to calibrate and qualify the scientific equipment with respect to quality of the output data.

Engineers will be responsible for the design and qualification of the instruments to survive the mission environment and to meet the established scientific requirements. In addition, engineers will be responsible for the integration of the scientific instrumentation with the mission support equipment. The engineers required for this phase will probably be those who have been previously concerned with the design of the mission support equipment. Such an approach would be most efficient because this type of engineering personnel would be familiar with the environmental design requirements and with the hardware interfaces between the scientific instrumentation and the mission support equipment.

The major problem during this phase and during actual lunar scientific operations will be organization and management. The space scientist's laboratory will be partially on the lunar surface, partially in space, and partially on earth. His assistants will include scientists, astronauts, engineers, data reduction personnel, and laboratory technicians. His equipment will range from lunar-based fixed and mobile instruments through satellites to Earth-based computers, microscopes, and test tubes. His major technical problem will be rapid identification and reduction of the most significant data to provide scientific direction for the remainder of the mission.

Upon completion of the mission, the greatest problem will be rapid reduction of the return data. The magnitude of resources spent in accomplishment of the scientific mission will direct great public attention to the results. The need for data results will be heightened by the requirements for planning the successive missions. The major problems foreseen for scientific Earth support of lunar missions are organization, management, facilities and equipment, and scientific manpower available for reduction and interpretation of the return data.

In approaching this task, the following organizational assumptions are made:

1. A mission control center at, or similar to, the mission control center at NASA/MSC will be operative for the full period during which exploration is taking place on the lunar surface.

2. The Manned Space Flight Network receiving stations will be operative to receive data from the lunar surface, transmit data to the mission control center, receive engineering and scientific analysis and control from the control center, and transmit to the lunar surface.

3. All raw data for development on the Moon will be transmitted to Earth for evaluation. Discarding of data as not significant by the astronaut could preclude possible use in ascertaining the relationship between different phenomena, correlations of data with other data, and other uses.

4. Photographs taken on the lunar surface during the extended exploration phase will be developed there. Photos taken in lunar orbit will be developed at the NASA receiving station after return of the space vehicle. Television photographs will be processed at the mission control center. Only processed film and pictures will reach the principal investigators.

Based upon these assumptions and upon the outputs of the computer program, a methodology was developed for translation of Earth return data, samples, and equipment into scientific support requirements. The criteria for this translation are given in Section 8.2.

8.2 CRITERIA FOR EARTH-BASED SCIENTIFIC SUPPORT REQUIREMENTS

The data returned from experiments performed on the lunar surface and in lunar orbit will be in the form of telemetered data bits, film, emulsions, lunar samples, and other miscellaneous material. Information from the experiments on the lunar surface will be recorded and transmitted in a variety of forms. Most of the data will be telemetered directly to Earth. (The cost of return weight will probably preclude the return of tapes. Thus, tapes would be used only to record prior to telemetry.) In addition to telemetered data, Earth samples will make the round trip, and lunar samples, films, and emulsions will be brought to Earth. The man-hours required for technicians to handle telemetered data and to process emulsions and films, along with the man-hours required for scientists to evaluate results of the experiments and investigations, are the subject of this section.

8.2.1 TELEMETERED DATA

The determination of data reduction and analysis manpower requirements will be based on full data return. The quantity of data transmitted may not tax the communications systems or storage systems on the lunar surface or on Earth. It may, however, tax the men analyzing the data. The following is the base for analysis: (1) data bits generated can be converted to words at the ratio of 20 bits per word; (2) words can be perused and analyzed at 100 per minute; (3) information can be synthesized and reports prepared at a factor of 20 percent of analysis time.

8.2.2 PHOTOGRAPHS AND TELEVISION PHOTOGRAPHS

Based on current experience, and assuming extensive learning to reduce evaluation time, the following criteria are established for photographic analysis: (1) a weight allowance of 10 percent is allocated to packing the film; (2) the size of the film may range from postage-stamp size to Polaroid size; (3) the average photograph would weigh 2.5 grams; (4) 15 minutes will be required to analyze each photograph; (5) information synthesis and compilation of reports will require 25 percent of analysis time.

8.2.3 NUCLEAR EMULSIONS

Nuclear emulsions will be used in exploring the lunar radiation environment. The processing and evaluation of these emulsions can be quite critical and time consuming. Requirement estimates are based on the following criteria: (1) all processing and evaluation will be done on Earth; (2) microscope time will be based on examination in layers 400 microns thick, and a field of view of 200 microns in diameter; (3) each observation will require 10 seconds. The personnel requirements for analysis of nuclear emulsion, based on one kilogram of sample, are: 230 man-hours for scientific evaluation and reporting; and 3,000 man-hours for technician effort. The technician effort is highly concentrated in microscopists but include development technicians, computer programmers, key punch operators, and their supervision. It is further assumed that automatic scanning techniques will be utilized.

8.2.4 LUNAR SURFACE SAMPLES

Lunar surface samples are to be brought to Earth to meet requirements imposed by the Geosciences, Physics, and Biology Disciplines. The analysis will be for biota search, mineralogical analysis, physical analysis, and chemical (including isotope) analysis. The scheme of sample handling includes separation into packages for delivery to laboratories and sequencing of laboratory analysis so that the chemical analysis will not destroy biota before it is analyzed and physical analysis will not destroy features needed in chemical analysis.

The requirement estimates are based on the following criteria: (1) the sample size at laboratory will be 15 grams; (2) each sample will be analyzed three times at four laboratories; (3) four man-hours per analysis will be required to prepare each sample and make the analysis at each laboratory; (4) synthesis of results will require 15 minutes per sample per analysis; (5) report preparation will require 10 minutes per sample per laboratory.

8.2.5 OTHER ITEMS

Other items that will affect Earth support requirements consist of maps returned, Earth samples and instruments returned. The analysis is based on the following criteria: (1) the average map will weigh 100 grams and take 1 hour to analyze and 6 minutes to report on; (2) Earth samples and instruments utilized on the lunar surface and returned to Earth will require 4 man-hours per 100-gram sample at a physical laboratory for analysis and a 5-percent increase for report preparation.

Table 32 shows the Earth-return mass and data bits for a single run of the experiment list, based on the Exploration Phase experiment sequences appearing in Volume 4 (Appendix A). The return data and samples were summed for each phase. This table is used as a basis on which to determine the Earth support requirements. The footnotes refer to items which do not follow the pattern of repetition established in Table 33.

