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ORBITING LUNAR STATION (OLS)

PHASE A FEASIBILITY AND DEFINITION STUDY

VOLUME I

OLS OBJECTIVES

FINAL REPORT

Space Division
North American Rockwell

APRIL 1971
Prepared by Advanced Program Engineering

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(FINAL REPORT)

APRIL 1971

Approved by

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Space Division
North American Rockwell

FOREWORD

This report contains the results of North American Rockwell's analyses conducted under the Orbiting Lunar Station Feasibility and Definition Study (Phase A), Contract NAS9-10924, in accordance with line item 5 of the Data Requirements List (DRL5).

This report is compiled in six volumes for ease of presentation, handling, and readability of the data in the report. In general, each volume is a compilation of the data generated in a specific phase of the study.

This is Volume I of the report (SD 71-207) and contains Orbiting Lunar Station (OLS) operational objectives, scientific objectives, and scientific support requirements.

The documents comprising the study report are:

Volume I	OLS Objectives
Volume II	Mission Operations and Payloads Analysis
Volume III	OLS Performance Requirements
Volume IV	OLS Configuration and Systems Analysis
Volume V	OLS Configuration Definition
Volume VI	Comparison of OLS Configurations

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1.0 SUMMARY

This section presents a brief summary of the contents of this volume of the report. The three major divisions are OLS Operational Objectives, Science Objectives, and Science Support Requirements.

1.1 OLS OPERATIONAL OBJECTIVES

Section 2.0 of this report presents the operational objectives of the OLS, which have been categorized as general mission objectives and engineering and technological operations objectives. The general operational objectives may be summarized as follows:

1. Maintain capability for initiation of operations through earth launch, earth orbital checkout, mating and transfer operations, cislunar flight, lunar orbit establishment, and quiescent lunar orbit storage.
2. Operate effectively as a base of lunar operations for cislunar shuttle flights, lunar tug sorties, and Lunar Surface Base (LSB) support.
3. Provide operational support for lunar orbit experiments and habitation for an eight-man crew for an operational period of 10 years.
4. Support the operations of other lunar exploration elements by providing communications, command and control capabilities, and emergency provisions.

Eleven major operational support and engineering and technological objectives are identified. When these objectives are met, the OLS will have demonstrated autonomous operations, assured development of key planetary mission capabilities, satisfied major lunar exploration and scientific research needs, and developed high confidence in multiple manned spacecraft operations.

1.2 SCIENCE OBJECTIVES

The top-down formulation of the post-Apollo lunar exploration and exploitation program science objectives is presented in Section 3.0. First, the overall program objectives are listed and these objectives are expanded into disciplinary subobjectives and then into quantitative observation requirements. (The next step, experiment and equipment definition, is presented in Section 4.0.) A specific set of definitions for these various terms is presented.

Four program objectives are listed followed by 35 subobjectives in the disciplines of astronomy, geology and geochemistry, geophysics, bioscience, aerospace medicine, lunar atmosphere, particles and fields, and geodesy and cartography. Within each discipline, consensus observation requirements are synthesized from a review of standard data sources and the interpolation of NR-generated data.

An assessment is made of the accomplishments in the lunar exploration program through the projected completion of the Apollo missions. Considering the limited knowledge of the moon, Apollo and pre-Apollo missions have and will make significant contributions to man's understanding of lunar characteristics. However, contributions of these missions to the postulated overall lunar exploration program are limited by such factors as mission coverage, mission duration, payload constraints, and available crew size and skills. In general, they are precursor missions which can enhance the scientific activities of the OLS era. The post-Apollo program is not dependent upon the successful completion of the currently planned Apollo program.

Basic observations in astronomy include high-resolution X-ray imaging through the use of a crater rim as an occulting edge, optical and infrared measurements, and radio measurements, particularly at frequencies that cannot penetrate the earth's magnetosphere. Lunar astronomy should emphasize observations of faint objects at wavelengths that suffer interference from some aspect of the earth's environment.

In geology and geochemistry, there is a requirement for synoptic orbital observations supplemented by point data taken on the surface. Geologic and stratigraphic mapping must be augmented by core drilling and various types of mineralogic and chemical analysis.

The principal geophysics observations concern the mass distribution and figure of the moon, the physical state of the lunar interior, and lunar dynamic properties.

Bioscience and aerospace medicine observations emphasize the determination of the effects of unique aspects of the lunar environment, in particular the local one-sixth g force of gravity.

Post-Apollo observations of the lunar atmosphere relate to the determination of escape, transport, and loss rates at high sensitivity.

Particles and fields observations are essentially extensions of Explorer XXXV and ALSEP measurements.

In the geodesy and cartography discipline, the major requirements are for the establishment of a geodetic control system over the lunar surface and the preparation of maps at various scales.

It is clear from the data presented in Section 3.0 that much will remain to be accomplished in lunar exploration after the completion of the Apollo missions. It also is clear that extensive surface and orbit observation programs are required to fully achieve the objectives defined in Section 3.0.

1.3 SCIENCE SUPPORT REQUIREMENTS

The ultimate objective of the post-Apollo lunar exploration and exploitation program definition activity is to determine the requirements imposed upon the configuration, subsystems, and operations of the OLS. In Section 4.0 the scientific support requirements are established by expanding the objectives and observation requirements (previously defined in Section 3.0) to the experiment and equipment levels.

The first step in the expansion is to determine if the objective/observation can be accomplished in lunar orbit or must be accomplished on the lunar surface. The approach is to conduct the investigation in orbit if feasible because of the inherently lower cost for this mode of operation. Each observation requirement is evaluated against a set of formulated criteria. The criteria are (1) the nature of the experiment, (2) ground and orbit correlation requirements, (3) precision and scale of the measurement, and (4) required environment. Applying these criteria to the observation requirements of the various scientific disciplines resulted in the identification of 16 orbit and 53 surface experiments.

The surface experiments are listed in summary form only, by title and discipline, correlated with the subobjectives they principally support. For each experiment, major equipment items also are listed.

The surface experiments are used to construct typical space tug missions to the surface and thus identify OLS support requirements for these missions. The typical tug mission employs a crew of four men on the surface for 28 days to conduct a set of exploratory scientific investigations. The scientific payload is approximately 2000 pounds for each of the three missions formulated, and mobility requirements range up to 350 kilometers.

The orbit experiments are also listed in a summary format. An additional analysis is performed on these experiments to determine whether they should be operated within the OLS (integral mode) or on subsatellites (detached mode). Factors considered include contamination, acceleration, attitude and stability, electromagnetic interference, orbit, and safety. Eight of the 16 orbit experiments should be conducted in the detached mode. They are grouped on three independent subsatellites. With some degradation in performance, many of these subsatellite experiments could be performed in the integral mode if required.

Narrative descriptions and master timelines are developed for each orbit experiment. Experiment equipment definitions are expanded with descriptor sheets that provide physical characteristics as well as logistics, operational, and other interface requirements.

The orbit experiment definitions and timelines are used to construct support requirement profiles for power, data, and crew skills based on an experiment operation schedule. Other requirements, such as OLS pointing and stability accuracy also are taken from these experiment definition data. These requirements are presented as OLS Experiments Provisions requirements in Section 4.0 of Volume III.

2.0 OLS OPERATIONAL OBJECTIVES

2.1 SUMMARY

In this section OLS Operational, Technological and Engineering objectives are identified. The rationale for their selection and the supporting OLS functions are presented. In addition, OLS objectives that directly contribute to planetary mission preparation are identified. Table 2-1 and Table 2-2 summarize OLS objectives.

Table 2-1. OLS Operational Objectives Summary

1. Provide a control center for all program elements operating in the lunar vicinity.
2. Provide an operational base for lunar landing missions.
3. Support Lunar Surface Base normal and contingency operations.
4. Provide an orbital facility for integration of remote sensing, mapping, and other orbital scientific experiments.
5. Provide a laboratory facility for initial screening and data processing of scientific data.
6. Provide a support, resupply and maintenance facility for free-flying satellites in the lunar vicinity.
7. Provide habitable environment for all personnel operating in the lunar vicinity during both normal and contingency or rescue operations.
8. Demonstrate autonomous operations of a space vehicle.

Table 2-2. OLS Technological and Engineering Objectives Summary

1. Evaluate candidate planetary bases communication systems.
2. Evaluate candidate planetary vehicle materials and thermal control coatings.
3. Evaluate planetary surface shelter concepts.

2.2 OPERATIONAL OBJECTIVES

To begin identification of operational objectives, it is necessary to postulate the overall OLS mission sequence in gross terms and to identify other space program system elements with which the OLS must interface. The mission is envisioned to begin with the unmanned OLS launched to earth orbit, either by an INT-21, an upper stage to the EOS booster, or in the EOS orbiter payload bay. Once placed in earth orbit, critical systems would be activated and checked out remotely either from earth or earth orbit (e.g., by an EOS or tug crew). A crew would then be delivered to orbit and brought to the OLS either directly by the EOS or transferred via tug. Following docking operations, which necessitate that the OLS maintain attitude hold, this crew would board the OLS and perform in-orbit checkout of all necessary systems operations. At the completion of this checkout, the checkout crew would depart, and OLS systems would be powered down and/or deactivated. The OLS would then be moved by a space tug to the fueled cislunar shuttle (CLS) and mated. The CLS, at the time of the right launch opportunity, would then begin its translunar flight. Upon arrival at the moon, the CLS would inject into a circular 60-nautical mile polar orbit. The OLS G&C subsystem would be activated to maintain attitude hold as would other subsystems critical to orbit maintenance, and the unmanned OLS would await the arrival of the first 8-man OLS crew, which would arrive on the next CLS flight.

The first OLS crew would arrive on board a space tug delivered by a CLS and after OLS life support systems were activated, would dock their tug to the OLS and come aboard. The CLS would return to earth orbit. Following an initial period of systems activation and checking, orbit experiment operations would commence. For a period of 7 to 7-1/2 months, surface mapping and othe precursor activities would be carried out in preparation for later tug lunar landings. The tug during this period would remain at the OLS, thus providing an escape vehicle in event of emergency.

Cislunar optimum payload opportunities, which occur approximately every 55 days, allow a certain flexibility in crew rotation. The baseline mission plan, which is detailed in Volume II of this report, utilizes every second optimum earth orbit to lunar orbit opportunity; thus, CLS flights would occur every 109 days. The model indicates that half of the OLS crew is rotated each CLS flight. Between CLS flights, a surface sortie would be made by one of the tugs. These sorties would be manned by four of the OLS crew and would last an average of 31 days, 28 days on the surface plus 3 days for orbit-surface-orbit operations. The primary purpose of the sortie is to conduct short-term scientific investigations of the lunar surface. A secondary purpose is to investigate and evaluate lunar sites for later establishment of a permanent lunar surface base (LSB). Both surface roving vehicles and lunar flyers are envisioned to be employed by the sortie crews in their visits to the majority of surface sites. Surface and subsurface samples would be obtained as well as data from emplaced experiments.

Communications between the tug on the surface and the OLS would be maintained through relay satellites, which are placed in their orbits by one of the tugs.

The proposed mission model indicates eight tug sorties over approximately three years before initiation of LSB operations. The LSB shelter would be delivered to lunar orbit by a CLS. Half of the planned 12-man LSB crew and a third space tug would be brought to lunar orbit on the subsequent CLS flight. The six LSB crewmen would then check out, to the degree possible, LSB shelter subsystems in orbit prior to its being carried to the selected surface site by one of the tugs. The LSB crew would then descend to the base in a tug and initiate base operations. The other half of the LSB crew would arrive next with an additional space tug. For planning purposes, LSB crew rotation is programmed in the same manner as the OLS crew rotation. Half the crew is rotated every 3-1/2 months in conjunction with a planned CLS logistics resupply flight.

During the planned five years of base operations, orbital experiment activities would continue in the OLS but at a reduced level compared with earlier prebase operations. The frequency of tug sortie missions to sites other than the LSB would continue at the same rate, or during each 109-day period between CLS logistic flights for the OLS.

The OLS during this base operations period would serve as an orbital operations control center, which will provide command and control of surface sorties as during the prebase era as well as control/backup of tug resupply trips to and from the base, and control/backup of remote-from-base surface excursions. In addition, control of subsatellites and the on-orbit tug trips rendezvous and docking operations between the CLS and OLS would be an OLS objective.

In support of tug sorties, the OLS would serve as an operational base providing logistics support, crew support, scientific laboratory support, rescue, and communications. Also, while docked to the OLS, tug maintenance and repair and pre-mission checkout would be performed. Subsequent sorties would be planned on the basis of information obtained by previous sorties and analysis of surface samples. Much the same functions would be provided by the OLS in support of LSB activities.

OLS operational objectives defined herein were formulated based on a review of the Lunar Exploration Program objectives as defined in the OLS SOW and the PDD's of the involved NASA Integrated Program Plan elements: OLS, LSB, space tug, CLS, EOS, manned Mars expedition, and propellant depot. The objectives defined herein are those to be satisfied by the OLS and its crew as an element of the Lunar Exploration Program. Table 2-3 lists the operational objectives, supporting rationale, and the OLS functions required to fulfill these objectives.

Table 2-3. OLS Operational Objectives and Supporting Functions

OBJECTIVE
The OLS will function as a control center, managing many elements of an advanced lunar program. The OLS shall have the capability to command, control, and monitor all lunar elements of the integrated program, including remote control of manned and unmanned surface or orbital vehicles.
RATIONALE
The scope of the planned lunar program involves several vehicles operating simultaneously in the lunar vicinity. Included are cislunar shuttles, space tugs, surface mobility equipment, scientific subsatellites, manned orbital science experiments (OLS), data relay satellites, the lunar surface base, and possibly remote maneuvering units, cargo modules and propellant depots. A local centralized operations center is required and should be incorporated in the OLS.
SUPPORTING FUNCTIONS
1. Track position of all lunar orbital and surface vehicles. 2. Receive, record, process, monitor, and interpret data from all lunar orbital vehicles, satellites, and experiments, and from surface vehicles, experiments, and devices, and perform mission planning. 3. Command and control the operation of the vehicles, devices, and experiments in the lunar vicinity. 4. Maintain a real-time, two-way voice communication link with all manned vehicles operating in lunar space or at any point on the lunar surface. 5. Furnish navigation data to facilitate the safe, efficient flow of spacecraft operating in the lunar vicinity. 6. Perform the command and control function for both manned and unmanned vehicle landing and docking operations.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS (Continued)
7. Command and control all OLS flight operations; i.e., guidance and navigation, orbit maintenance, orbital assembly operations, station-keeping, rendezvous and docking, and checkout operations.
8. In conjunction with the space tug, inspect, service, maintain, and check out a lunar orbiting data relay satellite system required for the performance of the above OLS functions.
OBJECTIVE
Provide an operational base for manned and unmanned landing missions for the purpose of lunar exploration and exploitation.
RATIONALE
The OLS must provide an operational base for manned and unmanned landing missions for the purpose of lunar exploration and exploitation. Numerous lunar surface sites (100-150) are currently candidates for investigation. After appropriate screening 25 to 50 sites will be selected and subsequently visited and investigated. An Orbiting Lunar Station that is a base of operations for such functions as crew provisions, staging storage, communications, maintenance, and rescue for the tug, tug crew, and surface equipment will significantly reduce the logistics costs of the lunar program.
SUPPORTING FUNCTIONS
1. Provide all life support requirements including medical facilities, safe accommodations, and recreation for lunar lander tug crew members during their OLS staytime.
2. Provide capability for tug subsystem inspection and checkout and provide tug maintenance and repair service. This will require OLS storage of critical tug spares and consumables, excepting those consumables stored by the lunar propellant depot.
3. Provide capability for tug docking and for cargo transfer to and from the tug.
4. Provide OLS storage of experimental devices, supplies, and equipment required by the tug during lunar surface operations.
5. Provide continuous tracking of the tug throughout mission, and supply navigation data as required.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS (Continued)
6. Provide communications and data processing services to the tug (including color TV reception and transmission to earth) during the surface mission.
7. Receive lunar samples and/or data from the tug, and provide laboratory services as required (see science laboratory objective).
8. Provide command and control function for unmanned tug missions (see control center objective).
9. Direct personnel rescue operations and provide the requirements of item 1; provide the communications services and tug interfaces necessary to facilitate emergency return to earth.
OBJECTIVE
Provide support for a lunar surface base (LSB) during the 1980's.
RATIONALE
To accomplish the long-duration high activity at a lunar surface site, a lunar surface base (LSB) is also planned for the 1980's as part of the integrated Lunar Exploration Program. While the LSB will be designed to operate autonomously, the OLS is uniquely qualified to furnish the LSB support functions defined below. The basic capabilities are required for OLS support of tug sorties and could be utilized to supplement LSB requirements and possibly significantly reduce the complexity, cost and weight of the LSB. For example, the OLS information subsystem could be utilized to reduce the LSB data processing equipment requirements.
SUPPORTING FUNCTIONS
1. Provide the OLS interface functions of (a) tug support and (b) crew care and cargo storage required in the LSB resupply operation. For LSB resupply, an OLS-based tug rendezvous with the CLS and transports men and/or materials either directly to the LSB or to the OLS for storage. Similarly, it supports all LSB cargo and crew return operations.
2. Provide all life support requirements including medical facilities, safe accommodations, and recreation for LSB crewmen during their OLS staytime. This includes the staytime involved during the routine rotation of LSB crewmen as well as staytime during unanticipated or emergency situations.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS (Continued)
3. Direct LSB personnel rescue operations and provide the requirements of items 1 and 2. Provide the communications services and the tug/CLS interfaces necessary to facilitate emergency return to earth. 4. Provide communications and data processing services to the LSB including color TV reception and transmission to earth. 5. Provide scientific laboratory support as required (see science laboratory objective). 6. Conduct orbital surveys of potential LSB sites and in conjunction with the tug explore and inspect candidate LSB sites. 7. In conjunction with the space tug, deploy outpost shelters and support emergency local and remote cargo drops. 8. Monitor and integrate the lunar experiments program. 9. Perform wide-area coverage of scientific missions, unmanned missions, remote in-situ missions, and combined missions in support of the LSB science program.
OBJECTIVE
Provide a lunar orbital facility from which remote sensing and mapping of the lunar surface can be performed.
RATIONALE
IITRI Report No. P-34, Candidate Lunar Experiments, dated June 1970, and other similar sources identify orbital science experiments to be conducted as part of the Lunar Exploration Program. To accomplish the mapping and sensing portion of the lunar orbital science program, the OLS must provide the support functions noted below. The presence of a princial investigator for real-time data evaluation and of maintenance personnel for repairs, film changing, and adjustments are of obvious advantage. Another advantage of the OLS in connection with this objective is the possibility of physical film return to earth which permits simpler and more accurate data reduction.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS

1. Maintain a desirable circular orbit.
2. Check out and maintain photomapping equipment and resource sensors.
3. Photograph lunar areas of interest including candidate tug sorties and LSB sites. (These data will aid in the location of surface sites for tug sortie missions and for selection of the LSB site. Examination of candidate sites by the OLS from orbit will minimize the number of lunar landings required.)
4. Process photo data in OLS science laboratory.
5. Analyze photo and resource sensor data onboard the OLS.
6. Transmit data to earth via shuttle vehicle for further analysis.

OBJECTIVE

Provide laboratory facilities to support the lunar surface operations and lunar orbital activities.

RATIONALE

Film processing on the OLS is mandatory because of the deleterious effects of galactic radiation during extended lunar operations. In addition the severity of the logistics problem makes it advantageous to process, reduce, evaluate, and analyze some of the data, photographs, samples, etc. (which are the products of the surface and orbital science experiments) on the OLS rather than in earth laboratories. Furthermore, those samples required on earth for further analysis must be examined, recorded, and specially packaged before shipment; these activities are OLS laboratory functions.