Table 32. Earth Return Mass (Per Single Run of Experiment List)

Exploration Phase \ Return	Film (kg)	Emulsions (kg)	Lunar Samples (kg)	Other (kg)	Telemetry (bits)
Orbital	185	3.5	0	0	4.37×10^{10}
A	10	0.0	205	0	3.04×10^{9}
B	1153	1.0	106	47†	3.0×10^{10}
C	71	75.0	215	0	4.0×10^{10}
D	42*	59.0	0	0	5.54×10^{10}
E	20**	0.0	0***	200††	1.17×10^{9}

*Exclusive of 355 kg required for astronomy throughout Phase D.
**Exclusive of 350 kg required for astronomy throughout Phase E.
***Exclusive of 2000 kg of deep drill core containers returned from Experiment 2120308 throughout Phase E.
† Consists of 45 kg of geological maps and 2 kg of earth samples taken to the Moon for environmental exposure and returned to Earth for analysis.
†† Consists of instruments used under exposure to the lunar environment and returned to Earth for analysis

8.3 SCIENTIFIC PERSONNEL REQUIREMENTS

The requirements for Earth-based scientific personnel in support of extended lunar exploration is justified by crew safety and cost effectiveness considerations. The high cost of investment per man-hour on the lunar surface justifies extensive Earth-based support so that the expenditure will be as productive as possible. Support teams representing the various disciplinary areas should be available on a 24-hour basis. It may be impractical to have these teams at the mission support center for the full duration of long lunar surface missions. Therefore, it will be highly desirable to have the principal investigators, supporting scientists, and disciplinary representatives available to the mission control center by way of closed-circuit television. In this way they could be quickly marshalled to focus attention on any scientific contingency, or unexpected phenomena.

The following analysis pertains to the requirements for scientific support only. Later sections discuss technician requirements.

In order to determine the requirements for scientific personnel, it was first necessary to determine the experiment loading in each phase. As indicated in Section 5.5, the criteria used to define a single "replication" of an experiment varied with the nature of that experiment. In order to have a simple model for the experiment loading, the spectrum of experiments was surveyed to determine an average number of repetitions of a single run of the entire experiment list that would be representative for the exploration phase in which the experiments were introduced and for each subsequent exploration phase. The values for "repetition estimating factors" represent the average number of times the applicable portion of the experiment list would be repeated in a given exploration phase. When subsequent mission and exploration analyses refine these factors, the results may be factored into revised predictions of scientific personnel requirements. Table 33 shows the repetition estimating factors selected for the experiment loading model.

The repetition estimating factors of Table 33 were multiplied by the corresponding man-year requirements for each exploration phase shown in Table 34. The results are shown in Table 35. These numbers were divided by the estimated phase duration giving the average number of scientists required in each exploration phase. For the purpose of the estimate, Phase A was assumed to be the duration of the Apollo program after the first landing, or approximately two years. Phase B was assumed to be the duration of the potential AAP program, or two years. Phases C and D were each assumed to be two years, and Phase E two and one-half years to encompass an exploration period of roughly one decade. If these periods

Table 33. Repetition Estimating Factors

Experiment Type* \ Exploration Phase	A	B	C	D	E
Orbital	9	9	9	9	9
A	25	20	15	10	5
B		25	15	10	5
C			25	20	15
D				25	20
E					25

*Exploration phase in which a given experiment is introduced.

were to change, the replication estimating factors would probably change proportionally. Little effect would be shown on the manpower requirements to support extended lunar exploration. Table 35 shows the growth of the scientific manpower requirements to support extended lunar explorations.

This table shows an average of 5800 scientists required in Phase A, with increasing requirements culminating in a peak average of 14,600 scientists required for Phase D. This peak drops off to an average of only 8,600 required in Phase E.

8.3.1 AVAILABILITY OF SCIENTIFIC PERSONNEL

It was assumed that the requirements derived were for doctorates in the required field, with over five years of experience. Accordingly, the forecast for availability of scientific personnel was developed for this requirement.

A forecast for available scientists with applicable doctorates, based on census information, National Science Foundation reports, and U.S. Government economic forecasts, has been prepared. These reports are tabulated in a corporate literature survey (Reference 52).

Figure 64 presents the number of degrees awarded by year, reflecting the general field of study and the level of degree. This information was derived from data tabulated in Reference 35 which were extended beyond 1975 with material from Reference 52. These data represent the development rate of scientific personnel and are utilized in forecasting the total available scientific personnel.

Figure 65 shows the available U.S. scientists with at least a first degree. This figure was derived by using census data for the initial point and adding applicable new degrees conferred. From this figure the attrition

Table 34. Scientific Man-Hour Requirements (Per Single Run of Experiment List)

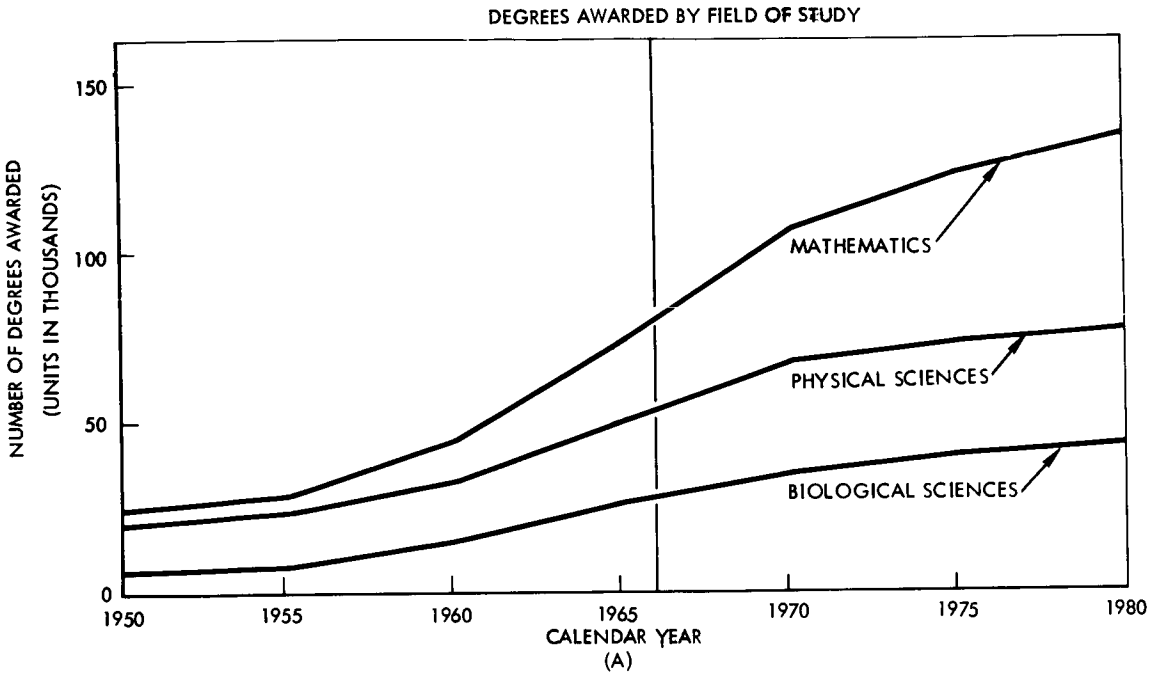
Return / Phase	Film (man-hours)	Emulsions (man-hours)	Lunar Samples (man-hours)	Other (man-hours)	Telemetry (man-hours)	Total (man-hrs)	Total (man years)
Orbital	20,800	800			437,000	458,600	234
A	1,100		706,100		30,400	737,600	376
B	129,700	200	365,100	600	300,000	795,600	406
C	8,000	17,300	740,500		400,000	1,165,800	595
D	4,700*	13,600			554,000	572,300*	292
E	2,300**		0***	8,400	11,700	22,400	11

*Excluding 39,900 man-hours (20 man-years) expended throughout phase D for analyzing film returned from the astronomy experiments.