SUPPORTING FUNCTIONS

1. Process photographic film.
2. Conduct screening and diagnostic analysis of lunar samples.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS (Continued)
3. Record specimen properties, catalog samples, and prepare for shipment. 4. Calibrate and repair scientific equipment. 5. Modify and assemble sensor packages. 6. Monitor and control detached experiments. 7. Conduct integral, detached and/or deployed experiments. 8. Analyze and evaluate potential surface site data. 9. Observe, analyze and evaluate targets of opportunity. 10. Singularly or in conjunction with sensors placed on the lunar surface record, analyze and evaluate rapidly changing phenomena such as lunar outgassing. 11. Reduce, evaluate, and compress scientific data.
OBJECTIVE
Provide support of free-flying satellites in the lunar vicinity.
RATIONALE
Some of the orbital science experiments, for example some lunar atmosphere experiments which require various orbits and which would be affected by OLS contaminations (RCS pollution, seal leakage, etc.), are best accomplished utilizing a free-flying module. The OLS must, however, maintain command and control of such modules as well as provide communications and logistics support.
SUPPORTING FUNCTIONS
1. Provide storage capacity for satellites prior to their deployment and following retrieval, if desired.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS (Continued)
2. Inspect, service, maintain, repair and check out satellites both prior to their deployment and as required after their deployment. 3. Command and control deployment, retrieval, change of orbit, and/or disposal of satellites as required in conjunction with either a tug or directly with the satellite. 4. Track and status orbital parameters of satellites. 5. Provide for continuous command and control of satellites. 6. Provide capability for continuous two-way communications with satellites. 7. Provide data processing services for all data generated by sub-satellites. 8. Transmit reduced satellite data to earth.
OBJECTIVE
Provide safe crew quarters and facilitate rescue from the lunar vicinity.
RATIONALE
The necessity to provide safe crew quarters in the event of any credible accident is self-evident; but in addition to providing safe crew quarters on the OLS, overall lunar program safety can be appreciably increased by including provisions for sortie crew and/or LSB crew members in the event of credible accidents with these other program elements. Also, by maintaining a tug in operational readiness at the OLS, rescue of crewmen from either lunar surface or lunar orbit operations can be accomplished more efficiently and in significantly shorter reaction times.
SUPPORTING FUNCTIONS
1. Protect the OLS crew and any tug or LSB personnel aboard from the hostile lunar environment including meteorites and nuclear radiation, and including that radiation present during major solar flare events.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS (Continued)
2. Provide for contingencies such as subsystem component failure, meteoroid puncture, late arrival of the logistics resupply vehicle, etc. 3. In conjunction with the tug, evacuate personnel from hazardous conditions occurring in other lunar program elements to regions of safety within the OLS. 4. Isolate hazardous materials and equipment. 5. Direct rescue operations at any point on the lunar surface or in lunar space. 6. Maintain continuous communications with and tracking of the rescue vehicles and the crewman in need and supply navigation data as needed. 7. Provide medical facilities and all crew life support facilities for rescued crewman brought to the OLS by space tug for treatment and/or return to earth. 8. In conjunction with the tug, provide emergency return to earth capability when required. 9. Provide communications link with earth and coordinate rescue support operations required in earth orbit; i.e., rendezvous or cislunar shuttle or space tug with the EOS.
OBJECTIVE
Demonstrate autonomous operation to the degree necessary.
RATIONALE
The difficulty and cost associated with OLS logistics necessitate that the OLS operate as autonomously as possible. Furthermore, the autonomous operation of the OLS serves as a precursor model for planetary vehicle operations.

Table 2-3. OLS Operational Objectives and Supporting Functions (Continued)

SUPPORTING FUNCTIONS
1. Incorporate storage capacity, crew and cargo transfer provisions, and docking ports and air locks to permit operations for at least six months without resupply.
2. Provide OLS orbit maintenance either by the OLS or an OLS-based tug.
3. Provide OLS orbit plane changes by an OLS-based tug.
4. Perform OLS housekeeping operations.
5. Perform inspection, maintenance, repair and checkout of OLS equipment and subsystems.
6. Cross-train crew to facilitate normal and contingency OLS operations.
7. Provide OLS attitude control for both the manned and unmanned modes.
8. Provide for automatic checkout of OLS subsystems in either the manned or unmanned mode.
9. Perform station mission command and control operations.
10. Maintain station orientation and provide rendezvous and docking control.
11. Provide station attitude orientation for experiments
12. Deploy tethered and/or free-flying experiment modules.
13. Manage and maintain inventory of station maintenance, supplies, critical spares, expendables, and equipment.
14. Monitor and control experiment activities, evaluate and process data, and assign transmission modes/priorities.
15. Perform experiment data transmission operations.
16. Conduct damage evaluation and control operations.
17. Develop and implement in conjunction with the tug, emergency rescue operations.

2.3 ENGINEERING, TECHNOLOGICAL AND OPERATIONAL OBJECTIVES

In addition to the identification of OLS objectives which directly contribute to the lunar exploration program, engineering, technological and operational objectives that would contribute to other phases of the Integrated Program Plan and could be incorporated into the OLS were evaluated. The criteria for selection were (1) the objective cannot be adequately fulfilled in earth-based or earth-orbit tests, (2) the objective did not require the addition of another program element to the lunar program, and (3) the objective did not become a primary design driver on the OLS.

The primary source of candidate engineering, technological and operational objectives were the planetary mission reports listed in Table 2-4. These reports identified a need for various orbital tests, Mars Excursion Module (MEM) and Mars Surface Sample Return (MSSR) probe landing and ascent tests, and MEM and Planetary Space Vehicle (PSV) cislunar flight tests.

Table 2-4. Bibliography of Planetary Mission Reports

1. Integrated Manned Interplanetary Spacecraft Concept Definition, final report, D2113544, Boeing, six volumes.

2. Technology Requirements for Atmospheric Braking to Orbit About Mars and Venus, SD 67-613.

3. Definition of Experimental Tests for a Manned Mars Excursion Model, SID 67-588, and SD 67-755.

4. MSSR Probe, R&D study report, SID 66-1747.

5. Planetary Mission Concept, SD 70-165.

6. Study of Technology Requirements for Atmospheric Braking to Orbit About Mars and Venus, SD 67-994.

7. Manned Planetary Flyby Missions Based on Saturn/Apollo Systems, SID 67-549.

8. Studies of Interplanetary Mission Support Requirements, final report, D2-23588-3, Boeing.

Orbital operations suggested as areas of concern included orbital buildup, rendezvous and docking, fueling, long-duration flights to evaluate materials, subsystems, heat shield concepts, crew performance and training, planetary approach navigation accuracy, entry and exit guidance and control, orbit attainment, and autonomous operations.

Landing and ascent testing of the MEM and of the MSSR probe on the lunar surface has been suggested both as a qualification test and as tests to determine the suitability of the subject vehicles environmental protection and ECLSS subsystems as well as of the operational procedures employed.

MEM and PSV cislunar flights were proposed as qualification and training flights and as long-duration exposure tests to determine the systems ability to withstand the extended space environment.

Of the tests suggested, the only candidates that met with the selection criteria and were not either duplicated or closely approximated by the basic OLS objectives were (1) long-duration testing of materials, (2) evaluation of surface environmental protection concepts, and (3) evaluation of laser communication operations and equipment. These three engineering, technological, and operational objectives are summarized in Table 2-5. A summary of basic OLS objectives which are common to or closely simulate engineering technology, and operational objectives that would support planetary missions preparation is presented in Table 2-6.

Table 2-5. Lunar Exploration Program Technological, Engineering and Operational Objectives

OBJECTIVE
Evaluate the performance of, and the operational procedures connected with, the operation of candidate PSV laser communications systems and special components in a lunar to earth orbit environment.
RATIONALE
Use of a laser beam for the transmission of color TV signals from planetary space vehicles to an earth orbiting receiving station has been proposed. Such a system will require very precise pointing techniques and the ability to compensate for the varying rate of change of lead angle required due to the fact that the signal from the PSV (orbiting Mars, for example) will take on the order of 10 minutes to reach the earth orbiting receiving station. The receiving station must be located outside of the earth's atmosphere to preclude signal attenuation beam bending effects. To evaluate the signal attenuation and acquisition and maintenance capability of a candidate laser communications system will require a minimum transmission distance of 200,000 n mi, resulting in a transmission time lag on the order of one second. Testing of candidate PSV laser communications systems by transmitting from the EOSS to a receiver on the OLS will simulate the basic problems involved.

Table 2-5. Lunar Exploration Program Technological, Engineering and Operational Objectives (Continued)

SUPPORTING FUNCTIONS
1. Package and deliver candidate PSV laser receiver and antenna (parabolic mirror 1 meter in diameter) to OLS via EOS, CLS, and tug. 2. Mount antenna on OLS (may require EVA operation). 3. Check out and activate laser receiver equipment on OLS. 4. Conduct test evaluating quality of received signal and the operational procedures employed during the test. 5. Analyze test data and transmit results to earth. 6. Continue test or discontinue test, package equipment, and return to earth via space tug, CLS, and EOS.
OBJECTIVE
Evaluate the behavior of candidate space vehicle materials and thermal control coatings during long-duration exposure to a planetary space vehicle environment.
RATIONALE
The OLS operating outside the geomagnetosphere is exposed to the solar wind as well as to UV radiation, contamination, and micrometeoroids, which are the principal factors involved in the degradation of spacecraft thermal control coatings. The OLS is also exposed to higher levels of nuclear radiation including solar flare events than is the EOSS. The OLS, therefore, is a suitable test bed for the evaluation of candidate PSV materials and thermal control coatings, whereas the EOSS, operating within the geomagnetosphere, is not.
SUPPORTING FUNCTIONS
1. Prepare candidate specimens and special test fixtures and equipment for shipment, and transport them to the OLS via EOS, CLS, and tug. 2. Prepare specimens for test in OLS laboratory. 3. Locate specimens and/or test fixtures on outside of OLS (EVA operation may be required) or on extendable boom through airlock.

Table 2-5. Lunar Exploration Program Technological, Engineering and Operational Objectives (Continued)

SUPPORTING FUNCTIONS (Continued)

4. Inspect specimens, and perform tests in OLS laboratory (if required) to evaluate specimen performance at selected time intervals.
5. Analyze test data and transmit results to earth.
6. Continue test or discontinue evaluation, and package specimens and special test equipment for return to earth and further laboratory tests.

OBJECTIVE

Test and evaluate environmental protection concepts applicable to planetary space vehicle use and to lunar or Martian surface shelter use.

RATIONALE

The OLS/tug combination could perform related experiments and expose instrumented conceptual shelters and environmental protection concepts to the environment existing in lunar orbit and on the lunar surface. The OLS would monitor these experiments and tests and analyze and interpret the resulting data. Conceptual test shelters erected on the lunar surface exposed to thermal extremes, meteoroids, and secondary ejecta, and to nuclear radiation during solar flare events would furnish valuable information to be used in the selection of an optimum LSB concept. According to NASA TMX-53865, Natural Environment Criteria for the NASA Space Station Program, some environmental factors at Mars are on the same order or less severe than the lunar environment. Therefore, data obtained during such tests could also be applied towards the evaluation and qualification of Martian shelter concepts.

SUPPORTING FUNCTIONS

1. Package and transmit instrumented candidate environmental protection concept and/or surface shelter concept models to the OLS via EOS, CLS, and space tug.
2. Check out models in OLS laboratory.

Table 2-5. Lunar Exploration Program Technological, Engineering and Operational Objectives (Continued)

SUPPORTING FUNCTIONS (Continued)
3. Deploy models a. On extendable boom through OLS airlock b. As a free-flying module c. On the lunar surface via space tug 4. Monitor data from models and conduct periodic inspections. 5. Analyze test data, and transmit results to earth. 6. Continue test or discontinue evaluation and package models for return to earth.

Table 2-6. Commonality Between OLS Objectives and Engineering, Technological and Operational Objectives that Support Planetary Missions

OLS	PLANETARY
OBJECTIVE: SPACE BASED CONTROL CENTER	
Provide operations control of OLS, cislunar shuttle, space tugs, subsatellites, surface sorties and traverses, and stationkeeping of logistics modules.	Provide operations control of PSV, MEM, MSSR, subsatellites, planetary surface sorties and traverses, and possibly a companion PSV ("Buddy System" concept).
OBJECTIVE: SPACE BASED OPERATIONAL BASE	
Provide life support, medical, and recreational facilities for tug crew; consumables storage, maintenance, and repair of space tug and subsatellites; communications and tracking between program elements; data processing of experimental results and lunar sample diagnostic analysis.	Provide long-term life support, medical and recreational facilities for MEM crew; consumables storage, maintenance and repair of MEM, MSSR, and subsatellites; communications and tracking between PSV, MEM, MSSR and subsatellites; data processing of MEM sortie experiments and MSSR probe experiments; surface sample analyses.
OBJECTIVE: ORBITAL SENSING AND MAPPING	
Conduct orbital experiments in the disciplines of geology and geochemistry, geophysics, particles and fields, lunar atmosphere and geodesy and cartography. Evaluate sensor operations and accuracies. Develop lunar photo maps to assist in the selection of tug sortie mission sites.	Conduct orbital experiments in various scientific disciplines to determine planetary characteristics; develop planetary "maps" and establish desirable MEM and MSSR probe landing sites
OBJECTIVE: SPACE BASED SCIENTIFIC LABORATORY	
Develop film processing, sample diagnostic analysis and handling techniques. Conduct site analysis studies.	Develop and analyze planetary maps to select MEM and MSSR landing sites. Conduct analysis of samples and data returned from landing sorties

Table 2-6. Commonality Between OLS Objectives and Engineering, Technological and Operational Objectives that Support Planetary Missions (Continued)

OBJECTIVE: SUPPORT OF SUBSATELLITES	
OLS	PLANETARY
Provide command and control, tracking, deployment, communications and data processing of data from experiments on subsatellites.	Same (although the experiments and sensor packages may be different, the basic support function will be comparable.
OBJECTIVE: PROVIDE SAFE CREW QUARTERS	
OLS	PLANETARY
Provide meteoroid and radiation (solar flare) protection.	Same (The environments are quite similar and the effectiveness of the OLS shields over a long duration can be evaluated.
OBJECTIVE: DEMONSTRATE AUTONOMOUS OPERATIONS	
OLS	PLANETARY
Develop progressive independence of earth based operational support including mission planning, scientific investigations, consumables scheduling, crew activities, maintenance and repair, and data management.	Conduct mission planning, scientific investigations, consumables scheduling, crew activities, maintenance and repair, and data management essentially independent of earth based support

3.0 SCIENTIFIC OBJECTIVES

3.1 SUMMARY

The exploration and exploitation of the moon for scientific purposes have been studied extensively during the past ten years, spurred by the prospect and realization of lunar landings. These studies (see references at the end of this section) each reflect a consensus of opinion on the objectives of a lunar program but variations occur. These variations are not evident in qualitative terms because most sources agree on the overall goals and objectives of the lunar program. However, significant differences appear when one compares quantitative observation requirements. These differences are of primary importance in the derivation of an OLS where mission parameters and system capabilities that support the science program must be established.

The terms defined below are used throughout the report and indicate the progressive steps of analysis in the top-down definition of the post-Apollo lunar science program.

Objective	Top-level program goal stated in terms that are independent of specific implementation schemes or disciplinary specialty
Subobjective	A discipline-oriented data requirement expressed in qualitative terms arising from program objectives
Observation requirement (or measurement requirement)	A semiquantitative data requirement relating to a specific phenomenon to be investigated
Experiment	A description of the activities required to obtain data in support of one or more observation requirements
Instrument	The hardware (sensor plus support equipment) required to conduct the experiment
Support requirements	The requirements placed upon the mission, vehicle, and subsystems by the instrument

In this section, the first three items (objectives, subobjectives, and observation requirements) are synthesized from standard data sources (see references), condensed to eliminate redundancy, and evaluated including consideration of projected Apollo accomplishments to arrive at an NR-recommended set for the overall lunar program (Experiments, instruments, and scientific support requirements are derived in the next section, Section 4.0).

The overall lunar scientific program objectives are subdivided into scientific discipline subobjectives. The subobjectives and associated experiments that will be directly supported by the OLS are identified by scientific discipline in Table 3-1. The rationale for accomplishment of these experiments from lunar orbit is presented in Section 4.0.

Table 3.1. Summary of Scientific Objectives Supported By Orbital Experiments

Subobjectives		Orbital Experiment	
AY-6	Resolve radio and optical observations of solar system sources	5027	Radio interference from earth
GG-1 through GG-8	All geology and geochemistry subobjectives	5002	Orbital geological mapping and analysis
GG-2	Determine physical, mineralogical, and chemical properties of lunar materials	5006	Petrographic and mineralogic identification and analysis
		5017	Remote geochemical analysis
GG-8	Locate geologically favorable sites for advanced lunar exploration/exploitation scientific facilities	5016	High-resolution mapping of selected sites
GP-1	Determine lunar mass distribution	5020 5028	Spacecraft orbital perturbations Gravity gradient
GP-2	Determine physical state and composition of the lunar interior	5018	Electrical properties of lunar surface and subsurface
GP-3	Evaluate the lunar internal dynamics	5019	Thermal anomalies and surface structure
GP-4	Determine earth-moon mechanical interactions	5020	Spacecraft orbital perturbations
LA-1	Determine the total quantity and distribution of the component species of the lunar atmosphere	5024	Total pressure
		5025	Composition of lunar atmosphere
LA-2	Determine principal natural atmospheric source, loss, and transport mechanisms and their rates	5026	Escape and transport rates in lunar atmosphere
LA-3	Monitor atmospheric contamination resulting from lunar missions, including transport and escape rates	5024, 5025, and 5026	
PF-1	Evaluate solar wind-moon interaction	5021 5023	Solar wind and energetic particles Electric fields
PF-2	Evaluate fundamental physics of plasma interactions	5021, 5023	
PF-3	Determine magnetic and electric fields	5022 5023	Magnetic fields Electric fields
PF-4	Measure lunar particle environment	5021	Solar wind and energetic particles
GC-1	Establish a three-dimensional geodetic control system of the lunar surface	5013	Geodetic grid construction and topographic mapping
GC-2	Collect photogrammetric data and construct topographic maps	5013	Geodetic grid construction and topographic mapping

3.2 LUNAR PROGRAM EXPLORATION AND EXPLOITATION OBJECTIVES

The lunar program exploration and exploitation objectives are as follows:

1. Improve our understanding of the solar system and its origin through determination of the physical and chemical nature of the moon and its environment

2. Compare the earth and moon, thereby better understanding the dynamic natural processes that shaped the earth and led to our present environment, including the development of life

3. Evaluate the natural resources of the moon and utilize its unique environment for scientific research and technological processes

4. Evaluate and extend man's capability in space and his ability to explore other planetary bodies

These objectives have been selected to be both all-inclusive and consistent with the definition presented earlier. Candidate objectives that appear in many data sources but were not included here generally failed to be sufficiently top-level or programmatic in nature, or were too closely tied to a single discipline such as: "Obtain Topographic Maps of the Entire Lunar Surface" or "Establish a Lunar Surface Observatory." These and others are covered at lower, more detailed, levels of program definition.

The first of our selected objectives expresses perhaps the most fundamental objective, in that improving our understanding of the solar system and its origin is the fundamental goal of all space research and much ground-based research as well.

The moon provides us with another planetological data point -- conditions and processes there have apparently been quite different from those on earth. What can we learn from studying the moon which can provide us with greater insight concerning our own planet's evolution?

Clearly, if useful natural resources can be found (particularly water) and efficiently extracted, this would result in an enhanced capability to exploit and eventually colonize the moon. The moon possesses resources that we already know could be scientifically useful: little or no atmosphere, exposure to the interplanetary particle and field environment, little or no intrinsic magnetic field, reduced gravitation, slow earth-synchronous rotation, low levels of seismic disturbance, and no detectable radio noise output.