**Excluding 39,400 man-hours (20 man-years) expended throughout phase E for analyzing film returned from the astronomy experiments.

***688,900 man-hours (351 man-years) expended throughout phase E for analysis of cores returned in deep drill core containers. This is based upon one-third of return weight in containers, a sample size of 100 gms, and the same analysis requirements as shown in paragraph 8.2.4.

1960 man-hours per man year.



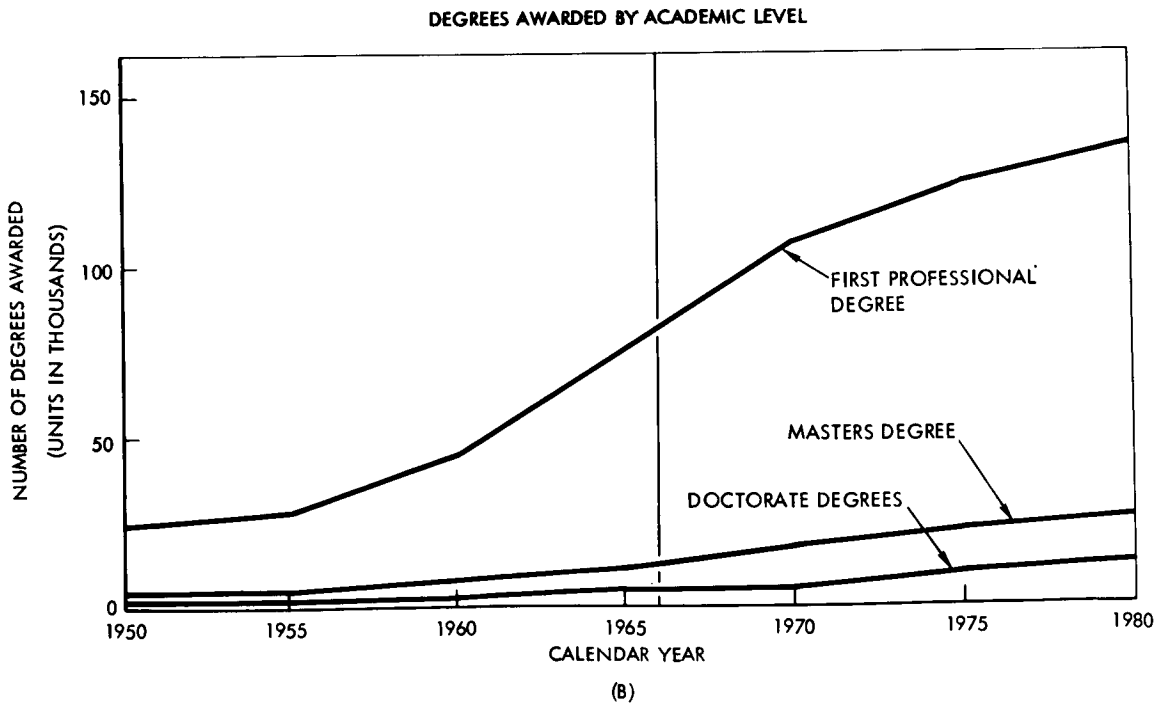


Figure 64. Professional Degrees by Year (Derived From Reference 35)

Table 35. Earth-Based Scientific Man-Power Support Requirements

Experiment Type* \ Exploration Phase	A	B	C	D	E
Orbital	2,106	2,106	2,106	2,106	2,106
A	9,400	7,520	5,640	3,760	1,880
B		10,150	6,090	4,060	2,030
C			14,875	11,900	8,925
D				7,320**	5,840
E					646***
Total Man-Years	11,506	19,776	28,711	29,146	21,427
Scientists Required (Average)	5,800	9,900	14,400	14,600	8,600

*Exploration phase in which a given experiment is introduced.
**Includes 20 man years for Astronomy experiments. See footnote of Table 33.
***Includes 20 man years for Astronomy experiments and 351 man years for deepdrill experiments. See footnotes Table 34.

due to initial change of career, death, retirement, and other losses, equivalent full-time graduate students and instructors, and those with less than five years of experience was subtracted. These estimates were derived from Reference 36 and other sources shown in Reference 52. The result is a curve of the available U. S. scientists in applicable fields with first degrees and five years of experience.

Figure 66 utilizes the data of Figure 65 to forecast the number of scientists available by level of degree. This is a cumulative type of curve wherein all scientists with doctors degrees are assumed to have both a master's degree and a bachelor's degree. Therefore, the line showing first degrees includes those to whom a higher degree has also been awarded.

Figure 67 is the forecast of scientists with doctorates in applicable fields who would be available for lunar exploration studies. This forecast is based on space program employment (Reference 51), known NASA programs, and a curve of their anticipated growth. The data are cumulative in that a point on the space program curve represents the scientists with doctorates available to work on space programs, including lunar exploration.

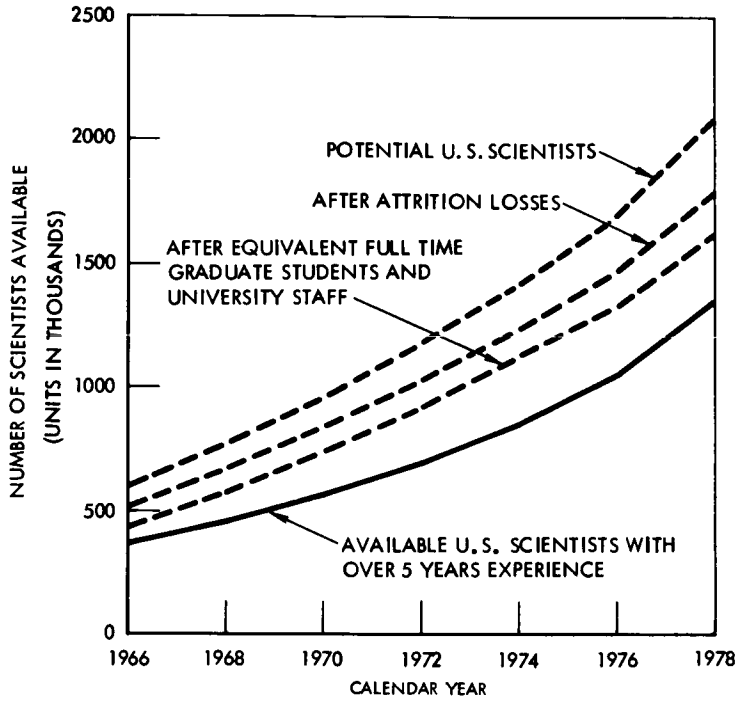


Figure 65. U.S. Scientists With at Least First Degrees (Reference 36)