It can be argued that the last of the previously listed objectives is not purely scientific. It is included, however, to cover for example those investigations in aerospace medicine aimed at determining man's reaction to the unique combination of effects found in the lunar environment and casting the role of the earth's environment in the proper light. Do the effects of the lunar environment on man and other living systems make it less or more likely that life exists elsewhere? Can we expect to be able to successfully explore other planets?

3.3 DISCIPLINARY SUBOBJECTIVES AND OBSERVATION REQUIREMENTS

The disciplines for which subobjectives and observation requirements have been defined are as follows (with abbreviations used in this report in parentheses):

Astronomy (AY)
Geology/Geochemistry (GG)
Geophysics (GP)
Bioscience (BI)
Aerospace Medicine (AM)
Lunar Atmosphere (LA)
Particles and Fields (PF)
Geodesy/Cartography (GC)

The assignment of subobjectives and observation requirements to disciplines which follows is somewhat arbitrary and some overlap is unavoidable. For example, the determination of the detailed gravitational field of the moon could just as easily be categorized under geodesy/cartography or geophysics. In this case, the geodesy/cartography discipline was restricted to observation requirements relating to map-making and establishing the required controls; gravity measurements were assigned to geophysics. Considerable overlap also exists between particles and fields and astronomy -- direct measurements of particle fluxes, energies, etc., were assigned to particles and fields, whereas indirect measurements such as the determination of the electron density in cislunar space by radio techniques were assigned to astronomy.

Observation requirements are specified in varying degrees of quantitativeness. The more descriptive disciplines, such as geology, bioscience, and aerospace medicine, tend to have their observation requirements specified more qualitatively than geophysics or astronomy. Additionally, coverage of the various disciplines by the standard references varies in depth, with less stress on the life sciences than on physical sciences. In those cases where no constructive purpose would be served by comparing recommended observation requirements, only a consensus requirement is shown.

3.3.1 Astronomy

Subobjectives

AY-1 Investigate weak extended and discrete celestial X-ray sources

AY-2 Investigate celestial gamma-ray background and flux anisotropies

AY-3 Perform radio and optical observations of weak and/or earth-obscured galactic and extragalactic sources

AY-4 Determine lunar surface and near-surface electrical properties

AY-5 Investigate properties of the cislunar medium

AY-6 Perform high-resolution radio and optical observations of solar system sources

Rationale for Selection

Astronomical observations from earth and earth-orbital satellites have made significant contributions to our knowledge of the solar system, the galaxy, and the universe. In particular, radio astronomy, a comparatively new science, has permitted great advancements to be made in understanding the earth and its environment through ionospheric sounding, radar propagation through the earth's magnetosphere and whistler investigations. The availability of the moon as a base for studying the earth from the outside, the opportunity to study the local solar plasma without earth magnetosphere interference, and the capability to extend the frequency range of radio astronomy investigations will provide an even greater increase of our knowledge of the solar system and the universe. The moon has special advantages for more advanced programs than earth or earth orbit programs; these include large accessible stable areas for long continuous exposures with interferometers and large telescopes, shielding and removal from earth-based interference associated with other large-scale physical experiments, and travel through positions completely free of the magnetosphere. A unique advantage is offered by the ability to study closely the lunar environment per se. An important consideration is the fact that the moon may eventually be the best if not the only suitable base for flexible, precision astronomy over a wide unobstructed frequency spectrum.

The deletion here of some portions of the spectrum, in particular millimeter astronomy and ultraviolet and high-energy gamma rays, results from the promise of future artificial earth satellites. Although atmospheric absorption from earth-based stations in the millimeter region of the spectrum is a nuisance, expected advances in technology will probably eliminate this as a serious problem in the post-Apollo era.

The present and expected earth-orbital astronomy satellite programs are continuing to provide valuable data. These programs and the lunar programs should be highly complementary, particularly for subobjectives AY-3, AY-5, and AY-6.

Observation Requirements

AY-1 - Investigate Weak Extended and Discrete Celestial X-Ray Sources

Santa Cruz. (See references, pp 3-54, 55, for the complete identification of these cited source documents)

X-rays in the energy band of 1 to 20 kev

Measure intensity distribution as a function of angle
15^{o} x 60^{o} field-of-view collimator

Energy range of 20 to 100 kev

15^{o} x 60^{o} field of view

Falmouth. X-ray - subtended angle 0.5 second of arc, which measures out to an occultation angle being covered in two seconds of time. Occultation on the surface observing X-ray sources using the rim of a large crater.

NAS. Precise angular determination ($<$ 1 minute) of X-ray sources. Perform search for weaker discrete sources.

NASA Astronomy Mission Board

X-rays E $<$ 15 kev

Provide surveys 1 - 8 kev region with 0.5-degree resolution
(possibly 0.1 degree)

Broadband energy resolution

X-ray imaging telescope
Positions to 1 arc-second

Wavelength to $\frac{\Delta\lambda}{\lambda} = 0.01$

Interchangeable instruments are at focus to provide image detectors, polarization measurements, spectral studies.

NASA S&T Advisory Committee for MSF. Special-purpose less extensive arrays would be useful on the moon for X-ray astronomy to yield finer position determination using the lunar horizon as an occulting edge.

Energy range = 2 to 10 kev

Consensus (X-rays). The energy band is from 1 to 10 kev. The lunar surface (for example, the rim of a large crater) is utilized as the occulting edge to perform a search for these weak discrete sources. Resolution is at possibly 0.1 degree. X-ray imaging telescope to yield position accuracies of 0.5 arc-second.

No reference states that X-ray observations should be made from lunar orbit. The lunar surface-based program for X-ray observation is more promising, particularly near the lunar equator. The reasons for a lunar-based program in X-ray astronomy are the availability of an extremely stable platform and very long exposure times and the occulting edges of the horizon and craters.

Apollo Accomplishments. None of the planned Apollo era experiments contribute significantly to this subobjective.

Remaining Requirements. Same as consensus.

AY-2 - Investigate Celestial Gamma-Ray Background and Flux Anisotropies

Santa Cruz. Omnidirectional measurements for the gamma-ray energy region of 0.1 to 10 Mev. Integration time of about one second.

Directional measurements for gamma-ray observation greater than 50 Mev. Observation will be made to detect the electron-positron pair produced by a gamma-ray photon conversion in a crystal. Rotation through 180 degrees from zenith to nadir in six steps to measure angular distribution of the background radiation.

NAS. Directional and spectral characteristics in the 1 Mev region and >100 Mev.

NASA Astronomy Mission Board. Extend the energy spectrum of the background radiation to energies above 1 Mev. From 1 Mev to 10.0 Mev.

Study the energy spectrum and departures from isotropy in order to separate galactic and extragalactic components and to determine their production mechanisms.

Study background radiation with angular resolution of 1 degree to separate background from weak sources and a true diffuse background. Study nuclear transition gamma rays coming from supernova remnants or other gaseous regions. Measurements of diffuse gamma-ray flux in the Mev to 10^{10} ev energy region to determine if the high gamma-rays are diffuse or discrete.

Sensitivities of discrete sources should be 10^{-6} to 10^{-7} photons/cm^2/sec, and angular resolution equal to 0.5 degree. Observations require pointing to within 2 degrees for days. High energy gamma-ray detectors best suited for semi-automatic to automatic operation.

Consensus. Gamma-rays. No reference states that gamma-ray observations are needed from lunar orbit. No requirement for lunar surface to be used for gamma-ray astronomy.

Balloon and low earth orbit satellites fulfill the astronomical observatory site requirements better in the gamma-ray region because of the reduced background radiation as compared to that resulting from lunar surface backscattering and the natural lunar radiation background. Also, the high energy gamma-rays are observable from earth orbit as well as from lunar orbit. Therefore, this subobjective is deleted from any further consideration in the OLS study.

AY-3 - Perform Radio and Optical Observations of Weak and/or Earth-Obscured Galactic and Extragalactic Sources

Santa Cruz. Measurement of ambient noise levels and position, intensity and motion of sporadic radio signals. Frequency range, 500 kHz - 15 MHz.

NASA Astronomy Mission Board. Measure flux densities of 50 to 100 extragalactic and galactic sources at a number of frequencies around 1 MHz. In the area of self-absorption and plasma effects, map the cosmic background noise level of the entire sky from 0.5 to 10 MHz to yield information on the distribution of free electrons in the galaxy and later the extragalactic component. This would determine the large scale structure of the universe.

Measure brightness distribution across radio sources which are occulted by the moon. Obtain angular information as well as spectral descriptions which relate directly to the mechanisms of radio emission.

NASA S&T Advisory Committee for Manned Space Flight. Long wavelength radio astronomy could use the moon as a support for extremely large-filled-aperture radio telescope many kilometers in extent.

Millimeter astronomy - Very large fixed dish with a movable feed and operated only during lunar night.

North American Rockwell (SID 66-381). Measurements of certain galactic and extragalactic sources utilizing directive elements are to be conducted. These measurements include low-frequency spectra of supernova remnants, gaseous nebulae, and extragalactic radio sources and determination of the spatial distribution of hydrogen clouds in the galactic medium and determination of the energy spectrum and density of relativistic electrons emitting by the synchroton process with the assumed galactic halo. The frequency region will be from 300 kHz to 20 MHz.

Measurements of the scintillation of quasistellar radio sources and Jupiter radiation could be observed to infer the structure of the interplanetary medium. Galactic radiation at frequencies near the interplanetary plasma frequency would be useful to determine the medium, including the spatial and temporal variations injected into it by the sun and earth.

The frequency range would be confined to the interplanetary plasma frequency. Also, 21-cm radiation from neutral hydrogen should be observed.

Directivity is very important (less than 1 degree) and can be accomplished with occultation. Wide bandwidth phenomena predominate which implies no need to adapt bandwidth or to sweep frequencies. Observations should be made at selected frequencies. Both the front and backside of the moon will be used for sites.

Optical Astronomy. The projected (optimistic) capability in earth orbit for achieving attitude stability (0.1 arc-sec) can support diffraction-limited performance from a 1 meter diameter optical telescope. The moon provides a much more stable platform with additional advantages of a very dark sky and long (2 weeks) lunar nights (exposures could be indefinite at the poles). Eventually, additional sites could be used to permit several concurrent exposures.

Consensus. Radio astronomical observations to a high degree of angular resolution (1 degree) will cover the frequency range of 300 kHz to 15 MHz. One of the antenna arrays will have an operating bandwidth from 300 to 1000 kHz. Another antenna system will cover the range from 1.0 MHz to 15 MHz which would correlate with earth observations. The angular extent bounds should be 2π steradians with the angular position known to approximately one degree. The polarization sensed could be right- or left-hand or circular polarization.

These measurements will be made from the lunar surface at one or more sites, with the possibility of one site on the far side of the moon. The measurements will include flux densities of galactic and extragalactic sources. These sources are supernova remnants, quasistellar radio sources, gaseous nebulae, hydrogen clouds in the galaxy, and relativistic electrons emitted by the synchroton process from the assumed galactic halo. The parameters to be measured include angular position, angular extent, intensity, polarization (both degree and sense), and temporal variation.

Initial telescopes (12-inch) could be positioned for environmental effects on the surface and with favorable results could be extended to 60 inches or more. Optical astronomy on the lunar surface has the advantage of minimum background light and noise for faint signal discrimination. The moon's surface relieves the earth orbit or lunar orbit difficulties of deployment, storing, and stabilizing the large structures and antenna arrays (kilometers) required to obtain adequate resolution for the study of galactic and extragalactic sources.

Apollo Accomplishments. None of the planned Apollo era experiments contribute significantly to this objective.

Remaining Requirements. Same as consensus.

AY-4 - Determine Lunar Surface and Near-Surface Electrical Properties

Santa Cruz. Measure the complex impedance of an antenna in the vicinity of the lunar surface as a function of frequency and height above the lunar surface up to heights of six feet. Frequency range will be 50 kHz to 10 MHz. Measure the local ionosphere and/or photoemission clouds.

Falmouth. Measure the conductivity and dielectric constant of the lunar soil at frequencies on the order of 10 MHz. After the cosmic noise and impedance properties have been determined, the electron density in the lunar environment could be determined, but at lower frequencies.

IITRI. Obtain measurements concerning the subsurface structure.

North American Rockwell (SID 66-381). Basic investigations include a spectral noise survey, spatial variation of plasma cutoff frequency, collision frequency, electron gyro frequency, particle velocity, and flux measurements.

The observables will be the constituents of the solar wind, lunar ionosphere, and the earth's magnetic tail. Their interactions and separate characteristics can be determined through a careful choice of the observation times and locations of the surface or orbital station.

The noise survey will define the gross characteristics of the local plasma environment. The upper frequency is determined by the lunar plasma frequency, $\sim$ 200 kHz, and the lower frequency is determined by proton resonance effects, $\sim$ 0.1 Hz.

After the noise is located, the problem is to determine intensity, source (which source is predominant -- local noise or extralunar noise), and in what form the noise exists (traveling electromagnetic wave, an induction magnetic field), and in what direction. If the extralunar noise is greater than the lunar noise, then a swept receiver could sweep the range of cutoff frequencies. If the extralunar noise is equal to the lunar noise, then a lunar orbiter could carry a swept frequency beacon with the receiver on the lunar surface. If the lunar noise is greater than the extralunar noise, the lunar orbiter could carry a swept frequency beacon alongside the receiver. Wave polarization measurements could be made to determine the direction of arrival. Measurement of the magnetic field strength, magnitude, and direction as a function of time and position could be made at frequencies between 0.01 and 10 Hz (see Particles and Fields discipline). Ionospheric measurements could be made by receiving extralunar noise signals at a frequency above the plasma cutoff frequency (30 kHz). The degree of absorption of waves passing through an ionized medium yields information on the collision frequency of the ions and electrons in the ionosphere.

The signal intensity varies exponentially with the distance and with the attenuation factor which, in turn, is a function of the electron density, magnetic field, and collision frequency. The measurement could be made on a single frequency with an expansion to a multifrequency measurement and then to a multistation setup.

An electron-density profile of the lunar environment could be determined. Transmitted signals less than the plasma cutoff frequency could be swept over the expected range to measure height as a function of frequency.

Supplemental measurements can be made on the amount of dust particles (charged or neutral) that accumulate on or near the surface of the antenna. There are additional advantages in lunar surface communications -- optimum frequencies can be determined for communications between stations and between stations and the OLS within line of sight and beyond line of sight.

Consensus. The lower frequency is determined by proton resonance effects, $\sim$ 0.1 Hz, and the upper frequency is determined by the lunar plasma frequency, slightly above $\sim$ 300 kHz. Therefore, the frequency region of interest will be 0.1 Hz to 300 kHz.

Measurement of the complex impedance of an antenna (whips, dipoles, wires) in the vicinity of the lunar surface over the frequency range of 10 Hz to 10 MHz will provide data on the subsurface material (permittivity, conductivity, and depth of penetration) and on the near-surface plasma (electron density and conductivity).

Detection of any lunar plasma or ionospheres near and above the surface and measurement of the electrical potential versus time and the electric field gradient above the surface up to 10 meters will be made. Measurements of naturally occurring electromagnetic signals in the frequency range 10.0 Hz to 300 kHz and detection of signals (low-frequency plasma waves) in the frequency range of 0.1 to 10 Hz will be made.

A surface radio wave propagation experiment should be made over the lunar surface for distances of 10 to 1000 kilometers. Several broad frequency bands from 1 kHz to 30 MHz could be used.

Measurements should be made of the moon's electromagnetic environment. Fundamental lunar plasma parameters include plasma cutoff frequencies, local plasma frequencies and electron densities which can be measured as a function of time and position. Also, waves that originate inside the local plasma will be sensed for magnitude, frequency spectra, direction-of-arrival, and polarization. Measurements will be made of extralunar noise at frequencies near the local plasma frequency. The observables will be the constituents of the solar wind, lunar ionosphere, and earth's magnetic tail and their interactions. Their interactions and separate characteristics can be determined through a careful choice of frequencies, observation times, and location of the surface stations along with coordinated observations from satellite and earth-based observations.

Apollo Accomplishment. Static magnetic field measurements; static electric field measurements (±0.2 to 500 V/m, uncertainty ±2 percent or ±10 V/m); multifrequency radiometer -50 kHz to 50 MHz to study background.

Remaining Requirements. Same as consensus.

AY-5 - Investigate Properties of the Cislunar Medium

Falmouth. Utilize a radio transponder (CW or pulse). Utilize an optical corner reflector.

North American Rockwell (SID 66-381). Investigations of the cislunar wave propagation environment (electron density) include an explicit description of the propagation properties of cislunar space and the direct geometric measurement of the earth-moon system and its absolute dimension and their temporal and spatial variations.

The measurements to be performed by a transponder system include (1) more sensitive and precise measurements to explore the cislunar medium (both average and time-varying shapes and densities), the earth's ionosphere, the earth's magnetosphere, the sheath between the magnetospheric boundary and the bow shock formed by the solar wind, magnetospheric wake of the earth, interplanetary medium, and possible shock and wake around the moon; and (2) precise measurements of range and range rate (±0.3 meters).

A number of parameters that are affected by the wave propagation characteristics of the cislunar media are phase path (delay or advance), group path (delay or advance), phase change, frequency change, Faraday (polarization) rotation, attenuation (absorption), refraction angle of wave, and differential absorption.

The lunar-based system would receive earth-based transmitted signals (50 MHz, 400 MHz, 2300 MHz and, possibly, 5000 MHz and 10,000 MHz) and retransmit them after a harmonically related translation in frequency (51 MHz, 408 MHz, and 2346 MHz). The frequencies are chosen so that the low frequency is low enough to show effects of planetary electrons but high enough so that refractive effects of the ionosphere are not applicable. The 200 to 300 MHz region is in the passband of the deep space net antenna feeds and is not affected by ionospheric refraction. Beamwidths of 7.5 degrees in the plane of its narrow dimension are needed to retain the earth within its half power points. The Doppler shift and rotation of the plane of polarization is determined from the carrier frequency. These measurements can be made (0.1 degree or better) continuously. The integrated electron density should be measured to an accuracy of one percent. To resolve range ambiguities, a number of modulation frequencies will be required at each carrier frequency depending upon the accuracy to which the lunar range and its variation is known. All data analysis and interpretation will be performed on earth.

VLF and LF measurements could be made between lunar surface and an earth orbiter to obtain phase and group path measurements. These frequencies would be above the ambient plasma frequency. The advantage for substituting a high satellite for a station on the earth's surface is two-fold. The effects of the ionosphere and inner magnetosphere are largely eliminated when earth, satellite and moon are in line, and a much lower frequency can be used that increases the sensitivity of the experiment.

Consensus. The parameters that are effected by the wave propagation through the cislunar media are phase path (a delay or advance), group path (a delay or advance), phase change, frequency change, Faraday (polarization) rotation, attenuation (absorption), refraction of wave, and differential absorption. The measurement of the total cislunar integrated electron density (accuracy, 1 percent) by the continuous wave dispersion technique should have accuracy of 2×10^{-2} cycles. Also, the extramagnetospheric integrated electron density accuracy is 1 percent utilizing Faraday rotation. The continuous wave dispersion technique should have an accuracy of 5 percent. To determine the range-rate (integration time, 10 seconds), the Doppler frequency shift (accuracy of 3×10^{-3} cycles) will be measured (corrected for plasma-induced frequency shifts). The earth-lunar range (accuracy of ± 30 cm) will be determined by group-path delay and phase-path advance techniques (an accuracy of 1×10^{-2} percent). Beamwidth and gain of VHF equipment would be 46 degrees and 10 db, respectively, and 30 degrees and 15 db for the higher frequencies (L- and S-band).