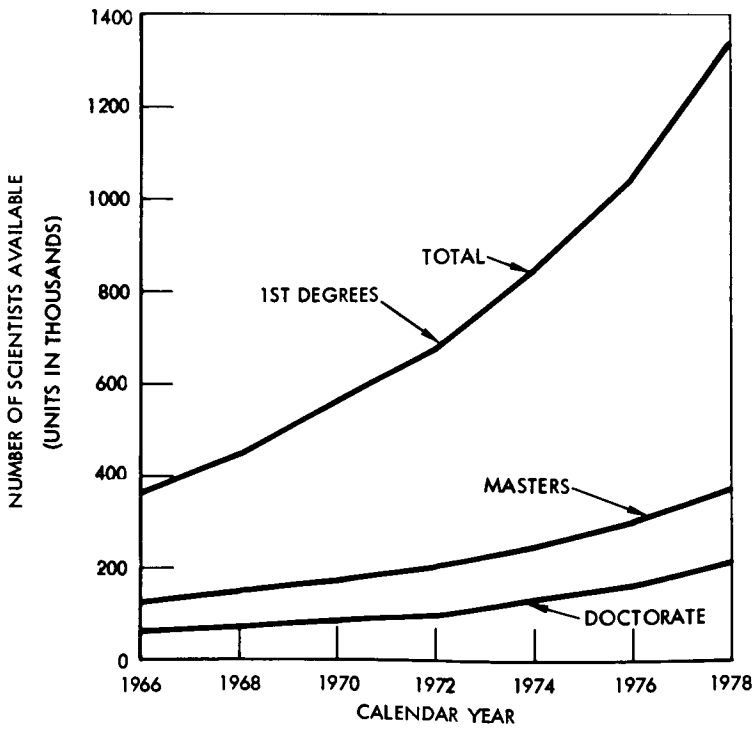


Figure 66. Available U.S. Scientists by Degree (References 35 and 36)

The primary area of interest in this figure is the area that includes biological, physical, chemical, geological, geophysical, and astronomical scientists. Mathematicians are included because they represent an interdisciplinary capability required to arrive at techniques handling scientific knowledge.

Figure 68 shows the numerical growth of scientists representing fundamental disciplines and available for Earth support of the extended lunar exploration programs. This curve shows a growth from 2,400 in 1968 to a peak of 14,200 in 1974 and lowering to 9,100 in 1978. This capability is compared with requirements in the following section.

8.3.2 REQUIREMENT VERSUS AVAILABILITY OF SCIENTISTS

Previous sections developed the requirements for scientists by exploration phase and the availability of scientists by year. These later data were converted to average availability of scientists by phase and were compared with requirements for scientists. Figure 69 shows the results of this analysis.

It is of interest to note the growth of requirements for qualified scientists and the corresponding lag of scientist availability. Requirements and availability of personnel peak in Phase D. The deficit of scientific personnel expected in the early part of the lunar exploration program extends throughout the program and reaches a peak of 1400 scientists in Phase D. The anticipated growth of availability of scientific personnel in the later stages of the program shows a surplus of 400 scientists in Phase E. The long lead time of training and the need for sustained interest renders the scientific personnel factor critical and requiring immediate action.

8.3.3 TECHNICIAN REQUIREMENTS

Technicians supporting computer operations, microscopists, chemical laboratory technicians, physical laboratory technicians, etc., are required in the analysis of all types of returned data. To gain insight into the possibilities of technician shortages, the support requirements for nuclear emulsion analysis, which are representative of a very high ratio of technicians to scientists were examined in detail.

The technician support requirements for nuclear emulsion analysis are developed in Table 36. The returned emulsion weights for each phase are in the body of the table. These were determined by multiplication of the returned weight of Table 32 by the Repetition Estimating Factor of Table 33. The man years were calculated by multiplying the emulsion mass in kilograms returned in each phase by 3000 man-hours per kilogram and dividing by 1960 man-hours