Measurement of the cislunar medium includes those of electron densities in the magnetospheric and extramagnetospheric region, and the measurement of the range to the moon and accompanying range-rate. The Doppler radar technique will be used for the range-rate, a cislunar ranging technique for absolute range, continuous wave dispersion technique for total cislunar integrated electron density, and a Faraday rotation technique to determine the magnetospheric electron density.

Apollo Accomplishments. Good coverage at S-band frequency on communication channel; ruby laser reflector in conjunction with MacDonald Observatory obtained earth-moon distance to ±0.3 meter, ±0.15 meter accuracy expected later in program.

Remaining Requirements. More than one site for the transponder configuration (three or more) is required, in addition to measurements described in consensus.

AY-6 - Perform High-Resolution Radio and Optical Observations of Solar System Sources

North American Rockwell (SID 66-381). The radio emission is monitored from discrete sources in the time domain. Jupiter decameter burst and solar meter-wave burst are of importance plus searches for low frequency emissions from other objects in the solar system. The frequency range will be from 300 kHz to 20 MHz. The investigations will cover a wide variety of temporal signals from the sun, Jupiter, earth, and possibly other planets at low frequency. The useful investigation will include the time occurrence, details of time variations, the dynamic spectra and polarization, all measured with low directivity (5 degrees). The narrow-band phenomena will predominate. Observations of the sun, Jupiter, and the background will be made at 10 to 20 MHz Phase-switching can be incorporated to eliminate the dc background. The advantages of using the moon as a radio astronomy base is the moon's stable position and attitude, a large rigid base area, a large mass for shielding earth, location outside the magnetosphere, and man's capability for checkout and modification.

The investigations particularly slanted toward the sun are the slowly varying component, which comes and goes with sunspots, burst activities at millimeter wavelength and at low frequencies including the time-dependence and spectral and spatial characteristics and occultations of radio stars by the corona.

Santa Cruz.

Nonsolar optical astronomy

Wide field photometry of sky brightness (1-degree resolution)

Map sky brightness near the sun after sunset and before sunrise to one-arc-minute resolution

Obtain coronagrams of the sun

Jupiter - high resolution imagery of near polar object at 100-kilometer resolution

NAS. Jupiter bursts below 10 MHz

NASA - S&T Advisory Committee for Manned Space Flight. The moon is to be used as a solid base for an optical interferometer. The Starlight Deflection Experiment will study the outer corona and optical nonsolar astronomy. Infrared astronomy is used to study outer layers of the sun, especially the corona.

The planetary atmospheres will be analyzed to determine the chemical compositions and heat balance.

NASA - Astronomy Mission Board. For frequencies from 5 MHz to 500 MHz, the far side of the moon is recommended in order to block out interference from earth.

Dynamic radio phenomena, location of strong sources, including variable sources at low frequencies as well as at high frequencies, will be studied. Permanence of a baseline makes radio direction finding easier. Baselines with distances of 50 to 100 kilometers could be deployed from a manned lunar exploratory vehicle.

Data will be obtained on the statistical parameters of cosmic background noise fluctuations at several frequencies near 1 MHz.

Studies will be made of variable interplanetary absorption and interplanetary scintillation effects that are in the inaccessible region beyond the earth's orbit.

Consensus. Investigation should be made of strong discrete sources exhibiting temporal variations such as Jupiter and solar radiation in the range of 0.6 MHz to 1.5 MHz. Since Jupiter and the sun emit signals that are partly polarized, polarization density receptions should be made to measure the degree and sense of polarization. To achieve a 1.7-degree beamwidth at 1 MHz, the separation distance should be 9 kilometers (0.17 degree at 90-kilometer separation).

Radio interference from earth could be monitored in the range of 100 kHz to 3 GHz. The emissions would be from reflected energy, man-made emission, ionospheric emissions, etc.

For frequencies from 5 MHz to 500 MHz, observation should be taken from the far side of the moon. Any optical astronomy measurements or infrared measurements should be taken, if at all, from sites near the poles because of the long viewing times afforded by darkness.

Most of the time-variable signals in the low-frequency, nonthermal radio emission region would correspond to sources lying within the solar system. Sources outside the solar system seldom show any significant time dependence. Therefore, when the temporal variations in a received signal are detected by a lunar-based system, then identification of the source can be made through correlation of this temporal behavior with that of more directional radio astronomy telescopes (operating perhaps at higher frequencies) deployed on earth. Utilizing this rationale, simpler antennas would be employed that would allow polarization measurements and would provide for measuring calibrated intensity, whereby the cosmic background could be determined. Solar astronomy can be achieved better from high earth orbit rather than either lunar base or OLS mainly because of the amount of viewing time (80 percent versus 50 percent) and the signal strength.

Apollo Accomplishments. Multifrequency radiometer; 50 kHz to 15 MHz to study background; expected results from the RAE satellite experiment from 400 kHz to 10 MHz.

Remaining Requirements. Same as consensus

3.3.2 Geology/Geochemistry

Subobjectives

- GG-1 Determine the type, form, structure, distribution, and relative age of lunar surface features
- GG-2 Determine the physical, mineralogical, and chemical properties of lunar materials
- GG-3 Deduce the nature and relative importance of dynamic natural processes on the lunar surface
- GG-4 Study the effects of ancient or long-term geologic processes
- GG-5 Compile a geochronology of lunar events from the early stage of formation to the present day
- GG-6 Construct geologic maps of the lunar surface, delineating lithologic contacts, tectonic structures, physiographic, and petrographic provinces
- GG-7 Determine the nature of morphologic differences between the near and far side of the moon
- GG-8 Locate geologically favorable sites for advanced lunar exploration/exploitation scientific facilities

Rationale for Selection

Geological exploration of the moon, including its subdisciplines, petrology, stratigraphy, mineralogy and geochemistry, has received and will probably continue to receive the major emphasis in the lunar exploration program. This is a result of several influences, among which are the necessity to be on the lunar surface to obtain definitive answers to fundamental questions and the major impact on crew time which such investigations have. The subobjectives listed above have been selected to assure that adequate emphasis is placed both on the acquisition of geologic data and on its interpretation and use. Thus, many of the listed subobjectives will be accomplished to a major extent by the careful preparation of geologic maps, but the large variety of uses for such maps, each with its own requirements for data type and scale, is reflected in the large number of listed subobjectives and observation requirements. The selected subobjectives represent a distillation or summary of the goals of lunar geological exploration as expressed in the documents referenced throughout this section.

Observation Requirements

GG-1 - Determine the Type, Form, Structure, Distribution, and Relative Age of Lunar Surface Features

Falmouth 1965.

Surface mobility: 15 kilometers, 600-pound payload

Flying mobility: 15 kilometers, 300-pound payload

Subsurface exploration: > 300 meters

Laboratory mobility: 800 kilometers, 2 months operation

Topo maps: 1:250,000, 20 to 30-meter contours.
Special purpose at 1:100 K

Orbital sensing: X-ray, gamma-ray, particle spectroscopy, high-resolution panoramic photography, multiband, and ultra-high resolution photography (1-m resolution)

La Jolla 1968.

Extended traverse measurements, especially of mascons

Three-dimensional network of seismic measurements

Subsurface exploration at least several hundred meters

Woods Hole 1965.

Systematic orbital remote sensing followed by detailed surface studies

Topo maps of 1:1,000,000, 1:250 K, and 1:100 K

USGS No. 19 1970. (Astrogeology Interagency Report)

Remote sensing: bistatic radar probing, passive microwave, and X-ray spectrometry

Surface analytical sensing: alpha backscatter, X-ray fluorescence, and neutron activation

Santa Cruz 1967.

Orbital sensing: High resolution photography (resolution, 20 cm), Infrared (IR) radiometry, passive microwave, imaging radar, bistatic low frequency radar, ultraviolet (UV), visible-IR scanning (imaging)

Surface: Traverse with visual and analytic investigations

Subsurface and geophysical probing

Sample return and remote in situ analysis

LESA 1965.

Orbital sensing of gamma-ray spectra

Borehole logging for self-potential, resistivity, sonic, and nuclear logging

Neutron activation chemical analysis

IITRI

Orbital sensing:

- Metric photographs, 2-m resolution
- Panoramic 1/2-m resolution
- Radar probing, 25 percent of surface
- Gravity gradient
- Magnetometry, 0.5-degree resolution or 0.01
- IR-UV imagery, 100-m resolution

Consensus.

Orbital sensing:

- High-resolution photography, resolution 20-cm (specific areas)
- Front and backside gravity survey
- IR-UV imagery and passive microwave
- Gamma-ray spectroscopy, 1 km^2 resolution
- X-ray fluorescence, 1 km^2 resolution
- LF bistatic radar

Surface: visual, inspection/analysis geologic mapping; local and traverse geophysics; subsurface sampling and logging

Mobility: 100 kilometers radius, 10-day

Flying mobility: 100 kilometers, 300-pound

Apollo Accomplishments.

Four landings: sample return and site geology at two Mare sites; one near-highland site; one Mare/volcanic (?) site; magnetometry at two sites.

Orbital sensing: photography - local coverage, high resolution and low resolution

Gamma-ray spectra, omnidirectional

Frontside gravity map

Remaining Requirements.

Orbital sensing:

High resolution photography, 20-cm resolution locally
Backside gravity map
IR and UV imaging at 100-meter resolution

Gamma-ray and X-ray fluorescence from polar orbit, 1 or 10 km^2 resolution

LF bistatic radar

Surface: Visual, inspection/analysis, geologic mapping, and sample return. Local geophysics and geochemistry analysis. Subsurface sampling and logging.

Mobility: 100-kilometer surface radius, 10 days

Flying mobility: 100 kilometers

Natural continuation and extension of Apollo exploration will be accomplished. Investigation of lunar features (e.g., basins, highlands, craters, rilles, ridges, volcanic land forms, ejecta blankets, etc.) will be affected by Apollo accomplishments to the extent that individual sites or features similar to those already visited need not be reinvestigated. In general, however, such scientific investigations spawn more interest and deeper questions as the studies progress. All Apollo investigations are of low-latitude regions, whereas OLS/LSB programs are concerned with global coverage. Apollo X-rays and Gamma-ray orbital experiments are omnidirectional. Better resolution from 1 to 10 km^2 will be more meaningful.

GG-2 - Determine the Physical, Mineralogical and Chemical Properties of Lunar Materials

Falmouth 1965.

Orbital sensing: Microwave spectra, electromagnetic pulse probing, radar scatterometry, low-frequency radar imaging, microwave imaging, X-ray fluorescence spectra, Gamma-ray spectra, UV reflectance and luminescence multispectral photography, and IR imager.

Surface investigation: Sample return. In situ analysis by petrographic microscope, X-ray diffraction, X-ray spectra, mass spectra, natural radiation measurements, and physical measurements.

La Jolla 1968.

Sample analysis
Composition data
Isotopic ratios
Resource prospecting

Woods Hole 1965.

Emphasis will be placed on search for ancient rocks for clues to lunar origin

Petrographic examination

X-ray spectra

Measurement of atomic masses 12 to 200, and gas pressures to 10^{-14} torr

USGS No. 19 1970.

Mineralogic analysis emphasized, X-ray diffraction

Remote chemical analysis by alpha backscatter, X-ray fluorescence neutron activation, and optical emission spectroscopy

Santa Cruz 1967.

Orbital sensing: (Same as GG-1, plus Gamma-ray and X-ray fluorescence spectra, and mass spectrometry)

Surface: Sample return and in situ petrologic investigations by microscope, X-ray diffraction, gas chromatography, solids mass spectrometry, and neutron activation device

LESA 1965.

Water search using vertical and horizontal nuclear logging

Bellcomm 1969.

Orbital geochemistry:

Gamma-ray spectra:
Natural: K, Th, U --- induced: Na, Mg, Al
X-ray spectra: O, Mg, Si, Fe
Mineralogy by IR emission and spectral reflectance

IITRI 1966, 1970.

Orbital (polar) geochemistry

Visual - UV spectral signatures, 100 - 7000A, 100-meter resolution

IR spectra: 7 - 40μ

Passive microwave, 30μ to 30 cm (~ 150K temp) at 10 km^2

Consensus.

Orbital sensing: polar orbit

High resolution sensing of Gamma-ray and X-ray spectra, 10 km^2 or 1 km^2

IR and UV spectra and imagery

Passive microwave

Low-frequency radar probing

Surface investigation: Sample return, petrographic micrography, X-ray diffraction, X-ray spectra, Mass spectrometry, neutron activation. Auger spectrometry.

Subsurface sampling, electric and nuclear logging

Apollo Accomplishments.

Orbital: omnidirectional Gamma-ray and X-ray spectrography S-band bistatic radar, Apollo 16, also Explorer 35 and Lunar Orbiter

Surface: Sample return from two Mare, one near highland, and one volcanic (?) site

Subsurface: soil cores 70-cm depth, auger-percussion drill to 3 meters

Remaining Requirements.

Orbital sensing in polar orbit:

High-resolution Gamma-ray and X-ray spectrography at 10 or 1 km^2 resolution

IR and UV spectra and imagery

Passive microwave

Low-frequency radar probing

Surface:

Sample return

In situ petrographic micrography, X-ray diffraction and spectrometry, mass spectrometry, neutron activation, or auger spectrometry.

Subsurface sampling and logging, electrical and nuclear. Sounding for velocity measurement. Depths of order of 300-m desirable.

Mass distribution of lunar differentiated materials is best determined by orbital sensing. Apollo gamma- and X-ray spectra experiments have practically no resolution and are restricted to equatorial region. Good resolution and global coverage are required and sensitivity of instrumentation can be calibrated according to results of Apollo experiments.

Passive microwave and IR imagery will indicate regional heat flow and locate anomalies and possible tectonically active zones and areas for surface exploitation. UV imagery will assist geologic mapping and identify some areas of mineralization.

In situ petrographic and geochemical measurements will screen samples for earth return and assist geologists in mapping and exploration tasks. More work is required in highland areas of the moon and at sites of reported transient activity. Mass spectrometer experiments are especially useful for studying outgassing (See section under "Atmosphere").

Subsurface sampling and investigation has been very limited in the Apollo program. Deep samples and probing are required to obtain oldest rocks and to detect fossil life and possible permafrost.

GG-3 - Deduce the Nature and Relative Importance of Dynamic Natural Processes on the Lunar Surface

<u>Falmouth 1965</u>

Atmospheric measurements
Seismometry

<u>La Jolla 1968</u>.

Heat flow measurements in hole some tens of meters deep

<u>Woods Hole 1965</u>.

Broad recommendation for the investigation of interior and exterior processes -- coordinated with geologic mapping

Santa Cruz 1967.

Orbital geochemistry measurement

Gamma-ray spectra, 0.3 - 10 Mev
Alpha-particle measurement
Mass spectrometry and IR spectra
Neutron albedo

LESA 1965.

Gas composition

Thermoluminescence

Isotopic geochemistry:

Pb/U, C, S, H/He, I^{129}, Xn

Erosion study by stereo-microscopy

Bellcomm 1969.

Geomorphic procurement studies

Field analysis. Landforms, ash flows, solifluction, rille formations, mass wasting, etc. Atmospheric isotope determination. Heat flow anomalies.

IITRI 1966, 1970.

Lyman - alpha radiation

Charged particles 1 ev - 500 Mev

$0 - 10^3$ cm^{-2} sec^{-1}

Cosmic-ray electrons, 0.05 - 50 Mev. 0.3 - 500 Mev protons,

$1 - 10^{10}$ cm^{-2} s^{-1} omnidirectional

Level-3 and some level-2 type investigations

Consensus. General and varied.

Apollo Accomplishments. Local site investigations will be made of effects of solar and cosmic bombardment, micrometeorite bombardment, and impact effects. A qualitative study of erosion phenomena will be made. Passive seismometry at as many as three sites will be conducted. Identification of widespread phenomena, e.g., glass spherules and regolith breccia, glass blobs, and surface mounds remain puzzling to many.

Remaining Requirements. High-resolution photography, 20-cm, at selected sites. Determination of atmospheric variations, density and composition. Geologic mapping and geophysical traverses. Subsurface sampling and logging to 300 meters. Mobility up to 100 kilometers. Extensive passive seismometry.

Dynamic natural processes on the moon include degassing, thermal activity, mass wasting phenomenon such as slumping, micrometeorite erosion, formation and "gardening" of the regolith, various impact phenomena, including the formation of rays, glass spherules, blebs and blobs. Also included is seismic activity due to impacts or tectonic activity and bleaching/darkening effects of material caused by solar/cosmic radiation.

Interpretation of these require in situ field analysis assisted by high-resolution (HR) photography and laboratory support. In some cases, subsurface sampling and geophysical exploration will be required.

Apollo missions are answering many questions, but also raise new questions. Dynamic process studies of post Apollo will probably be more detailed and deal with unexpected anomalies and large-scale or isolated volcanic phenomena.

GG-4 - Study the Effects of Ancient or Long-Term Geologic Processes

Falmouth 1965.

Gravity and geological surface mapping of the Appenines

Woods Hole 1965.

Search for history of cosmic radiation variations

USGS No. 19 1970.

Stratigraphic and structural determinations by remote sensing studies

Santa Cruz 1967.

Gravity anomalies

Magnetic anomalies

LESA 1965.

Differentiation effects (Gamma-ray spectra)

Isotopic ages

Bellcomm 1969.

Deep-seated material, excavations, ejecta blankets, and central peaks

IITRI 1966, 1970.

Outcrop and structural patterns, local and regional

IR anomalies

Differential masses (Gamma spectra 0.01 - 100 photons per cm^2-sec, 0.1 - 10 Mev); (X-ray fluorescence of 0.01 - 100 photons per cm^2-sec, 0.1 - 10 Mev, 100-meter resolution)

Consensus.

Crustal differentiation by Gamma-ray spectrography and gravity anomalies

Apollo Accomplishments. Mare and semi-highland areas will have been sampled and briefly studied in situ. Also, remote geochemical analysis (Gamma-ray, X-ray, alpha emission) will be performed for limited durations from lunar orbit on Apollo J missions.

Remaining Requirements.

Orbital:

High-resolution photography (1 meter) of key areas

Global coverage from polar orbit with resolution better than 1 km^2 of gamma radiation, 0.1 - 10 Mev, 0.01 - 100 photons per cm^2-sec; X-ray fluorescence spectra, 0.1 - 10 kev, 0.01 - 100 photons cm^2-sec

IR (3 - 25 micron spectral range) imagery and UV imagery at 100-meter resolution

Surface: geologic mapping on topographic base maps

Subsurface sampling and logging to 30-meter depth. Mobility, 10 to 500 kilometers. Active seismic, gravity, and magnetic traverses

Ancient or long-term geologic processes to be studied include chemical and mineralogical differentiation of the lunar crust, magmatic intrusion, volcanism, mountain building and basin subsidence, isostatic readjustment to major bolide impacts, formation of fracture nets and lineations, faulting, convection, hydrothermal or pneumatolytic activity, and cosmic and solar bombardment.

The recommended measurement objectives are an extension of Apollo investigations and generally are in agreement with the Santa Cruz study. The gamma- and X-ray spectral sensing will delineate areas of silicic or felsic concentrations in the crust. UV imagery may indicate areas of zones of mineralization. High-resolution photography will assist elucidation of border and structural features, also stratigraphic relations. Impact or endogenic processes which caused crustal anomalies will be discovered by gravity and magnetic surveys and active seismic surveys.

The Apollo program will leave many questions unanswered, especially in highland areas and for large features; e.g., mascons. Its gamma-ray spectography data will indicate the levels at which radiation needs to be measured, but resolution may be insufficient for other than intelligent planning purposes.

GG-5 - Compile a Geochronology of Lunar Events from the Early Stage of Formation to the Present Day

Falmouth 1965.

Subsurface exploration, > 300 meters

Woods Hole 1965.

Unraveling of the stratigraphic sequence for the "exploration of time" as well as space

Santa Cruz 1967.

Determine solar and cosmic radiation history by subsurface exploration, petrographic analysis for radiation damage indicators

Isotopic age dating of returned samples

LESA 1965.

Isotopic age dating best done by earth laboratories

Bellcomm 1969.

Isotopic age dating techniques

Zircon, Pb^{207} - Pb^{206}
Zircon, U^{238} - Pb^{206}
Hornblende, K - Ar
Biotite, Rb - Sr
Biotite, K - Ar

Consensus.

Isotopic dating of surface and subsurface samples, Mare and highland

Apollo Accomplishments. Obtained isotopic ages of major lunar events: eastern and western Mare formation, Mare Imbrium impact data, and crystallization of some highland rocks. Better understanding of lunar evolution.

Remaining Requirements. Synthesis of orbital and surface studies with emphasis on stratigraphic investigations and collection of meaningful specimens representing major and typical lunar events. Requires geologic mapping and field stratigraphy combined with intensive interpretation of orbital remote sensing data.

Dating will be done in earth-based laboratories until suitable portable instrumentation can be developed.

Determination of the evolution or geologic history of the moon is not a singular task, but will develop as a ynthesis of all lunar geoscience investigations. Isotopic dating is simply the mechanic processes of assigning an absolute age to specimens affected by lunar events, indicated by study of field and microscopic study of other phenomena caused by the event and preserved in lunar rocks.

GG-6 - Construct Geologic Maps of the Lunar Surface, Delineating Lithologic Contacts, Tectonic Structures, Physiographic, and Petrographic Provinces

Falmouth 1965.

Systematic geologic mapping at 1:25,000,000, 1:1,000,000 and 1:250,000

Mapping of key areas at 1:25,000 and 1:100,000

Orbital remote sensing with ground truth landings

Rover mobility and flying mobility

Woods Hole 1965.

Geological plotting on topo base maps of scales: 1:1,000,000, 1:250,000 and 1:100,000

USGS No. 19 1970.

Orbital remote sensing aided by bistatic radar sounding and passive microwave

Santa Cruz 1967

Orbital remote sensing: Global geologic mapping by photointerpretation and remote sensing data

Surface: Ground truth at scattered strategic sites, using geologic and geochemical methods, and lunar surveying system and electromechanical line scanner.

IITRI.

Orbital: low-frequency radar probing. Radar imagery, 100-meter resolution. Gravity gradiometer surveys, microwave (passive) surveys, IR mapping, and 25 percent coverage.

Surface: surface mapping, long and short traverses

Consensus.

Orbital: photography, high-resolution (1 meter). IR and UV imagery at 10-meter resolution. Gravity gradient surveys and low-frequency radar sounding.

Surface: geological, geochemical, and geophysical surveys and traverses. Subsurface sampling and logging. Traverses from 10 to 500 kilometers.

Apollo Accomplishments. Provide useful ground truth information at four sites (two of which are in key areas) important for extrapolation of remote sensing data. Subsurface data minimal.

Remaining Requirements.

Orbital: photography, high-resolution (1 meter). IR and UV imagery, 10-meter resolution. Gravity gradient and low-frequency radar sounding.

Surface: geologic/geochmical/geophysical traverses and surveys with subsurface sampling and logging. Laboratory and mobility support.

The tasks consist of plotting geologic data on topographic maps constructed photogrammetrically. Method is the same as used on earth in remote, undeveloped terrain: (1) reconnaissance of area using photographic and other remotely sensed data, (2) spot (ground) investigations at strategic or problem areas, and (3) continuation of interpretation of remote sensing data using and extrapolating knowledge gained by the surface investigations.

Apollo has provided four spot investigations, two of which were very limited in scope and were in relatively homogeneous geologic areas. Further landings must obtain more subsurface (stratigraphic) field investigations and geophysical traverses.

GG-7 - Determine the Nature of Morphologic Differences between the Near and Far Side of Moon

USGS No. 19 1970.

Exploit color characteristics with multiband photography and photometry.

Santa Cruz 1967.

Recommends polar but no far side investigations except Mare Orientale

LESA 1965.

Remote areas probed by unmanned experiment packages

Bellcomm 1969.

Farside and highland areas best sources of oldest possible material

IITRI 1966, 1970.

Radar imagery of far side, 100-meter resolution
Ideal base site in Mare Orientale

Consensus.

Same procedures used on front side to be applied to far side

Apollo Accomplishments. Near-side information is indispensible for planning far side investigations and comparing results.

Remaining Requirements.

Orbital: High resolution (1 meter) photography from polar orbit. Gravity gradient of entire surface with high resolution magnetic field measurement. Low frequency radar probing, 50 to 150 meters deep. IR and UV imagery, 10-meter resolution.

Surface: Visual analytical fields survey, local geological mapping and subsurface sampling and geophysics. Preliminary landing for engineering purposes; e.g., nature of surface and underlying regolith, trafficability analysis.

Utilizing of orbital and surface investigations for comparing the near and far side geomorphology of the moon and to assist in determining the reasons for the differences of the two sides with respect to the presence or absence of maria and mare concentration.

Apollo contributions to far side geology have been minimal, but their near side accomplishments will be essential to carrying out this subobjective.

GG-8 - Locate Geologically Favorable Sites for Advanced Lunar Exploration/ Exploitation Scientific Facilities

Falmouth 1965.

Historical interest

La Jolla 1968.

Select sites on basis of self-sufficiency for colonization, refueling capability and quarantine for planetary missions.

USGS No. 19 1970.

Unmanned landers determine lithology, texture and mineralogy of area. Representative quality of site is important.

Santa Cruz 1967.

Unmanned probes and high resolution photography

LESA 1965.

Recommends three sites accessible by 1500-kilometer range vehicle

Bellcomm 1969.

Selection based upon proximity to: significant geologic formations, rilles, elongate craters, mare ridges, impact crater with fresh rays, central peaks, highland volcanic features, mare volcanic domes, and major mountain range.

IITRI 1966, 1970.

Utilize virtually all sensors. Concept of feature clusters.

Consensus. Utilize remote sensors and unmanned lander or short landing mission to check out site after consideration of feature cluster and general significance of the area.

Apollo Accomplishments. Apollo will obtain high resolution photography of low latitude candidate. Surface conditions encountered may be extrapolated for mobility planning.

Remaining Requirements.

Orbital: High-resolution (1 meter) photography from polar orbit. Low-frequency radar probing, 50 to 150 meters. IR and UV scanning at 10-meter resolution.

Surface: Preliminary landing for engineering purposes; e.g., nature of surface and underlying regolith, trafficability analysis.

Selection of sites for advanced lunar exploration activities can be approached from a feature-cluster concept, that is, utilizing sites with numerous features of interest within range of available mobility aids. All applicable sensors will be employed to locate or begin detailed studies of known features of interest before a surface visit.

3.3.3 Geophysics

Subobjectives

GP-1 - Determine the mass distribution and figure of the moon

GP-2 - Determine the physical state and composition of the lunar interior

GP-3 - Evaluate the internal dynamics (heat flow, circulation, creep, etc.) of the moon

GP-4 - Determine earth-moon mechanical interactions

Rationale for Selection

GP-1 - Distribution of Mass and Figure of the Moon

There will be a continuing requirement to refine the measurements of the mass distribution of the lunar interior and establish more precisely the overall physical shape of the moon. Better knowledge of the gravitational potential of the moon is required to determine the degree of departure of the moon from an equilibrium configuration. The presently available representation of the gravitational potential to the fifth degree harmonics must be extended through the 10th or 15th degree to adequately test the hypothesis of isostasy. More precise determination of the moment of inertia is required. The present relation among the three unequal axial moments of inertia of the moon contributes to the understanding of the evolution of the moon and the establishment of the time at which the figure of the moon was stabilized.

GP-2 - Physical State and Composition of Interior

There is presently much less information on the seismicity of the moon than on its magnetic or gravitational fields and this may well still be the situation at the end of the pre-OLS/LSB period. Seismic measurements are considered to have the very highest priority in future lunar missions because they represent a powerful probe for inferring structure and composition of the interior from a remote station on the surface. Ideally, a network of many short period seismic stations over the entire lunar surface with communication links to the LSB would be desirable. A long wavelength network is also desirable and would provide surface wave data inferring structure and anelastic properties of the interior.

GP-3 - Internal Dynamics of Moon

A direct measurement of the heat escaping from the lunar interior is an important goal of lunar science. The net heat flow outward is derived from energy generated from internal processes and energy retained from the initial formation of the moon. In the case of the moon, the surface heat results from heat sources distributed throughout a larger fraction of the lunar volume and, therefore, is more revealing of internal processes than in the case of larger bodies such as the earth and other planets. The internal sources presently contributing to the surface heat are believed to be the long-lived decaying radioisotopes of uranium, thorium and potassium.

By the time of the OLS/LSB period, heat-flow experiments at the lunar surface should be extendible from shallow holes to deep holes down to 100 meters or more.

Infrared radiometer orbital sensing should continue with higher resolution to record anomalous hot spots and cold spots in previously undiscovered locations; e.g., spotted from polar or high inclination orbits.

GP-4 - Earth-Moon Mechanical Interactions

The use of the moon as an astronomical platform will require a continual refinement of the calibrated position and motion of this platform. The determination of lunar librations in longitude, including their excitation and decay, is of considerable interest. There may also be a lunar libration in latitude analogous to the Chandler wobble of the earth.

Observation Requirements

GP-1 - Determine the Mass Distribution and Figure of the Moon

Santa Cruz. More detailed gravity measurements to establish gravitational potential out to the 10th or 15th harmonics to test theory of isostasy. Map figure of moon to ±100 meters. Determine moment of inertia more accurately.

IITRI. Mascons revealed by Doppler shift of lunar orbiter signals; i.e., velocity components along earth-moon line. More accurate method is to measure spacecraft total velocity and position versus time laser ranging and photographs.

NAS. Produce gravity map of far side of moon. Measure large scale variations in elevations of topography to ±100 meters at 2-degree intervals.

Other. Medium resolution general topographic mapping with 100-meter resolution with metric camera system capable of 10-meter positional accuracy. Determine spacecraft orbit perturbations to 10-meter accuracy -- radar altimetry and laser ranging with surface reflectors.

Consensus. Make gravimetry measurements to allow field representation to 15th harmonic on both sides of moon. Photographic mapping of moon to 100-meter resolution. Determine camera position to ±10 meters. Use radar altimetry and laser ranging with surface reflectors.

Apollo Accomplishments. Present Lunar Orbiter provides data to determine harmonics through 5th. Photographic mapping on Apollo 17, 18, and 19. Laser altimetry, Apollo 17, 18, and 19. Apollo 12 found small mascons under Ptolemaeus and Albategnius.

Remaining Requirements. Conduct more extensive measurements of far-side gravity anomalies. Extend field representation to 15th harmonic on both sides of moon. Photographically map moon to 100-meter resolution. Define camera position in orbit to ± 10 meters.

GP-2 - Determine the Physical State and Composition of the Lunar Interior

Santa Cruz. Measure seismic data from propagation of elastic waves from: moonquakes, meteor impacts and artificial missiles (e.g., S-IVB shells). Measure short wave periods, 0.01 to 20 Hz. Measure long wave periods:

Free oscillations: 0.1 mm, T $<$15 min/cycle

Tides: T $\sim$ 28 d/cycle
1 milligal $\pm$0.1 percent

Secular strains: 10^{-8} $\pm$0.1 percent

Tilts: 0.1 second of arc $\pm$0.1 percent

IITRI. Passive seismic measurements are judged to satisfy more scientific objectives than any other surface experiment.

NAS. Active seismic energy source: define source location (e.g., impact of S-IVB shell) to $\pm$ 1 kilometer, and time to $\pm$0.1 second.

Other.

Dynamic range: 1.0 millimicron to 10 microns

Short-period interval: 0.2 - 25 Hz

Long-period interval: 0.004 - 3.3 Hz

Consensus. Make seismic measurements with dynamic range of 1.0 millimicron to 10 microns. Measure moonquakes, meteor impacts, and artificial impacts. Determine artificial impact point location to $\pm$ 1 kilometer.

Apollo Accomplishments. Active seismic measurements on lunar surface on Apollo 14 and 16. Passive seismic measurements on lunar surface on Apollo 15, 16, 17, 18, and 19.

Remaining Requirements. Provide for simultaneous measurements from an array of seismic sensors on the lunar surface. Measure long and short period waves at representatively different locations.

GP-3 - Evaluate the Internal Dynamics (Heat Flow, Circulation, Creep, etc.) of the Moon

Santa Cruz. Measure the energy budget (mechanical and thermal) and response of the moon to internal and external stresses. Measure heat flow, creep, movement of magma, seismicity, tectonic activity and electrical properties. Measure thermal conductivity for which temperature fluctuations of 0.015 C for which sensor resolution of $\pm$0.001 C is desirable. Conduct polar orbit radiometry measurements 30 to 300 microns $\pm$100 meters.

IITRI. Not discussed except that heat-flow probes are second only to passive seismometers in satisfying the most scientific objectives for lunar surface measurements.

NAS. Measure heat flow in hole 1 to 10 meters deep in both typical and atypical locations to obtain conductivity. Measure microwave emissions from lunar surface from orbit for different sun elevations to obtain average temperature profile versus depth.

Other. Measure thermal anomalies with 100-meter resolution with IR (5 to 300 microns) to find anomalously hot or cold areas and determine mineralogical characteristics and composition variations. Measure gamma rays from orbit to infer radiogenic elements on surface to aid in interpreting heat flow measurements. Accuracy of heat-flow measurements: ± 0.05 microcal per cm^2-sec over a range of 0 to 5 microcal per cm^2-sec.

Consensus. Make IR measurements of thermal anomalies with 100-meter resolution for wavelengths of 5 to 300 microns from lunar orbit. Extend measurements into microwave region. Arrange for high-latitude (including polar) orbits. Measure heat flow in deep drilled holes 1 to 10 meters. Require temperature resolution of 0.001 C to measure fluctuations on the order of ± 0.01 C. Obtain net outward heat flux from surface of moon. Compare with earth's. Heat flow measurements together with seismic measurements will provide information on composition and physical state of lunar interior.

Apollo Accomplishments. IR scanning radiometry measurements had been scheduled on Apollo 18 and 19. Heat-flow measurements of vertical conductivity in shallow (3-meter) holes had been scheduled on Apollo 13 and 16.

Remaining Requirements. Measure heat flow in holes 10 to 100 meters deep in both typical and atypical locations. Measure radiometrically from polar and other high-latitude orbits the total heat flux as a function of position and deduce lateral thermal gradients. Require resolution of 100 meters.

GP-4 - Determine Earth-Moon Mechanical Interactions

Santa Cruz. Measure orbital perturbations, librations, and lunar moment of inertia.

Other. Measure librations.

Consensus. Determine spacecraft orbit perturbations to 10-meter accuracy. Make microwave radar measurements. Make laser altimeter and retroreflector measurements.

Apollo Accomplishments. S-band transponder measurements had been scheduled on Apollo 17, 18, and 19. Earth transmitter, 2106 MHz, transponder, 2287 MHz measure librations, variations in earth rotation rate, and earth-moon distance.

Remaining Requirements. Measure perturbations in lunar motion at lunar surface sites for purpose of selecting location for large radiotelescope.

3.3.4 Bioscience

Subobjectives

BI-1 Determine the existence of viable life forms or dormant spores

BI-2 Evaluate the lunar environment for survival of terrestrial microorganisms and the amount of forward/backward contamination

BI-3 Determine the effect of lunar environment on the behavior and rhythms of plants and animals

BI-4 Determine genetic effects of lunar conditions and earth/moon trips on plants and microorganisms.

Rationale for Selection

The subobjectives selected for implementation in this discipline are those which compare the effects of the lunar environment with those of the terrestrial environment on imported typical terrestrial life forms. In addition, a search for viable intrinsically lunar life forms has been retained although early results from Apollo 11 and 12 have been negative. The former type of study (comparison of terrestrial versus lunar effects) is far more likely to produce positive results and will clearly establish a new data point in the study of processes which are known to be of interest. Again, the selected subobjectives represent a summary of the recommendations of the referenced studies.

Observation Requirements

BI-1 - Determine the Existence of Viable Life Forms or Dormant Spores

This topic was suggested by NAS, Woods Hole, Falmouth, Extended Lunar Exploration (ELE), Santa Cruz, and IITRI.

Although the lunar samples to date have not yielded any life forms, samples have not been taken from deep within the moon, and samples remain to be taken from high latitudes (above and below the +40-degree latitude covered by Apollo). IITRI identifies the measurements as $\overline{C}O$ at 200, N_2 at 150, H_2 at 40 to 50, Alkane at 0.1, and Porphyrin at 0.1. All of the values are in parts per million except Porphyrin which is per billion.

Falmouth estimates that the physical presence of 10^{-6} grams in 1 kilogram of lunar samples can be detected. Falmouth also identifies nucleosides, bases, sugars, liquids, and hydrocarbons as candidate observables. All of the previously mentioned constituents require surface samples.

Each sample area will basically be performed from the viewpoint of a unique, initial sampling. The areas to be sampled will have been selected for their distinguishing characteristics; therefore, each sample will be examined and will require examination for such constituents.

Corliss identifies three observables that should be monitored to aid the definition of life; namely, metabolism, reproduction, and isolation (mutation).

BI-2 - Evaluate the Lunar Environment for Survival of Terrestrial Microorganisms and the Amount of Forward/Backward Contamination

Contamination of the moon by man or his effects will be a continuing problem during lunar exploration. The influence of propulsion combustion of the orbiting/arriving/departing spacecraft is presented in the atmosphere section. Propulsive combustion due to the tug (lunar logistics tug) will certainly modify the immediate vicinity of the tug. Microbial contamination will follow man on the moon to some degree. Determination of the modification of the lunar surface by both types of contamination is required, on a continuing basis, to enable positive identification of the true lunar material. Santa Cruz recommends the use of the optical rotary dispersion and stable isotope ratio for contamination measurement. Apollo contamination measurements are performed through the ALSEP Mass Spectrometer and primarily indicate the rate of loss of the contamination in the landing area. Distribution of the contamination will enable selection of the correct samples. Apollo also evaluates a common astronaut strain and the effect of the lunar environment on spores of bacteria, fungi, higher plant forms, and their progeny. Apollo does not evaluate on the basis of exposure to one full day; therefore, this experiment should be continued to perform that evaluation.

BI-3 - Determine the Effect of Lunar Environment on the Behavior and Rhythms of Plants and Animals

Suggested by the ELE/LESA to determine the effect of the longer duration day-night cycle on plants and animals. Apollo is not conducting any experiments along this line. LESA recommends such studies to support the aspect of growing plants on the moon for the purpose of growing food during later expeditions. The overall purpose is to identify the effect of the light/dark cycles in combinations with the associated environmental factors. Requires plant cultivation for evaluation. The response of mice and owls to the lunar environment is measured by comparison with earth-bound control group to identify any subtle change induced by their presence on the moon.

BI-4 - Determine Genetic Effects of Lunar Conditions and Earth-Moon Trips on Plants and Microorganisms

Suggested by ELE/LESA to investigate the effects of additional ionizing radiation received, and the possible genetic effects of the vibration/acceleration to which the cells will be exposed during the trip. The search is for chromosome changes which have occurred in the earlier phases of the plant life; and gene mutation, which is generally evidenced by a shortcoming of chlorophy development. LESA recommends these comparison tests be performed on earth. It is necessary to establish a procedure for identifying the forward/backward mutations, but eliminating the mutation similating phenomena. Apollo is not experimenting along this line, thus the entire area remains open.