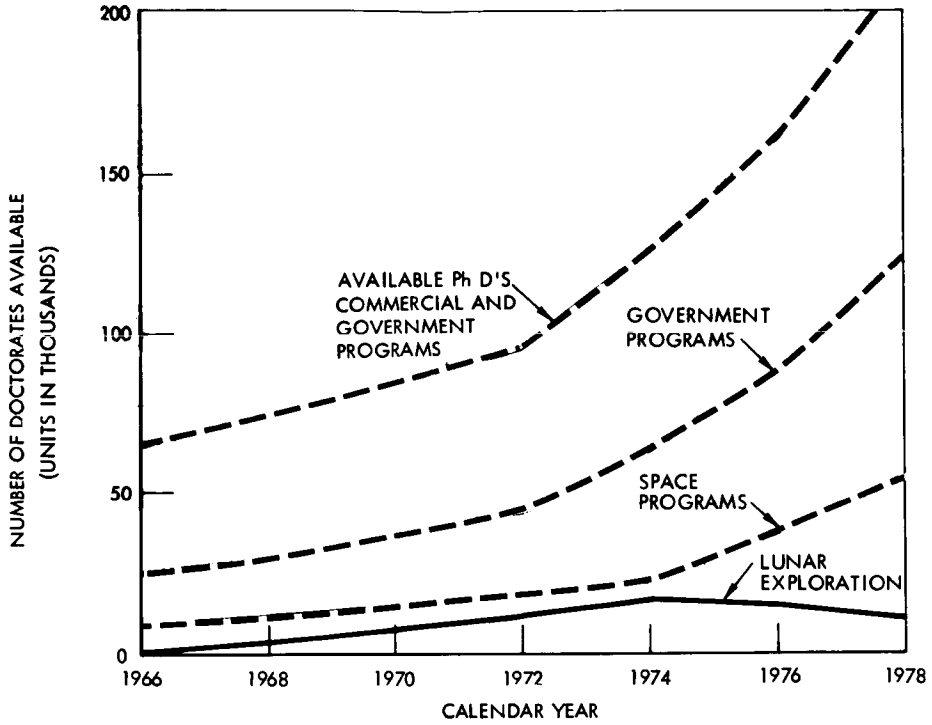


Figure 67. Doctorates Available for Lunar Exploration Work

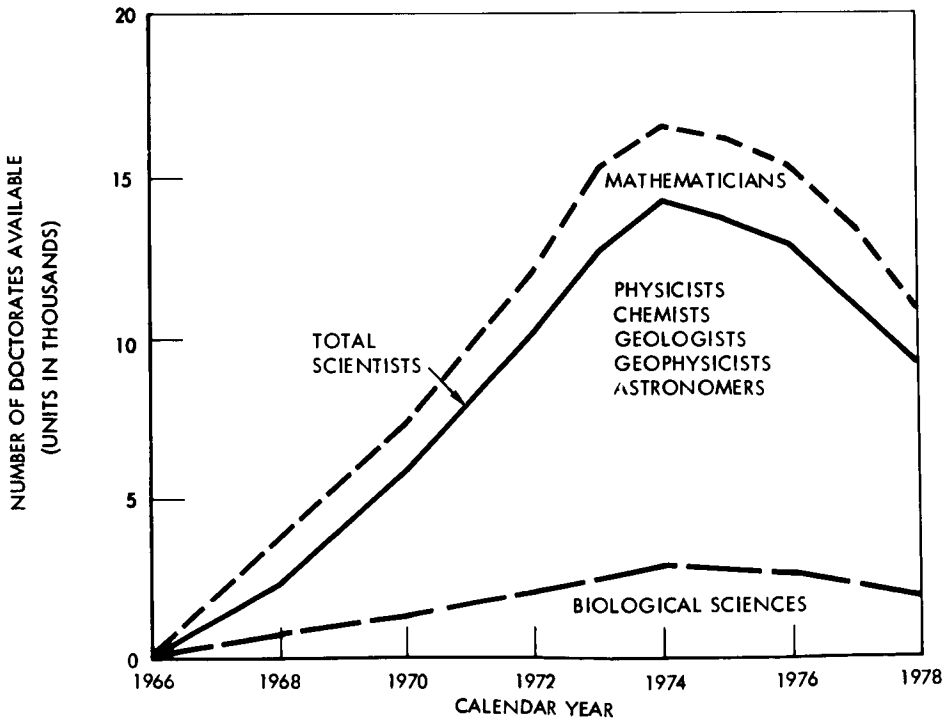


Figure 68. Doctorates Available for Lunar Exploration Work by Field

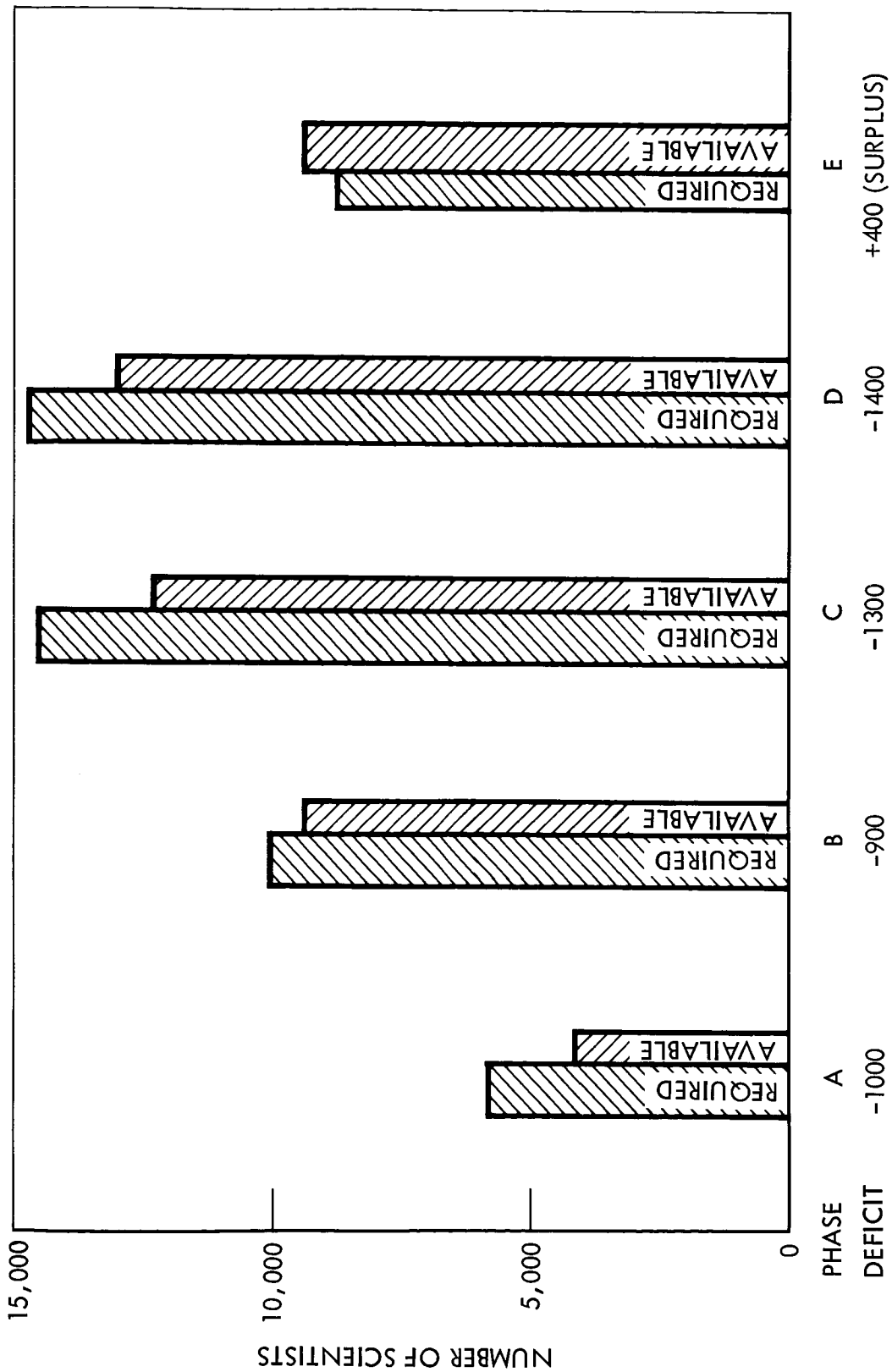


Figure 69. Scientists Required Versus Scientists Available

per year. Finally, the average number of technicians required per exploration phase for analysis of the nuclear emulsions was determined by dividing the man years by the phase durations given in paragraph 8.3. Microscopists would comprise the dominant fraction of these support requirements.

A major proportion of the microscopists could be at the technician level (one year of college and good eyesight). Part-time college students could be considered as a source that would satisfy this requirement. All other requirements for technicians could be satisfied by graduate students, anticipated trained technicians, and some specially trained technicians with short training lead time. The educational requirement is much less than that of a "first degree" scientist, therefore the requirements shown in Table 36 were compared with the expected availability of a "first degree" scientist for sensitivity. The 2300 technicians required would represent less than 0.3 percent of the available first-degree scientists and a much smaller percentage of the total available technicians. The short lead time required in training technicians could make even a larger number available on as short a lead time as six months. From this analysis, it would appear that technicians would be available or could readily be made available, for analysis of returned data and material.

8.3.4 ENGINEERING PERSONNEL REQUIREMENTS

Engineering support for the space and lunar vehicles is not based on return data, but it has a profound effect on the ability to return the data. Therefore, it is mentioned here. Engineering support similar to that developed for Apollo and envisioned for the Apollo Applications Program should be adequate for extended lunar experimentation. Engineering representatives with capabilities in the various hardware systems would be at the mission control center. Additional capability at the hardware supplier would be on direct line from the control center.