3.3.5 Aerospace Medicine

Subobjectives

AM-1 Determine the effect of the reduced magnetism on the body rhythms

AM-2 Determine the effect of the reduced gravity on man

AM-3 Determine the effect of the combined isolation and modified gravity and atmosphere on man's psychological health

AM-4 Verify the effect of the lack of atmosphere on man's vision

Rationale for Selection

The primary objective supported by the biomedical discipline is AM-4, evaluating and extending man's capability in space and his ability to explore other planetary bodies.

Selection criteria were based upon the differences between the moon environment and that of earth. Gravity and atmosphere are apparent differences; the reaction of man to them is understood for short durations, but leaving the question of the extrapolation of these results to the longer durations of later planetary studies unanswered. Readjustment of man to those environments of earth after being elsewhere (the moon) also is not answered. The effect of magnetic differences (earth and moon) has not been determined and is amplified within as the first subobjective. The effect of the differences in atmospheres requires evaluation of vision effects in addition to the physiological effects mentioned earlier. Therefore, the combination of the environmental differences (between moon and earth), with the primary objective of man's capability, generate the subobjectives previously listed.

Differences in radiation levels have not been included since it is agreed that effects due to combination of radiation -- weightlessness can be investigated in single environment levels -- radiation or weightlessness and then combined. Rules for combination do not seem to be available.

Observation Requirements

AM-1 - Determine the Effect of the Reduced Magnetism on Body Rhythms

Physiological and psychological observations of man in the reduced magnetic field of the moon is required to verify or qualify the Larmar

Theorem which offers the theory that motion of the human body within the earth's magnetic field imparts a precession of 2000 cps to all H_2 nuclei in the human body, thereby providing spatial clues which the human has become accustomed to physiologically and psychologically.

The "Compendium" continues to mention a study of six men in a reduced magnetic field that is less than 50 gammas, five incurred significant alterations in scotopia (vision in dim light, dark adaptation) critical flicker fusion and lightness discrimination. However, another study (14 days) of two men in a field of about 50 gammas showed no abnormal responses in physiological or psychological effects.

Thus, no definite trends may be concluded from such sparse data and investigations. The lack of an atmosphere in space presents adaptation difficulty to the eye; since there is no atmosphere to diffuse light, the shift from light to shade and shade to light is more pronounced. If the trend of "scoptopia" were to persist toward degradation then rapid changes from light to dark would have to be avoided to prevent disorientation of the individual.

Critical flicker fusion level is measurable in the individual by monitoring physiological data.

1. The flicker fusion effects should be investigated for its relationship to low magnetic fields.

2. The duration of any changes should be determined.

3. The relationship of flicker fusion (if any) to dark adaptation should be determined.

4. Combined effects of partial g - low magnetic field on flicker fusion should be determined.

Vision protection is being evaluated during the Apollo program by experiments in biomedicine in the area of surface reflections (IR and UV ranges).

AM-2 - Determine the Effect of Reduced Gravity on Man

The effect of the reduced gravity on man requires definition to evaluate man's adaptiveness to the partial g of the moon for application to the Mars and planetary programs. These areas are of interest because man is a participant in the plan for planetary/space research. The rationale is to assure that the projected plans for long-duration manned planetary missions will not induce unknown disability. The rationale takes advantage of the presence of man in the shorter missions to accumulate data which will assure his capacity or identify protective means.

Apollo is contributing to this objective for short stay times on the moon or in its locale by television monitoring of the surface crew to observe agility/dexterity, metabolic rate assessment, inflight aerosol analysis, pre- and post-flight and biomedical operational measurements.

The division of investigation falls into the duration categories of the OLS and LSB. Man's adaptability to intermediate length missions on the surface will certainly be established prior to the activation of a surface base program. This will lead to the inference that man's responses will lie between zero-g and 1-g. Man's recovery is a logical supplement to this area.

AM-3 - Determine the Effect of the Combined Isolation and Modified Gravity, Atmosphere on Man's Psychological Health

This area has been selected because of the combination of isolation and a foreign environment. Data observations will be directed toward correlation of the observed data with the isolation data acquired during earthbound tests. Tests will be paper and pencil, supplemented by television observation from earth.

Apollo has and will have performed observation of the astronauts during the lunar surface activities. Crew sizes up to 5 or more present situations as follows:

Crew size 2 - limited social interaction combined with interpersonal overexposure in irritability and friction

Crew size 3 - problem of two versus one split, minority is isolated but majority is not sufficient to dominate

Crew size 4 - no problem if authoritarian structure is maintained; otherwise, two versus two, three-to-one brings high pressure on the minority

Crew size 5 or greater - acceptable except with increase size, management role, communications, and structure assume importance

AM-4 - Verify the Effect of the Lack of Atmosphere on Man's Vision

This study is selected because of dark adaptation and object discrimination difficulties in atmosphereless environment. Dark adaptation requires 30 to 45 minutes while light adaptation requires only 3 or 4 minutes. Their shadows will complicate the individual tasks required outside the surface base. Discrimination is aggravated; for example, the sun view of the astronauts can appear as a point in the lunar environment.

Apollo is investigating vision effects for the purposes of protection from the IR-UV reflected radiation. Additional evaluation of discrimination per se is being performed in simulation tests within vacuum chambers in the earth's environment.

The validity of the earth tests is to be verified by lunar testing.

3.3.6 Lunar Atmosphere

Subobjectives

LA-1 Determine the total quantity and distribution of the component species of the lunar atmosphere

LA-2 Determine the principal natural atmosphere source, loss and transport mechanisms, and their rates

LA-3 Monitor atmospheric contamination resulting from lunar missions, including transport and escape rates

Rationale for Selection

There are several areas of lunar study to which data concerning the lunar atmosphere would be applicable. It is important in investigating the suggestion that noble gases, carbon dioxide, carbon monoxide, hydrogen sulfide, ammonia, sulphur dioxide and water vapor may be released by lunar volcanism and from rocks and magma. Other proposed mechanisms of release of gases from the surface; e.g., solar wind bombardment, perhaps can be affirmed knowing what the effluent gases are. Likewise, data on released gases will certainly afford some knowledge of the chemical processes underlying the lunar surface. Location of areas of released gases are related to the selenological structures in these areas.

The firing of tug engines would be a good example of a known point source of gas on the lunar surface. The rate of spreading of this gas cloud from the source around the moon can be studied from surface and orbit and diffusion rates for the various gases calculated. Also, the escape rates of gases of various molecular weight can be determined. Some of the gases from the rocket will be absorbed on the lunar surface materials, so the outgassing rates of these absorbed gases can be measured. From this information, the amount of contamination of the lunar atmosphere caused by the firing of rocket motors, both past and future, near the surface could be estimated.

Another significant problem is related to transport processes in planetary exospheres. The exosphere of the earth, and that of almost any other planet, is bounded by a dense atmosphere, in which hydrodynamic wind systems complicate the problem of specifying appropriate boundary conditions for exospheric transport. This contrasts sharply with the situation in the lunar atmosphere, which is entirely a classical exosphere, with its base the surface of the moon. Therefore, the lunar exosphere should be amenable to accurate, analytical study, and experimental determination of the global distributions of lunar gases can provide a reasonable check on theory, giving confidence to the application of theoretical techniques to transport problems in the terrestrial exosphere.

There is some evidence for the release of gases, at least sporadically, from the lunar interior. Middlehurst (1967) has summarized the visual evidence for color changes at specific locations on the lunar surface. These are interpreted as luminescence associated with gas release. About 400 cases have been observed, with maximum activity in the vicinity of Aristarchus. The best presumption is probably that the composition of the released gases is similar to volcanic gas on earth.

Although not much gas can be expected on the moon, any identifiable gases of internal origin will be important from a geochemical viewpoint. They should provide clues to the internal composition of the moon and, hence, possibly to its origin.

Observation Requirements

LA-1 - Determine the Total Quantity and Distribution of the Component Species of the Lunar Atmosphere

Santa Cruz.

Total pressure -- sensitivity to 10^{-15} torr, surface up to altitudes of 60 kilometers

Neutral mass spectra - mass range 1 -- 150 atomic mass units (amu), resolution 1 amu, sensitivity 10 particles per cm^3

IITRI. Mass spectra and total pressure (not quantitatively defined)

Falmouth. Total pressure and mass spectrum of neutrals; sensitivity of 10^{-15} torr

LA-2 - Determine the Principal Natural Atmosphere Source, Loss and Transport Mechanisms, and Their Rates

Santa Cruz. Concentration, flux, and mass spectrum of low energy ions, mass range 1 to 150 amu, resolution 1 amu, sensitivity 10 particles per cm^3, surface to altitudes of 100 kilometers. Provide triangulation capability to locate sources. Measure directed flux of neutral species. Detect and analyze subsurface gas up to molecular weight 150.

IITRI. Neutral particle fluxes, sensitivity one particle per cm^2-sec, energy range 0 to 10 kev, resolution 10 percent in flux and energy.

Falmouth. Total concentration, mass spectrum and directed flux of ions; instruments must be capable of operating with concentrations as low as 10 particles per cm^3.

National Academy of Sciences (in "Lunar Exploration, Strategy for Research 1969-1975"). Detect transient gas releases of such species as H_2O, NH_3, CH_4, N_2, H_2, O_2, and CO (no quantitative requirements).

LA-3 - Monitor Atmospheric Contamination Resulting from Lunar Missions, Including Transport and Escape Rates

Santa Cruz. Monitor vicinity of landing site up to 10 days after landing. Species of interest are H_2O, CO, CO_2, N_2, H_2, OH, and NO. Monitor controlled releases of specific volatiles with sensitivity to 10 particles per cm^3.

Falmouth. Contamination monitoring for several months. Measure diffusion and retention times for rocket exhaust gases in lunar surface.

Since the consensus observation requirements, Apollo accomplishments and remaining (post-Apollo) requirements are closely related in this discipline, they are listed below undifferentiated by subobjectives. All measurements listed support each of the Lunar Atmosphere subobjectives.

Consensus Observation Requirements

Total pressure of neutrals with sensitivity sufficient to detect total pressures down to 10^{-15} torr.

Mass spectra of neutrals whose concentration exceeds 10 particles per cm^3, with capability for isotopic abundance detection to atomic mass 150.

Directed flux of neutrals with capability of detecting direction of motion to ± 10 percent for fluxes of 1 particle/cm^2-sec.

Variation of above parameters to be detected on global and local scales as a function of height above surface, absolute surface position and position relative to sun.

Concentration, mass spectrum, and flux of low energy ($<$ 1 ev) ions (higher energy ions included under Particles and Fields discipline).

Apollo Accomplishments

Mass spectra of neutral particles will be obtained from 60-kilometer circular orbit on Apollo missions 16 and 17 (Experiment S-165).

Total pressure will be measured at the landing site with a cold cathode gauge on Apollo missions 14 and 16 (Experiment S-058). Mass spectra of neutrals will be obtained at the landing sites of Apollo missions 18 and 19 (Experiment unnumbered). Flux, number density, and mass and energy per unit charge of positive ions will be measured at the landing sites of Apollo 12, 14, and 15 (Experiment S-036).

The orbit experiment, S-165, obtains data in the mass range of 12 - 66 amu with an ultimate sensitivity of 10^{-13} torr.

The total pressure gauge, S-058, will be emplaced at the sites Frau Mauro and Davy Crater Chain. Its dynamic range is 10^{-6} to 10^{-12} torr.

The mass spectrometer is a candidate for emplacement at two sites to be selected from Marius Hills, Descartes, Copernicus, and Hadley-Apennine. (These are the current prime sites for Apollo missions 16 through 19, but the order of flight has not been selected. It should also be noted that the surface experiment complement for Apollo missions 16 through 19 has not been fully approved as of this date.) The mass range is 1 to 150 amu with resolution capable of detecting isotropic abundances throughout this range. It is sensitive to partial pressures as low as 10^{-14} torr. The suprathermal ion detector, S-036, detects nearly thermal positive ions (0.2 to 48.6 ev) and analyzes their masses to 120 amu (higher energy particles are also detected).

Remaining Requirements

Apollo measurements do not meet the consensus observation requirements in the following areas:

1. Neutral Atmosphere

   a. Measurement sensitivity - Apollo surface total pressure gauge sensitivity limit is 10^{-12} torr. Consensus requirement is 10^{-15} torr (approximately 40 particles per cm^3).

      Orbit mass spectrometer sensitivity is 10^{-13} torr; surface mass spectrometer sensitivity is 10^{-14} torr.

      Consensus requirement is 10^{-15} torr in both cases.

   b. Mass spectrum range and resolution - Apollo surface experiment adequate. Orbit experiment range 12 to 66 amu falls short of the required range of 1 to 150 amu. Orbit experiment resolution is adequate.

   c. Coverage and duration - Orbit experiment coverage marginally adequate to detect day-night variations at low latitudes with fair statistics. Range of altitudes and inclinations must be expanded. Surface experiment very inadequate for monitoring natural transient gas sources.

   d. Other - All orbital experiments will be concluded before emplacement of surface mass spectrometers; therefore, no correlated surface and orbital measurements of mass spectra can be made. No directional measurements are planned.

2. Ions

   The capability of the suprathermal ion detector seems adequate for most applications. Direct ionospheric sensing from low orbit remains to be performed as does coordinated simultaneous measurement for several sites. Directionality of the ionic flux also remains to be determined.

3.3.7 Particles and Fields

Subobjectives

PF-1 Study the interaction of the solar wind with the moon

PF-2 Study the fundamental physics of plasma interactions

PF-3 Determine the magnetic and electric fields around, on, and within the moon as modified by the relative positions of the earth and the sun

PF-4 Measure the primary and secondary nuclear particles in lunar space and at the surface of the moon

Rationale for Selection

PF-1 - Interaction of Solar Wind with the Moon

There has been considerable speculation as to whether or not the interaction of the solar wind with a lunar magnetosphere would be observable just as is the interaction of the solar wind with the geomagnetosphere, which the latter is compressed toward the earth in the solar direction and elongated into a tail in the anti-solar direction. Because the lunar magnetic field is so much smaller than that of the earth, a similar bow shock and magnetosheath region may not be observable. Estimates of the position of this lunar magnetosheath in the solar direction have ranged from standoff distances at the surface to 600 kilometers above the surface. The evaluation will require both orbital and surface measurements.

The passage of the moon through the tail of the geomagnetosphere and the modification of the solar wind flux and magnetic field in the vicinity of the moon during this event is also of considerable interest. Also, there has been some conjecture as to whether a few charged particles originally associated with the moon become trapped in the geomagnetosphere and find their way eventually to the vicinity of the earth.

The solar wind radiation damage effects on natural lunar surface materials, as well as on artificially introduced samples in the ambient lunar vacuum, is of continuing scientific and technological interest and will shed light on lunar evolution and space radiation effects on engineering materials.

PF-2 - Fundamental Physics of Plasma Interactions

Observations of the interplanetary plasma from the surface of the moon have advantages over those made from a moving spacecraft, wherein the latter there is difficulty separating the spatial from the temporal effects. So far, limited measurements near the lunar surface have not revealed a bow shock caused by the interaction of the solar wind with the lunar magnetosphere. Thus far, measurements of the lunar magnetic field have yielded only extremely small values (the order of a few gammas).

The moon provides a unique place from which to study a collisionless plasma; i.e., one in which the collision-mean-free path (approximately 10^7 kilometers) is much greater than the cyclotron radius (approximately 10^3 kilometers), and the collision period (approximately 10 hours) is large compared to the time scale for phenomena of interest. No such plasma experiments can be formed in a laboratory on earth because the dimensions of the vacuum chambers would not be large enough.

Of further interest will be a comparison of the properties of the relatively slow moving plasma within the geomagnetic tail as the moon swings through it compared to the properties of the solar wind which moves at least an order of magnitude faster with respect to the moon.

PF-3 - Magnetic and Electric Fields

Because the magnetic fields in interplanetary space are quite small and expected to vary, particularly at times during which interesting phenomena are occurring (such as during periods of high solar activity or passage of the moon through the geomagnetic tail), there is an obvious advantage to having simultaneous measurements from numerous symmetrically placed points in lunar space and on the lunar surface. The measurement of magnetic fields is essential to the understanding of the propagation of charged particles in the vicinity of the moon, and to the composition and past history of the lunar interior.

The electric field measurements in the vicinity of the moon are essential for the understanding of the interaction of the solar wind with the moon, the conductivity of the interplanetary plasma and acceleration processes occurring within the plasma. Electric fields as large as 1 volt/meter may arise in connection with the shock front formed by the encounter of the interplanetary plasma and the moon. In the cases where a shock is not formed, electric field data would help explain the rapid convection of magnetic fields through the moon.

PF-4 - Primary and Secondary Nuclear Particles

Solar particles above solar wind energies, primarily in the 10's of kev range up to 1 Mev, are of interest because they may also participate, as well as the solar wind, in the formation of the as yet unobserved bow shock at the moon. Such a shock might arise for conditions not prevailing thus far, e.g., during Explorer 34 measurements.

Higher energy solar particles may be measured at the lunar surface and compared with partially geomagnetically shielded fluxes arriving simultaneously in the vicinity of the earth. These measurements would give some insight into the spatial distribution of solar flare particles. The directionality of these particles will be of continuing interest in the explanation of propagation mechanisms. A comparison of fluxes on the solar and antisolar sides of the moon would be of interest.

Secondary nuclear particle detection and analysis near the lunar surface or beneath the surface may provide insight into lunar interior composition and evolution.

Simultaneous front and backside measurements of galactic flux would yield information on departures from isotropy of fluxes and effects of the interplanetary magnetic field on the low-energy end of the spectrum.

Observation Requirements

PF-1 - Study the Interaction of the Solar Wind with the Moon

Santa Cruz. Collect data concerning the lunar magnetic field, gross conductivity, distribution of conductivity, and interior temperature.

IITRI.

Differential energy flux: 10^5 - 10^{11} particles per cm^2-sec-steradian kev

Energy range: 1.2×10^2 - 5×10^3 ev/protons

3 - 3×10^2 ev/electrons

Measurement accuracy: ±2 percent in flux and energy

NAS.

2.5×10^8 per cm^2-sec

From propagation of solar wind magnetic field transient through moon, lunar interior temperature inferred to be 800 C

Measure Kr and Xe content of surface materials

Analyze precise photography of topography shaded from solar wind

Other.

Analyze erosion of surface layer by solar wind and compare with lower layer

10^8 - 10^9 per cm^2-sec

0 - 2×10^4 ev

Consensus.

Measure solar wind distribution in space and on surface around moon simultaneously

10^7 - 10^{10} per cm^2-sec
10^2 - 2×10^4 ev

Measure directionality

Compare properties of their lunar surface layers eroded by solar wind and lower layers.

Apollo Accomplishments. Heavier ion content of the solar wind determined on Apollo 11 and 12 on the lunar surface. Solar wind proton and electron spectral ($1 \leq E \leq 40$ kev), direction, and time variation on surface on Apollo 12 and 15.

Remaining Requirements. Simultaneous high and low altitude and surface measurements of solar wind flux in energy and direction as moon passes through geomagnetic tail at symmetric points in space and on lunar surface (e.g., at pairs of equatorial stations located at ± 60 degrees to the earth-moon line).

PF-2 - Study the Fundamental Physics of Plasma Interactions

Santa Cruz. Measure plasma angular distribution in 2 orthogonal planes and energy distributions in 1 to 5 seconds.

NAS. Measurement of large scale MHD flow in solar system (e.g., around moon) may cast light on early solar system evolution.

Other. Search for formation of bow shock at the moon (thus far not observed; may be none).

Compare fluxes in plasma sheets behind earth and moon with incident solar plasma.

Consensus. Same as for PF-1.

Apollo Accomplishments. Plasma angular distribution measured in one plane and energy distribution measured in 10 to 20 seconds on Apollo 20. Pioneer and AIMP recommended for F1, F2, F3 and F4 in early 1970's.