8.3.5 LABORATORY REQUIREMENTS

Laboratories and facilities utilized in data reduction analysis and report preparation will be found in government agencies, universities, and industrial facilities. It cannot be assumed that the entities involved will drop all other research or even drop all other space research to concentrate on utilization of their facilities on the problems of extended lunar exploration. The majority of the facilities requirement, then, would be for new facilities and laboratories at the location of the principal investigator. The time of construction of facilities is small relative to the time required for the training of the scientists who will work in them. The cost of facilities is small relative to the cost of lunar exploration and relative to training costs of the people who will work in the facilities. It appears, therefore, that the laboratory problem will require far less advance planning and contracting

Table 36. Technician Earth Support Requirements (Nuclear Emulsion)

Experiment Type* \ Exploration Phase	A	B	C	D	E
	Weight (Kilograms) of Emulsion to be Processed				
Orbital	32	32	32	32	32
A	0	0	0	0	0
B		25	15	10	5
C			1875	1500	1125
D				1475	1180
E					0
Total Weight of Earth-processed Emulsions per Exploration Phase	32	57	1922	3017	2342
Technician Support Requirements per Exploration Phase (man years)	49	87	2941	4616	3583
Average Number of Technicians Required per Exploration Phase	25	50	1500	2300	1400

*Exploration phase in which a given experiment is introduced.

than will the personnel problem. The estimate of laboratory facility requirements is based on the scientific manpower requirements and technician requirements previously developed. The area requirement per scientist is based on the criteria of 340 square feet of laboratory and 110 of office per scientist. Normally this requirement for scientists includes their supporting technicians. However, in the case of nuclear emulsion analysis, another 100 square feet of laboratory space is required per technician. These requirements are tabulated in Table 37.

Table 37. Laboratory Area Requirements

Exploration Phase	A	B	C	D	E
Average Number of Scientists Required Per Phase (Table 34)	5800	9900	14,400	14,600	8,600
Area Requirement for Scientists (thousands of square feet)	2600	4500	6,500	6,600	3,900
Average Number of Technicians Required for Nuclear Emulsion Analysis (Table 35)	25	50	1,500	2,300	1,400
Area Required for Technicians for Nuclear Emulsions Analysis (thousands of square feet)	Less than 10	Less than 10	100	200	100
Total Laboratory Area Requirements (thousands of square feet)	2600	4500	6,600	6,800	

8.4 SUMMARY

The scope of Earth-based support requirements for extended lunar exploration covers all Earth operations that support the missions and includes a spectrum from logistics to flight control. This study was restricted to the support requirements necessary to analyze Earth returned data. The primary requirements considered are for scientists, technicians, and laboratories.

Sensitivity analysis indicates that the most critical factor to the analysis of Earth-returned data and to the accomplishment of the scientific objectives is the anticipated shortage of qualified scientists. Estimates and forecasts of scientists were made as conservative as possible because of the many unknown factors. These include war possibility, major economic change, international plans for lunar exploration; concurrent NASA plans for planetary exploration and Earth-orbital missions and scientific breakthroughs. Such factors may radically change our knowledge of the lunar surface, result in quantum increases in engineering and technology capability, or may make obsolete our current vehicles, logistics, communication and transportation concept. As a result, they may affect the number of experiment replications considered at the present time to be sufficient for mission accomplishment and the type of desired experimentation.

The requirements for and availability of scientific personnel were forecast, and the results were analyzed in Figure 69. This indicated a shortage at the beginning of the program that would increase throughout the first four phases. An accumulated deficit of approximately 9200 man-years of scientific work is forecast to be accrued by the end of Phase D. This shortage could create a backlog compression wave of data that might jeopardize the program. The period needed to develop scientists, create interest, and channel activities makes this time critical.

The major types of technicians required to support the scientists, are microscope analysts, chemical laboratory assistants, and computer programmers. The short training requirement for technicians will allow development of a sufficient number with minimum planning, lead time, and cost. The 2300 required in Phase D for nuclear emulsions will be well within the availability.

A sufficient number of engineers is expected to be available to support the requirements associated with the scientific and engineering experimentation.

Laboratory space requirements were determined for each exploration phase. This analysis indicates a requirement for almost seven million square feet of new laboratory space by the end of Phase D to support extended lunar exploration. Considering the maximum laboratory costs and development times, the impact would be small compared with the total program cost and scientist development time. It would appear, therefore, that if the program can be financed, so can the laboratories, and if trained scientists can become available, laboratories should also be available.

The total Earth-based support required for extended lunar exploration includes the items analyzed in this report but is far more extensive than the evaluation of Earth-return data. It establishes scientific and technological requirements that hold profound implications in the socio-economic field. For these reasons, a full synthesis of all budgetary and socio-political factors that enter into the generalized picture of Earth-based support requirements is beyond the scope of this study.

9.0 EXPLORATION PROGRAM FACTORS

9.1 CONTINGENCY PLANNING

It is reasonable to assume that there will be marked changes in the knowledge, theory, and hypothesis concerning the Moon prior to and during actual lunar surface exploration. Indeed, present major theories may be disproven and new ones formulated and proven. Unexpected phenomena will most certainly be discovered. For purposes of discussion, these possibilities are defined as contingencies. When such contingencies arise, alternate courses of action will be taken in scientific experiments, investigations or missions, depending on the magnitude and timing of the unexpected changes or event. The resultant course of action will depend not only on the contingency itself and related experiments, but also on the types of mission support equipment or systems in use and their capabilities.

It is beyond the scope of this study to analyze the possibilities for various contingencies since by their very nature, they are unexpected. Also, literature is available that discusses and analyzes such possibilities. (References 37 through 41). It is incumbent upon mission planners, however, to account for the possibility of contingencies and to be able to respond quickly and positively to the occurrence of the "unexpected." Therefore, in the formulation of the experiment data management system and the methods by which the experiment sequences were put together allowance was made for contingency possibilities.

The experiments presented in this report are based on the current understanding of the Moon. The sequences of experiments provide an orderly extension of this knowledge with consideration of general limitations of exploration phases and the capabilities of the mission support systems. Planning and preparation for accomplishment of lunar surface scientific objectives include many long lead-time activities, such as experiment design and equipment development. It is necessary, therefore, to examine a methodology by which changes in proposed experiments, experiment sequencing, experiment emphasis, or changes in lunar systems capability can be accommodated in the overall lunar exploration plan as changes occur in our basic understanding of the Moon. Three types of contingencies that could substantially alter the lunar exploration experiments or their sequencing were examined: (1) those that would change the sequencing of experiments, (2) those that would require a change in emphasis among the list of experiments, and (3) those that would alter the capability of proposed scientific

installations on the lunar surface. Table 38 presents a list of typical specific contingency examples and their probable effect on the lunar exploration program.