Remaining Requirements. Provide resolution times of 1 to 5 seconds for energy and angular distribution in two orthogonal planes.

PF-3 - Determine the Magnetic and Electric Fields Around, On, and Within the Moon as Modified by the Relative Positions of the Earth and the Sun

Santa Cruz. Measure magnetic fields simultaneously at 2 equatorial stations at ± 60 degrees to earth-moon line and subsequent at 3 equatorial stations 120 degrees apart and at one high latitude station with simultaneous orbital measurements.

Magnetic fields: 0 to 100 gammas ± 0.1 gamma

Frequency response: 0 to 20 kHz

Sample frequency: > 1 per second

Electric fields: 10 to 10^2 volts/meter

Frequency response: 1 to 10^4 Hz

Sensitivity: < 1 millivolt/meter

IITRI. Relate measured magnetic anomalies with mascons revealed by gravity measurements P.1.

0.01 - 100 gammas $\pm$0.01 gamma or 0.5%
0 - 20 kHz

NAS.

2 - 8 gammas

Consensus.

0.5 - 100 gammas $\pm$ 0.1 gamma
0 - 20 kHz
Sampled at 1 per second

Apollo Accomplishments. Magnetic field measurements on the lunar surface on Apollo 12, 15 and 16. Electric field measurement on lunar surface on Apollo 19.

Remaining Requirements. Measure magnetic fields simultaneously on lunar surface at equator on earth-moon line at $\pm$60 degrees, and subsequently at 3 equatorial stations 120 degrees apart and at one or more high latitudes with nearly simultaneous orbital measurements; e.g., 1 equatorial and 1 polar orbit. Measure electric fields in the range of 0.5 to 100 $\pm$ 0.1 gammas, 10 - 10^2 volts/meter.

PF-4 - Measure the Primary and Secondary Nuclear Particles in Lunar Space and at Surface of Moon

Santa Cruz.

Low-energy solar particles (above plasma energies) 10^4 - 10^6 ev
Particles may be accelerated by shock waves
High-energy solar particles
High-energy galactic particles

IITRI.

Secondary charged particles from lunar surface: 0 - 10^3 per cm^2-sec
All directions
Resolution: $\pm$10 percent in energy and flux
1 ev - 500 Mev

Other.

10^2 - 10^5 per cm^2-sec

5×10^6 - 5×10^8 ev protons

10^7 - 10^{10} ev electrons

Consensus. Surface measurements and orbital measurements should be made of primary particles and surface measurements of secondary particles in the 10^4 - 10^6 ev range. Primary particle fluxes up to 10^{10} per cm^2-sec, and secondary fluxes up to 10^4 per cm^2-sec should be measurable.

Measure protons 3×10^5 - 5×10^8 ev, electrons 5×10^4 - 5×10^7 ev as a function of direction with ± 10 percent resolution in energy and flux.

Measure galactic nuclei flux 1 - 20 per cm^2-sec, 5×10^8 - 10^{10} ev ± 20 percent resolution. Discriminate from solar flux.

Apollo Accomplishments. Particles and fields subsatellite on Apollo 19 will measure 2.5×10^4 - 2×10^6 ev protons and 2.5×10^4 - 3.2×10^5 ev electrons. Will search for boundary layer at low altitude (approximately 100 kilometers).

Lunar surface measurements of solar protons and electrons are to be made on Apollo 17 and 19.

Cosmic ray detector will be operated at lunar surface on Apollo 16 and 18.

Remaining Requirements. Search for boundary layer of interaction of low-energy particles and moon (or lunar magnetosphere) with subsatellite probes measuring fluxes as on Apollo 19 and lower energies at low altitudes from 10 kilometers to 300 kilometers.

Make lunar surface measurements in antisolar and solar direction of incident charged particles during solar particle event and compare.

Conduct galactic particle flux measurements at antisolar location on lunar surface. Discriminate from solar particle influence.

3.3.8 Geodesy/Cartography

Subobjectives

- GC-1 Establishment of a three-dimensional geodetic control system over the entire lunar surface in terms of latitude, longitude, and height above the chosen reference figure
- GC-2 Collection of photogrammetric data and construction of topographic maps for scientific purposes and base site evaluation studies

Rationale for Selection

The selected Geodesy/Cartography subobjectives reflect the limited scope assigned arbitrarily to this discipline. Most physical geodesy (e.g., the determination of the large-scale lunar gravity field) was assigned to the geophysics discipline. However, the activities required to implement these subobjectives are among the most important and most universally recognized in the lunar exploration program. They result in the basic matrix against which most other physical data will be displayed for the determination of geographical trends. In addition, the scale of activity being considered for the lunar surface base, coupled with unique communication and navigation problems to be encountered on the lunar surface, makes top quality maps of such areas indispensable.

Observation Requirements

GC-1 - Establishment of a Three-Dimensional Geodetic Control System Over Entire Lunar Surface in Terms of Latitude, Longitude, and Height Above Chosen Reference Figure

Falmouth 1965.

Metric photography (6-inch focal length 9 x 9 format)
(For 10-meter tolerance) precision = 1 pt in 200K

Radar or laser altimetry

Lifetimes of several months

Stellar observation from ground stations

Absolute gravity measurements

Control grid

3D accuracy of ±100-meter

Vertical accuracy of ±10-meter (1 sigma)

Photogrammetric triangulation orbital dynamic supplemental control

Woods Hole 1965.

Lunar orbit metric photography, controlled from orbit parameters, and orientation and radar altimetry

USGS No. 19 1970.

Film return, wide angle (60 degrees to 90 degrees) metric photography

Time and stellar photography coupled

Radar altimetry

Santa Cruz 1967.

Stellar observation/photography from ground stations

Absolute gravity measurement

Metric with stellar photography: 6-inch focal length resolution 10-meter or 12-inch resolution 6-meter

Laser altimetry

IITRI 1966, 1970.

Metric photography - resolution 2 meters

Consensus. Metric photography, 6-inch focal length in conjunction with stellar photography and precise timing and radar or laser altimetry.

Apollo Accomplishments. Three-inch focal length Fairchild metric camera to fly on Apollo 16 through 19. Includes simultaneous stellar photography and altimetry.

Remaining Requirements. Metric photography with simultaneous stellar photography, precise timing, and laser altimetry. Polar orbit; ground observations to include absolute gravity measurements, stellar photo, and surface triangulations to 1-inch accuracy. Geodetic grid accuracy of ±100 meters, ±10 meters vertically.

In deference to Santa Cruz recommendations, Apollo accomplishments will not significantly affect overall geodetic program for they will be limited to equatorial zone, whereas OLS mapping should be from polar orbit.

Absolute gravity measurements are important in establishing the geodetic grid. Ground-based measurements should be performed with an absolute gravimeter.

GC-2 - Collection of Photogrammetric Data and Construction of Topographic Maps for Scientific Purposes and Base Site Evaluation Studies

Falmouth 1965.

Base maps for geology, 1:250,000 entire surface, locally at 1:25,000

Accuracy ±10 to ±100 meters

Woods Hole 1965.

Topo base maps of scales of 1:1,000,000, 1:250,000 and locally 1:100,000

USGS No. 19 1970

Adopts Santa Cruz requirements

Santa Cruz 1967.

Base maps for geologic mapping:

1:5,000,000; 1:1,000,000 complete coverage
Special areas at 1:250,000; 50,000; and 5,000

HR photography, 1-meter resolution

Orthographic, mercator and polar stereographic projection

IITRI 1966, 1970.

Metric photography - resolution 2 meters
High-resolution photography - resolution 0.5 meter

Consensus. Metric photography as previously mentioned. Maps required scales of 1:1,000,000; 1:250,000 and 50,0000 of special areas.

Apollo Accomplishments. Three-inch metric photography (previously mentioned). Nonmetric high-resolution photography, 24-inch focal length to photograph selected sites on Apollo 16 through 19 missions.

Remaining Requirements. Metric photography as previously mentioned. Photogrammetric construction of base maps, complete surface coverage at 1:5,000,000 and 1:1,000,000. Local coverage at 1:250,000, 1:50,000 and 1:5,000. Supplementary 24-inch photography required for feature interpretation.

Consistent and metrically accurate mapping program will await determination of geodetic grid with $\pm$100-meter accuracy and $\pm$10-meter vertical accuracy of stations.

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4.0 SCIENTIFIC SUPPORT REQUIREMENTS

4.1 INTRODUCTION AND SUMMARY

In this section the scientific support requirements of the OLS are developed. Experiments for each observation requirement of the discipline subobjectives presented in Section 3.0 are synthesized. Criteria to select either orbital or lunar surface operations for the conduct of the experiments are formulated. The criteria are as follows:

1. The nature of the experiment
2. Ground-to-orbit correlation requirements
3. Precision and scale of the measurement
4. Required environment for the experiment

The original list of experiments totaled 116. Commonality of operations and equipment permitted a reduction in the number of experiments to 69. Application of the orbit/surface selection criteria resulted in the identification of 53 surface experiments and 16 orbital experiments. Table 4-1 summarizes the orbital experiments and the discipline subobjectives that they directly support.

All subobjectives are directly supported by orbital science except Bioscience, Aerospace Medicine, and three of the four Astronomy subobjectives. This is as expected because Bioscience and Aerospace Medicine investigations either require operations on the lunar surface or can be conducted on an earth orbiting space station. Other than using the lunar horizon from orbit in occultation procedures, all astronomy investigations can be conducted with significantly improved performance from the lunar surface.

A lunar surface program model is developed. Site distributions are analyzed and a list of 24 potential scientific exploration sites are presented. Three of these sites are developed into sortie missions and the required scientific equipment is identified in order to establish a realistic payload/logistics model for OLS support operations. A surface scientific payload of 2000 pounds per sortie, including support equipment, is defined as the nominal.

Orbital scientific activities are investigated in more depth because of their direct interface and impact on the OLS. The 16 orbital experiments are evaluated for compatibility with the potential OLS environments of contamination, acceleration, attitude/stability, electromagnetic interference, orbit and safety. This analysis indicated that 8 of the experiments could be incorporated in the OLS. The remaining 8 experiments are accommodated on three free-flying subsatellites in the preferred mode. Several of these could be accommodated on the OLS with some degradation in performance. Table 4-2 summarizes the accommodation of the orbital experiments.

Table 4-1. Subobjectives and Supporting Orbital Experiments

Subobjectives		Orbital Experiment	
AY-6	Resolve radio and optical observations of solar system sources	5027	Radio interference from earth
GG-1 through GG-8	All geology and geochemistry subobjectives	5002	Orbital geological mapping and analysis
GG-2	Determine physical, mineralogical, and chemical properties of lunar materials	5006 5017	Petrographic and mineralogic identification and analysis Remote geochemical analysis
GG-8	Locate geologically favorable sites for advanced lunar exploration/exploitation scientific facilities	5016	High-resolution mapping of selected sites
GP-1	Determine lunar mass distribution	5020 5028	Spacecraft orbital perturbations Gravity gradient
GP-2	Determine physical state and composition of the lunar interior	5018	Electrical properties of lunar surface and subsurface
GP-3	Evaluate the lunar internal dynamics	5019	Thermal anomalies and surface structure
GP-4	Determine earth-moon mechanical interactions	5020	Spacecraft orbital perturbations
LA-1	Determine the total quantity and distribution of the component species of the lunar atmosphere	5024 5025	Total pressure Composition of lunar atmosphere
LA-2	Determine principal natural atmospheric source, loss, and transport mechanisms and their rates	5026	Escape and transport rates in lunar atmosphere
LA-3	Monitor atmospheric contamination resulting from lunar missions, including transport and escape rates	5024, 5025, and 5026	
PF-1	Evaluate solar wind-moon interaction	5021 5023	Solar wind and energetic particles Electric fields
PF-2	Evaluate fundamental physics of plasma interactions	5021, 5023	
PF-3	Determine magnetic and electric fields	5022 5023	Magnetic fields Electric fields
PF-4	Measure lunar particle environment	5021	Solar wind and energetic particles
GC-1	Establish a three-dimensional geodetic control system of the lunar surface	5013	Geodetic grid construction and topographic mapping
GC-2	Collect photogrammetric data and construct topographic maps	5013	Geodetic grid construction and topographic mapping

Table 4-2. Orbital Experiment Accommodation

Experiment		Accommodation	
		OLS	Subsatellite
5002	Orbital geological and mapping	X	*
5006	Petrographic and mineralogic identification and analysis	X	
5013	Geodetic grid construction and topographic mapping	X	
5016	High-resolution mapping of selected sites	X	
5017	Remote geochemical analysis		X**
5018	Electrical properties of lunar surface and subsurface	X	*
5019	Thermal anomalies and surface structure	X	
5020	Spacecraft orbital perturbations	X	
5021	Solar wind and energetic particles		X**
5022	Magnetic fields		X**
5023	Electric fields		X**
5024	Total pressure		X
5025	Composition of lunar atmosphere		X
5026	Escape and transport rates in lunar atmosphere		X
5027	Radio interference from earth	X	
5028	Gravity gradient		X

* Dipole antennas and receivers only

** Could be accommodated on OLS with some degradation in performance

The equipment required to conduct the orbital experiments, including laboratory facilities and subsatellites, is identified on descriptor sheets. The data includes weight, power, volume, consumables, guidance and control, data, command, and environmental requirements and characteristics. Three laboratories are identified: geochemistry, data analysis, and photography. Total area required to accommodate these laboratories plus the control center for operation of the experiments is approximately 300 square feet. The total required experiment sensor mounting area normal to the lunar local vertical is 110 square feet. A narrative and a master timeline for each of the orbital experiments, including those incorporated in the subsatellites, are developed. An integrated experiment program plan is developed which combines the characteristics of the equipment with the individual experiment timelines to determine the total OLS experiment support requirements. Power, data handling, and scientific crew skills profiles are presented. Nominal values for all experiment support requirements are summarized.

4.2 ORBIT SURFACE SELECTION CRITERIA

The general approach to this analysis is to assume that all observations that are feasible from orbit will be conducted there, because as a general rule this will result in reduced cost. Those observations selected for implementation on the lunar surface will be driven to that mode by specific requirements making them incompatible with (exclusively) orbital implementation. These requirements generally fall into the following four catgeogries:

1. Nature of experiment - Often there is a specific requirement for the analysis of physical samples of lunar materials or the emplacement of sensors in intimate contact with lunar surface or subsurface material. Examples of the latter include active and passive seismic studies.

2. Ground-orbit correlation - Several observation requirements specify simultaneous measurements to be carried out in orbit and on the surface. These include most experiments in the lunar atmosphere and particles and fields disciplines. In addition, there are requirements for the gathering of so-called ground truth data to support remote sensing experiments such as thermal mapping.

3. Precision and scale of measurement - While certain observations, such as photomapping, clearly benefit from the synoptic view provided from an orbiting vehicle, others are of such a large scale or require such a high precision that orbit observation is impractical. Examples of the former include detailed geologic mapping, particularly of local stratigraphy. The latter include in-situ photography to record alignments of small rocks and microcraters.

4. Environment - The orbit environment is one of zero-g, rapid movement, sensitivity to disturbance forces, etc., whereas the lunar surface is much more stable, slow-moving, one-sixth-g platform. This latter environment is preferred for those astronomy experiments that are appropriate for lunar implementation.

A brief review of the observation requirements of the post-Apollo lunar exploration program, applying the previously mentioned criteria, is contained in the following paragraphs.

Astronomy

Astronomical observations appropriate for the lunar vicinity are those which, by definition, cannot be achieved from the surface of the earth or earth orbit. Such observations can be classified into two major groups:

1. Observations of very faint objects at all wavelengths

2. Observations that would be obscured or otherwise disturbed by the near-earth environment

Faint objects can be observed in both imaging and nonimaging (spectroscopic, photometric) modes. The imaging observations can be conducted using large aperture stable optics in conjunction with image tubes or other electronic intensifiers. The nonimaging observations require long integration times, again from very stable platforms, free from fogging and other background noise.

The near-earth environment is only particularly annoying at long radio wavelengths (plasma cutoffs in the ionosphere, plasmasphere, and magnetosphere), infrared (atmospheric emission), and ultraviolet (upper atmosphere fluorescence, particularly from hydrogen), listed in the order of decreasing levels of interference.

These considerations tend to drive most lunar-based astronomical observations to the lunar surface. The stability and long ($\sim$100 hours) integration time requirements are the drivers for the IR, optical, and high-energy measurements. The long wavelengths of lunar-based radio astronomy (requiring antenna arrays on the order of kilometers in scale) result in a strong preference for surface operation.

Occultation, which is a technique that can improve spatial resolution of radio sources, is quite attractive for certain observations relating to earth radio emissions. The most desirable technique is from lunar orbit where relatively rapid changes in the degree of occulation are possible and repeatable.

Geology and Geochemistry

Geology and geochemistry observations are of the type that neatly divide into synoptic orbital and specific surface types. Small and medium scale geologic mapping is certainly feasible from orbit, with the condition that ground observations are absolutely necessary to resolve ambiguities. An exclusively ground-based program would never get the job done, however. Similarly, global gravity data are best collected from orbit, but detailed surveys of small anomalies require ground traverses. Thermal maps can be made employing an infrared scanner in orbit, but there is no way of separating actual temperature differences from variations in material thermal emissivity unless ground-truth data are collected. The same is true of subsurface sounding - the interpretation of electromagnetic reflection data and radar images cannot be done unambiguously without a distribution of deep core samples.

Only certain elements can be identified with any certainty from orbit; these include radioactive isotopes of U, Th, K, among others, and certain other elements which fluoresce when bombarded by energetic solar particles and X-rays. Geochemical analysis, therefore, definitely requires a sample collection.

Geophysics

Many geophysics observations can be conducted from orbit. These include the determination of the global gravity field, variations in heat flow, and, to some extent, internal structure. Most detailed observations are, by their nature, driven to the surface. These include seismic measurements (both active and passive) of tectonic activity, and other observations conducted on geophysical traverses. In addition, there are requirements to obtain ground-truth data to verify orbital heat flow measurements and near-surface structure. The determination of earth-moon mechanical interactions, such as tidal bulges, requires emplaced absolute gravimeters.

Bioscience

All bioscience observations are driven to the lunar surface by the application of the environment and precision-of-observation criteria. The zero-g behavior of plants and animals will have been thoroughly analyzed in earth orbit; the only remaining requirement will be evaluation at one-sixth g. Those investigations requiring analysis for dormant life forms are unlikely to be accomplished in lunar orbit because of the great sensititivity required; an earth-based laboratory will be required. An incidental measurement of organic molecule content may be made in the OLS laboratory in conjunction with diagnostic mass spectrometry.

The relevant lunar environmental factor, in addition to one-sixth g, is the 28-day light-dark cycle. (While this cycle can be reproduced on earth, the combination of it with one-sixth g cannot.) This is only available to a surface installation. Similarly, it is of interest to determine the effect of the total surface environment on the evolution of micro-organisms for the purpose of determining the probability of survival of an organism if it ever came in contact with the moon. Such an observation is, by its nature, driven to the surface.

Aerospace Medicine

Again, the environment in lunar orbit is very similar to that in earth orbit, so that most orbital measurements related to aerospace medicine will be for the purpose of routine evaluation of the crews' physiological and psychological health. The environment criterion drives most measurements in this discipline to the lunar surface.

Lunar Atmosphere

The ground-orbit correlation criterion applies to all observations in this discipline. Such correlation is a specific requirement for all observations, so that atmosphere escape rates can be measured and gas sources located. Because the lunar atmosphere will always be denser at the surface than at orbit altitudes, it is clear that surface measurements are required to fully establish its composition, particularly the heavy gases whose small scale heights make them undetectable from orbit.