A typical contingency would be the discovery that biota exists on the lunar surface. This contingency would require significant changes in the experiment sequences presented in this study. The sequencing of experiments would be changed to have investigations of biota take precedence over the other activities in order to minimize, to the greatest degree possible, the danger of destroying biota evidence by contamination resulting from the lunar landings and the general level of exploration activity. Preservation of the biota evidence also could require further analysis of the sampling techniques, sampling procedures, and sample preservation. Selection of landing systems and other mission support systems could emphasize a minimum of contamination rather than a maximum of payload or efficiency of operation. The early emphasis on the biological sciences could then result in delays in the development required for establishment of other facilities such as an astronomical observatory.

Some observatory experiments may be related to certain phases of the solar cycle. Therefore, the desired sequence of experiments in an area such as solar physics also may be affected by a change in solar events during the early phases of the lunar exploration program.

An example of a contingency which might change the emphasis, rather than sequence, of a lunar exploration would be the discovery of significant radio activity on the lunar surface. This contingency could substantially change plans for manned lunar traverses and space suit activity at the lunar base. More of the base experimentation would have to be maintained inside a protected lunar shelter, manned stay times at the moon would need to be reduced, and similar adjustments made to the lunar exploration program. For example, adjustments in geochemical analysis equipment, may be required if the samples to be handled inside a lunar shelter laboratory have a dangerous radioactivity level.

A type of contingency that could affect the planned lunar exploration program is the discovery of lunar phenomena that could change the assumed capability of a scientific installation on the Moon. For example, discovery of relatively continuous seismic activity on the lunar surface could limit the effectiveness of a planned lunar astronomical observatory and possibly preclude the installation of the largest of the planned optical telescopes.

In a more positive vein, the discovery of free water or other directly useful minerals, such as sulfur, could make practical a much more extensive lunar base installation than may be presently visualized.

Table 38. Scientific/Technological Contingencies

Event	Probable or Ramifications		
	Favorable	Unfavorable	Other
• Finding water	• Life support, fuels generation, reduced payloads required		• Change target sites
• Ores, minerals	• Accelerated interest, support more missions	• Claims and competition	
• Biota	• Stimulated scientific and public support	• Possible dangerous forms back contamination	• More handling care
• Seismic		• Poor for astronomy experiments	• Modify experiments. May change experiment program
• Volcanic	• Favorable chem strut • Might accelerate program		
• Communications from space	• Heightened interest/support		• May change experiment program
• Reduced gravity		• Possible decreased work capacity	
• Night operations	• Favorable heat rejection	• Limited visibility • Extreme cold	• Effect on staytime
• Pyrophorics		• Increased hazards slowed accomplishments • Changed designs	

*Lunar orb-rendezvous

Such changes in scientific system capability or mission support capability could greatly influence the mix of desired scientific experiments or their phasing. The preceding contingencies are typical of those considered in determining the required flexibility of the data management system established during the study. Because of the present early stage of the lunar exploration program, it appears logical to expect that discoveries will be made that will change the desirable sequence or emphasis of any given planned set of scientific experiments. Therefore, the experiment descriptions and support parameters on computer data cards should allow rapid compilation of a lunar exploration set of experiments in a revised sequence.

By use of the system for maintaining the experiment file on a current basis, experiments within the data bank can be changed as they are influenced by new data made available from current lunar studies. By use of the computer flexibility in sorting and summarizing data, the influence of changes in individual experiment data and in experiment sequences can be rapidly listed in the standardized formats found most useful to mission planners.

For the example of excessive seismic activity, the most direct primary effect may be the elimination of experiments utilizing telescopes and requiring a very stable foundation. This is accommodated by manually removing the applicable cards from the input card deck and reconstituting the input tape. Other side effects would be in the increased concentration on seismic experiments. The data management system is designed to accept changes resulting from the contingency, and rapidly make changes. The contingency effects on the extended lunar exploration experiment data file can be simply implemented.

The Discipline Sequences, Exploration Phase Sequences, and Composite sequences may be readily changed. For elimination of equipment, as in the example of excessive seismicity, the equipment list would show all experiments that utilize this equipment. The Type 1 cards for all such experiments can be pulled prior to a sequence printout. For elimination of an experiment, the Composite Sequence would show whether this experiment was a key experiment or whether others depended on it. The Type 1 cards for the experiment and all subordinate experiments would be pulled from the decks of sequences prior to printout.

Where the lunar exploration produces data that makes the experiment obsolete, as indicated in the preceding paragraph, the experiment can be removed entirely from the master data tape and the corresponding data card file.

Where the contingency information results in reordering the preferred sequence of the lunar experiments and only minor modifications of the affected experiments would be required, the experiment verbal description

and data entries would be reviewed for revision. If the affected experiment is accelerated in the time schedule, the equipment development time and cost estimates could require review and possible change. A compromise in equipment would be traded off against time of experimentation, reliability, etc. When required data alterations are assembled, the simple data change feature of the SMS-ELE computer program can be utilized to change data in the affected data fields. The data change cards for all the experiments in which data entry changes occur would be run against the master data tape prior to the printout of the updated master list of experiments. A change in experiment sequence can be accomplished by a change in the callout of experiment sequence instructions to the computer processing operations which has the effect of changing the order of experiments in the Discipline Sequence. This change is reflected in the other sequences developed from the Discipline Sequence.

Where the lunar exploration contingency results in a major revision of a proposed experiment, the extent of the revision will need to be analyzed to determine if the experiment should be entirely rewritten or if the data change routine should be utilized. A complete revision would be similar to the entry of a new experiment into the experiment data tape and data card file (see Section 4.7.2) except that the same experiment number may be utilized. Use of the same experiment number will require computer programming instructions to delete data cards of a given experiment number prior to entering the new data cards into the master data tape.

Consideration of contingencies with respect to the current SMS-ELE study may be summarized by the following:

1. Discoveries made during the present early phases of lunar exploration will change presently conceived desirable lunar exploration scientific experiment sequences.

2. Experiment program change factors can include items such as change of desired experiment sequences, change of investigation emphasis, modification of experiments, or addition or elimination of experiments.

3. The data management system developed during the SMS-ELE study provides the desired flexibility for rapidly changing the outline and summary descriptions of a revised exploration program.

4. The capability and flexibility of the computer data management system allows rapid assessment of mission support requirements of scientific program changes during the extended lunar exploration period.

9.2 RELATION TO PLANETARY EXPLORATION

The national space program planning already incorporates phased development of Earth orbital, lunar, and interplanetary exploration capabilities. Each phase of the program should be expected to utilize, to the greatest extent feasible, the scientific, technological, hardware, operations and support capabilities developed in the preceding programs. Continued application of this step-by-step development through advanced lunar and interplanetary missions will contribute to continuance of the high degree of success achieved in the manned missions flown to date. Manned planetary exploration may become the next major space goal after lunar exploration.

Planetary mission constraints, including infrequent launch windows, energy requirements, and criticality of weight relative to lunar missions, place added significance on the ensured effectiveness and validity of the planetary experiments and investigations. In addition, the extended duration and unavailability of abort and rescue during major portions of the missions lead to requirements for advanced technologies in subsystems, such as power and life-support, and for attainment of very high levels of equipment performance. The latter may be achieved through a combination of reliability, redundant design, and in-flight maintenance.

The development of space science and technology for manned Earth-orbital, lunar-orbital, and lunar-surface exploration missions is expected to bring experiment equipment and support system capabilities generally within reach of planetary mission requirements. In many surface exploration equipments, the more severe thermal-vacuum lunar environment may well be governing. In supporting systems, commonality of support requirements for extended duration lunar exploration and manned planetary exploration missions encourages consideration of commonality of technology and hardware.

9.2.1 SCIENTIFIC MISSION RELATIONS

Review of scientific objectives of planetary missions shows broad similarities with those of lunar exploration. Table 39 lists typical scientific objectives of planetary flyby missions. This list was derived from Reference 42, based on objectives presented to Congress by NASA, or suggestions by members of the scientific community, and results of other studies of interplanetary missions.

A much more extensive correlation of scientific objectives and related experiments and investigations will evolve from future planning of manned

Table 39. Typical Scientific Objectives of Planetary Flyby Missions (Reference 42)

Discipline Area	Scientific Objectives (Typical)
Geodesy	Figure of planet Surface maps Gravitational field
Geology and Geochemistry	Surface relief and photogeology Surface physical state Surface composition
Geophysics	Magnetic field Trapped radiation spectrum Effect of Phobos on magnetosphere Heat balance Surface temperature Surface radioactivity Soil thermal and electrical conductivity Seismic activity Meteoroid mass, velocity, and composition
Atmosphere	Atmospheric composition Atmospheric pressure, density, and temperature Sound velocity Ion, electron density
Particles and Fields	Solar wind protons Solar high-energy protons, electrons, alphas Galactic protons
Biology	Life forms
Astronomy	Planetary radio emission Radio reflectivity
Mars Satellites	Satellite figures, rotation periods Satellite relief, surface temperatures
Asteroids	Asteroid figures, rotation periods Asteroid relief, surface temperature

exploration missions to be performed on the surface of Mars. In surface exploration missions, a typical geodesy investigation will utilize surface surveying to establish ground reference data for Mars orbital mapping. Geology investigations will involve surface and subsurface sample collection, and determination of the subsurface structure. Determination of the geochemical, petrological, and mineralogical nature of the Martian materials will be a priority geochemical function. The broad scope of geophysics investigations involving similarity of objectives and techniques between lunar and interplanetary surface exploration missions is difficult to relate with a single example. Surface area surveys and borehole logging and sensor emplacement will be utilized to determine characteristics and physical properties of the Martian surface and subsurface. Active seismic surveys will be utilized to determine the nature of the planet's internal structure. Studies of the Martian atmosphere will, of course, differ from lunar atmosphere investigations. In this discipline area, a much greater similarity in parameter ranges exists between the interplanetary medium and the lunar atmosphere. Particles-and-Fields investigations will define the interaction phenomena with the Martian atmosphere. Biological investigations will build on previous unmanned life detection experiments and lunar contamination experiments. Back-contamination investigations will be added as a priority activity. A small telescope can support investigations of the physics of the Martian atmosphere, utilizing a spectrograph primarily to investigate absorption features of radiation from external sources as observed from the surface. This telescope will be used in aereodesy investigations and will provide independent positional data concerning bodies in the solar system.

Comparison with lunar scientific experiments and investigations compiled in this study indicates that scientific experiment objectives, experiment techniques, and equipment developed for and proven in extended lunar exploration will provide major advantages and support to planetary exploration.

9.2.2 MISSION SUPPORT RELATIONS

Manned exploration missions to Mars will nominally be on the order of 400 to 700 days duration. A major portion of this time will be spent in transfer from Earth to Mars and the return transfer from Mars to Earth. Support of the crew during these periods will be centered in a mission module of the interplanetary spacecraft. A crew of six has been considered nominal for this mission. For manned exploration performed from Mars, it is anticipated that a Mars excursion module and other exploration support equipment will be utilized. Surface exploration, to be most effective, will require mobile operations to the extent feasible. Complementary investigations could be performed concurrently from the mission module while in orbit about Mars.

Scientific missions for extended lunar exploration include investigations to be performed on the lunar surface and in lunar orbit. During early and

later phases of exploration, surface mobility capabilities are required for support of lunar-oriented investigations. In later phases of lunar scientific missions, support requirements are added for long-duration, lunar-based investigations. The lunar-based investigations utilize fixed-site telescope systems and require long-duration manned support from mission module-type facilities. A crew of nine has been considered nominal for this mission phase. Similarity of many general support requirements for extended lunar and planetary missions is evident.

The life sciences will be a priority area in planetary exploration. All disciplines, i.e., exobiology, biomedical and human factors, and life support, are critical to mission success. In lunar mission support, the "Biological Contamination of Lunar Soil" investigation provides an assessment of planetary life detection techniques and investigates survivability of earth organisms. The lunar applied biomedical and human factors investigations generally concern astronaut performance in a reduced gravity environment and astronaut physiological and psychological adaptation in prolonged missions, which are highly significant considerations for manned planetary missions. Life-support applied research is directed toward the advancement of closed-ecological-system technology and assessment of the biological effects of prolonged exposure to the lunar environment.

Lunar investigations in support of the geosciences will also support Mars exploration technology and, in some cases, will have Mars mission counterparts. "Lunar Geological-Geochemical Sample Cassettes," "Explosive Energy Coupling in Lunar Materials and Calibration of Remote-Sensing Techniques" are examples of these investigations.

From the standpoint of technology, many of the mission support investigations defined in this study will provide direct or indirect support to hardware development and mission planning for planetary exploration. For example, certification of proposed Mars manned landing sites will have to be performed from Mars orbit. Therefore, correlation with the "Topography of Proposed AAP LEM Landing Sites" investigation is indicated. Experiment techniques and equipment for the "Engineering Properties of the Lunar Surface" investigation appear applicable to similar investigations of the surface of Mars.

In the supporting technologies area, materials research in the hard lunar vacuum, and repair, construction, and maintenance techniques developed in support of extended lunar missions should be broadly applicable to the critical problem of ensuring equipment availability and mission success in manned planetary exploration.

In view of the relative remoteness of Mars, the potential utilization of Martian resources will be of special interest in planning the long-term manned

space program. Consequently, resources exploration and exploitation techniques developed for and during extended lunar exploration should be significant to planetary exploration and development.

Thus the lunar exploration program should be considered not only as a means of achieving intrinsic objectives but as a vital step in an evolutionary, long-range space exploration program.

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11.0 APPENDIXES

The appendixes to this report are published separately as volumes 4, 5, and 6. The subjects of these appendixes are

Appendix A	Experiment Sequences - Computer Printouts
Appendix B	Master Data Report - Computer Printouts
Appendix C	Computer Program