Particles and Fields

In particles and fields study there is a requirement for surface-orbit correlation. Orbital measurements at several altitudes are required to identify the interaction of the moon with the interplanetary medium. The solar wind standoff may be very close to the surface, if there is any standoff at all. The intrinsic lunar magnetic field is so small (less than 40 gammas at the landing site of Apollo 12) that surface measurements are mandatory. Investigations of solar particle effects on lunar materials requires a direct analysis of samples. Observations of the interplanetary and geomagnetic tail plasma from the lunar surface facilitates separation of spatial and temporal variations. An additional advantage of lunar surface particle and fields experiments is the feasibility of long-term (14 days) exposure to the interplanetary environment while being shielded from direct solar radiation.

Geodesy and Cartography

In this discipline, the major activity is carried out from orbit. However for precise mapping of selected areas, ground triangulation will be necessary, because the typical accuracies of such triangulation is 1 inch per measurement, which is unattainable from orbit. Also, absolute gravity measurements necessary to establish a primary geodetic control grid cannot be made from orbit.

4.3 LUNAR SURFACE PROGRAM MODEL

4.3.1 Tug Landing Site Distribution

Tug landing site distributions based on existing data reflect biases remaining from the emphasis placed so far on the analysis of potential Apollo landing sites. It can be expected that future Apollo missions and preliminary OLS reconnaissance will greatly modify any site distribution based on these presently existing analyses. In addition, it is beyond the scope of the OLS study to examine in detail a set of potential tug landing sites because a rough estimate of the number of such sites is 100 to 150.

Therefore, it is proposed that we assign equal exploration value to each unit area on the lunar surface. This differs from the assumptions used in previous analyses for which equal priority was assigned to each interval of latitude. The proposed site distribution probability as a function of lunar latitude is shown in Figure 4-1. This probability is

$$P(\theta) = \frac{1}{A_M}\frac{dA}{d\theta} = \cos\theta$$

where A_M = total surface area of moon

θ = lunar latitude

The site distribution function is thus normalized such that

$$\int_0^{\pi/2} P(\theta)\, d\theta = 1$$

The area under the curve to the right of a given value of latitude represents the fraction of tug landing sites expected above the given latitude (north and south). This is given by

$$\underline{P}(\theta) = \int_0^{\pi/2} \cos\theta' d\theta' - \int_0^{\theta} \cos\theta' d\theta'$$

$$= \int_{\theta}^{\pi/2} \cos\theta' d\theta' = 1 - \sin\theta$$

and is shown in Figure 4-2.

The figure shows that the probability of discovering a desired landing site decreases with increasing latitude. One-half of all landing sites will probably be found between latitudes of ± 30 degrees. It must be recognized, however, that there are very good reasons to expect that the lunar polar regions are worthwhile exploration objectives. Also, these considerations do not apply to the lunar surface base, because there is a much less statistical number of potential sites.

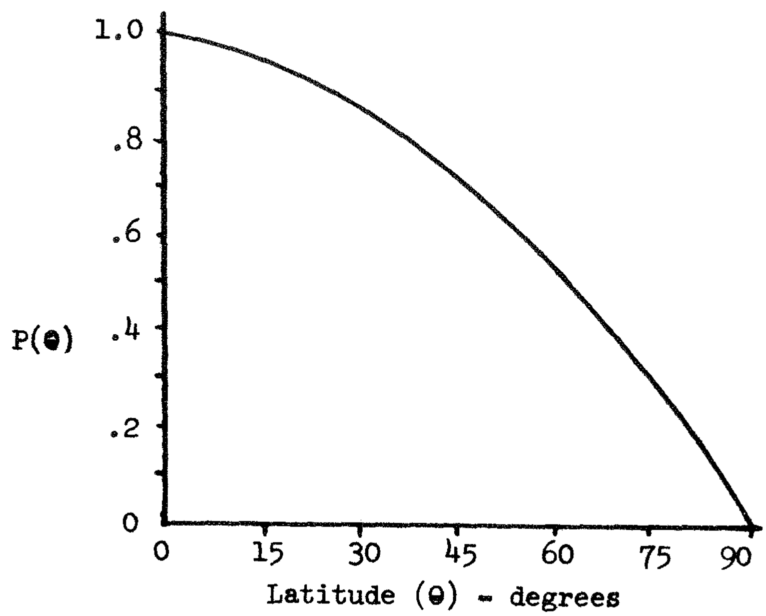


Figure 4-1. Tug Landing Site Distribution Function, P(θ)

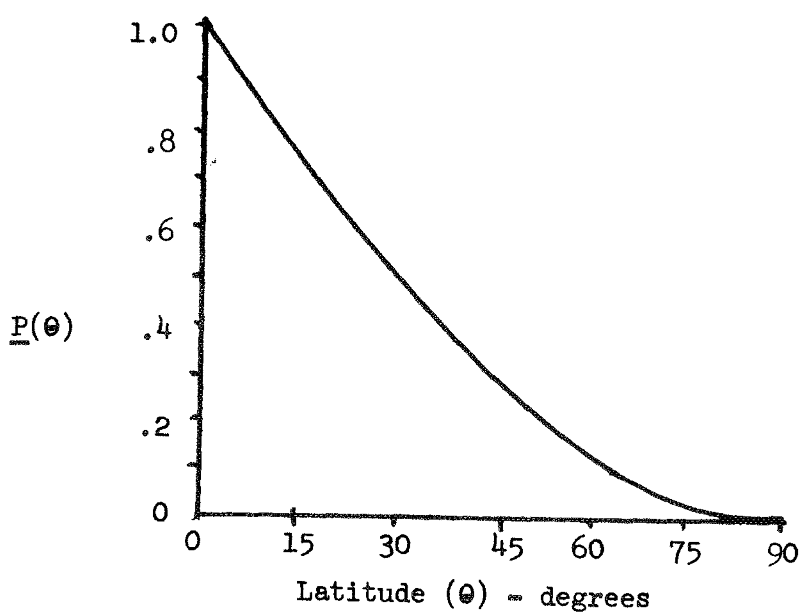


Figure 4-2. Fraction of Tug Landing Sites Above a Given Latitude, P(θ)

4.3.2 Landing Sites

A realistic set of tug/base sites presented in Table 4-3 was derived in order to complete the surface model. All candidate lunar surface base sites are also assumed to be candidate tug landing sites. Mission durations, based on the relative importance of the site in understanding fundamental lunar processes, are listed as are brief descriptors of the features of interest at each site.

4.3.3 Typical Tug Sortie Missions

The experiments and equipment items for several of the landing sites listed above have been defined in detail as part of the parallel Lunar Base Definition Study. In that study, experiment plans have been prepared apportioning these experiments to sortie sites and traverses associated with the several typical lunar base sites analyzed. To establish the interface between the OLS and a typical tug landing mission, subsets of these experiment plans were extracted that are appropriate to short duration (28 days) missions. Three typical tug missions are as follows:

1. Three closely grouped features in the vicinity of Aristarchus requiring moderate surface mobility (70-km total range) to investigate

2. Four features west of Picard requiring extensive surface mobility (350 km total range)

3. A crater within the larger elongate crater Schiller requiring only limited surface mobility

The payloads required to conduct these three missions are also summarized in Tables 4-4, 4-5, and 4-6. The average payload weight is 1350 pounds. Allowing 50 percent additional for dedicated support equipment (amplifiers, data formatters, transmitters, etc.), we arrive at the total scientific payload weight of approximately 2000 pounds. The items marked by an asterisk (*) are those which would be left behind, either totally or partly, for additional automatic data taking. The estimated weight of this nonreturned payload, including support equipment is 400 to 450 pounds. Of the equipment returned to the OLS, it is estimated that approximately 100 pounds would be unique to a particular site and, therefore, must be resupplied.

It should be pointed out that the durations shown on the following tables do not include time required to travel from site to site or for conducting traverses. In addition to the hardware payloads, it is estimated that 250 pounds of rock and soil samples and 200 pounds of other hard data (film, etc.) will be returned to the OLS after each tug sortie.

Table 4-3. Candidate Base/Tug Landing Sites

Site	Duration (Days)	Feature of Interest
Aristarchus	28	Volcanic plateau; sinuous rilles; transient phenomena
Mare Orientale	28	Limb; giant ring structure tectonic patterns; astronomy
Hadley Rille	28	High arcuate mountain range; sinuous rille
Picard, Mare Crisium	28	Volcanic crater, compact mascon
Hericlides Promontory	28	Imbrium mascon; Iridum mass deficiency; junction of two ring ranges
Grimaldi	28	Low albedo (fresh basalt?) floor highland - possible astronomy site
North Pole	28	Permanently shaded craters; astronomy site
Tycho (north rim)	28	Classic rayed crater; central peak
Tsiolkovsky	28	Farside; young volcanic flows; domes: highland terrain
Mare Moscoviense	28	Farside complex ring and impact structures in highland
Altai Scarp	14	Highland stratigraphy, tectonic collapse
Posidonius	14	Isostatically adjusted crater, low central peak; initiate serenitatus geophysical traverse
Sulpicius Gallus	14	Haemus range and structure complete Serenitatus geophysical traverse

Table 4-3. Candidate Base/Tug Landing Sites (Continued)

Site	Duration (Days)	Feature of Interest
Davy Rille	14	Rille, highland area
Descartes	14	Furrowed area of highland volcanism
Marius Hills	14	Volcanic domes rilles and transmare ridges
Gassendi, south	28	Crater walls, western highland, Mare Humorum Mascon
Alpine Valley	14	Wide possibly tectonic valley Imbrium Mascon and radial pattern
Alphonsus	7	Old crater, N-S transverse mountain range through crater
Copernicus (three locations)	14 (each)	Young rayed crater; central peaks and crater chains
Littrow	7	Wrinkle ridge genesis; young volcanic flow
Tycho, crater floor	14	Volcanic or rebound dome
Mare Veris	28	Outer ring of Orientale (north)
Mare Pacificus	28	Outer ring of Orientale (south)

Table 4-4. Typical OLS/Tug Mission 1

EXPERIMENT OPERATION DURATION LSB SITE - ARISTARCHUS			
Location No.	Feature	Preferred Experiments	Experiment Operation Duration (hr)
1 (Tug landing site)	Schroeter's Valley upper	4001, 4032, 4033, 4038 4039, 4047	36
2	Plateau, west of Schroeters (volcanic)	4001, 4033, 4038, 4044	48
3	Cobra Head (craterlike point of orgin of Schroeter's Valley)	4001, 4032, 4033, 4039, 4057, 4045, 4046, 4051	62
Total experiment operations			146
TOTAL TRAVERSE REQUIRED - - - - - - - - - - - - - - - - 70 km (See Map, Figure 4-3)			

Figure 4-3. OLS/Tug Mission No. 1

Table 4-4. Typical OLS/Tug Mission 1 (Continued)

EQUIPMENT REQUIRED					
		Weight (lb)			
ID No.	Name	Location 1	Location 2	Location 3	Total
11005	Gamma-ray spectrometer			85	85
11111	IR spectrometer	15		15	15
*11079	Down hole geophysical probe	200	200	200	200
*11081	Gravimeter (La-Coste-Romberg)		59	59	59
11082	Photogrammetric/stellar camera		330		330
11083	Photomicrographic camera	15	15	15	15
11086	Neutron activation analyzer	35	35	35	35
*11088	Seismometer (4-component Lamont)	24		24	24
11113	UV spectrophotometer	33	33	33	34
11096	X-ray diffractometer	20	20		20
*12002	Cold cathode pressure gauge	17		17	17
*14027	Portable mass spectrometer	51	51	51	51
14017	Multivator	10	10	10	10
*14028	Portable gas chromatograph	55	55	55	55
14021	Optical rotary dispersion (Gulliver)	2	2	2	2

Table 4-4. Typical OLS/Tug Mission 1 (Continued)

EQUIPMENT REQUIRED (Continued)					
ID No.	Name	Weight (lb)			
		Location 1	Location 2	Location 3	Total
14022	Organic carbon analyzer	10			10
*15008	Flux gate magnetometer			15	15
*15010	Metastable helium magnetometer			23	23
50009	Drill, 30m	200	200	200	200
*90011	Active seismic and other geophysical equipment	250	250		250
	Totals	937	1260	839	1450

* Totally or partly left behind for additional automatic data taking.

Table 4-5. Typical OLS/Tug Mission 2

EXPERIMENT OPERATIONS DURATION LSB SITE - PICARD

Location No.	Feature	Preferred Experiments	Experiment Operation Duration (hr)
(5-5')**	Concentric highland rim geophysical traverse	4032, 4038, 4044, 4045, 4046, 4058, 4047, 4053, 4057	30
8	Irregular shaped depressions	4032, 4033, 4038, 4045, 4058, 4059	60
9	Structures radial to Mare Crisium	4032, 4033, 4038, 4045, 4058, 4059	30
Total experiment operations			120

TOTAL TRAVERSE REQUIRED - - - - - - - - - - - - - - - - 350 KM
(See Map, Figure 4-4)

**Tug landing at location 5

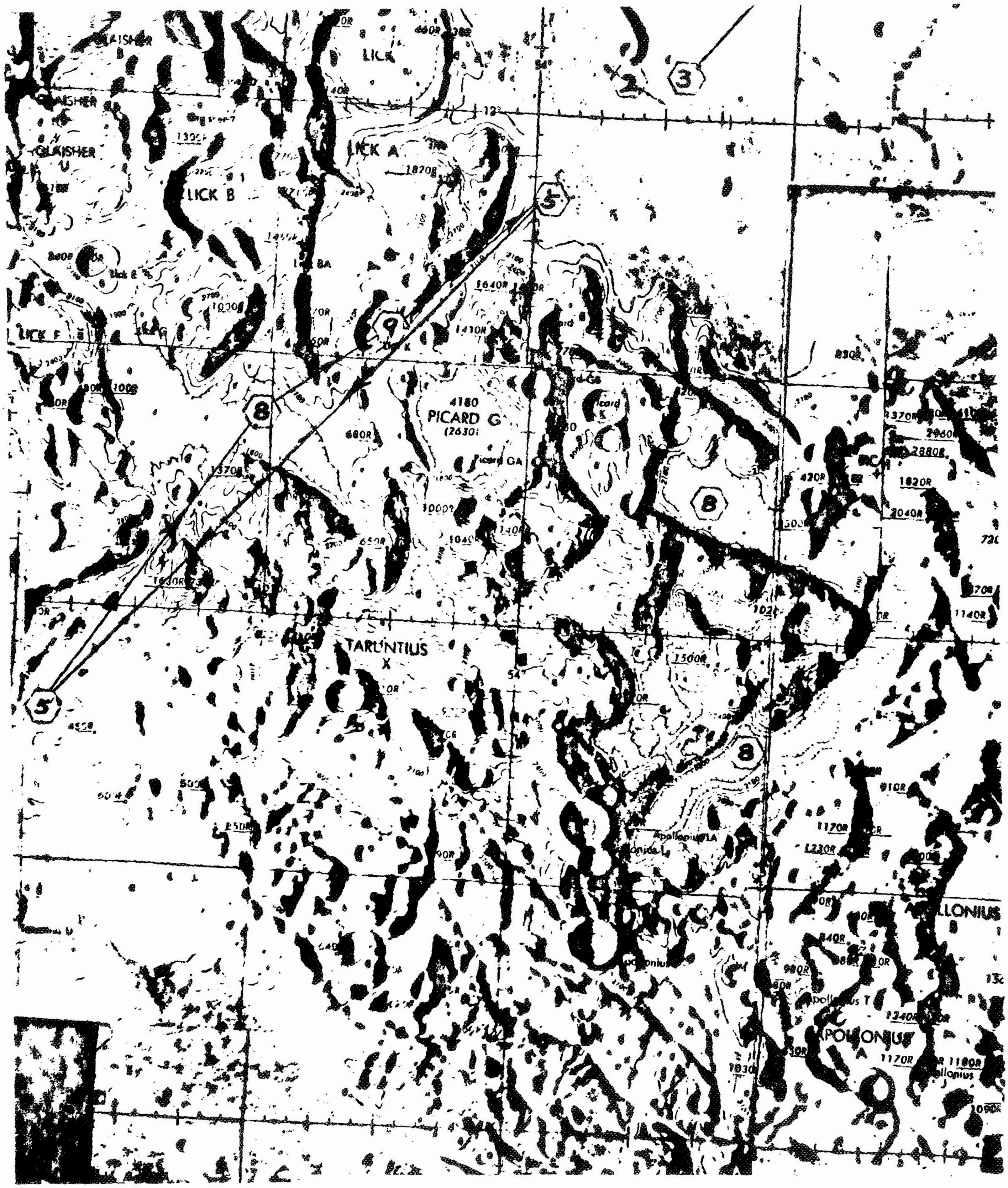


Figure 4-4. OLS/Tug Mission No. 2

Table 4-5. Typical OLS/Tug Mission 2 (Continued)

EQUIPMENT REQUIRED					
		Weight (lb)			
ID No.	Name	Location 5	Location 8	Location 9	Total
11005	Gamma-ray Spectrometer	85			85
11111	IR spectrometer	15	15	15	15
*11079	Downhole geophysical probe	200		200	200
*11081	Gravimeter (LaCoste-Romberg)	33	33	33	33
11082	Photogrammetric/stellar camera	330			330
11086	Neutron activation analyzer	35	35	35	35
*11088	Seismometer (4-component Lamont)	24			24
11096	X-Ray Diffractometer	20	20	20	20
*12002	Cold cathode pressure gauge	17			17
*14027	Portable mass spectrometer	51			51
*14018	Gas chromatograph	55	55	55	55
*14019	Mass spectrometer (quadrupole)	44			44
50009	Drill 30m	200	200	200	200
90008	Petrographic microscope	5	5	5	5

Table 4-5. Typical OLS/Tug Mission 2 (Continued)

EQUIPMENT REQUIRED					
		Weight (lb)			
ID No.	Name	Location 5	Location 8	Location 9	Total
*90011	Active seismic and other geophysical equipment	250	250	250	250
	Totals	1364	613	713	1364

* Would be left behind, totally or partly, for additional automatic data taking

Table 4-6. Typical OLS/Tug Mission 3

EXPERIMENT OPERATION DURATION LSB SITE - SCHILLER			
Location No.	Feature	Preferred Experiments	Experiment Operation Duration (hr)
1	Interior grater within crater	4001, 4032, 4037, 4038, 4044	350
Total experiment operations			350

TOTAL TRAVERSE REQUIRED: NONE

EQUIPMENT REQUIRED

ID No.	Name	Weight (lb)
11111	IR spectrometer	15
*11079	Downhole geophysical probe	200
*11081	Gravimeter (La Coste-Romberg)	33
11082	Photogrammetric/stellar camera	330
11083	Photomicrographic camera	15
11086	Neutron activation analyzer	35
11090	UV spectrophotometer	15
11096	X-ray diffractometer	20
*14027	Mass spectrometer	51
14017	Multivater	10
*14018	Gas chromatograph	55
14021	Optical rotary dispersion (Gulliver)	2
50009	Drill - 30m	200
90008	Petrographic microscope	5
*90011	Active seismic and other geophysical equipment	250
Total		1236

*Would be left behind, totally or partly, for additional automatic data taking

4.3.4 Surface Experiment and Equipment Summary

Table 4-7 contains the final list of lunar surface experiments and their associated equipment items. These experiments have been defined to accomplish those observation requirements for post-Apollo lunar exploration and exploitation (defined in Section 3.0) determined to be appropriate for lunar surface implementation by application of the selection criteria defined in paragraph 4.2.

The experiments are correlated with the disciplinary subobjective they principally support. Identification numbers have been assigned to each experiment and to each equipment item for the convenience of future users of these data. The list of surface experiments has been revised considerably as the definition activity has progressed. There have been deletions, additions, and combining of experiments. The initial list contained 87 discrete experiments. This final list contains 53 experiments; it reflects deletion of 13 experiments, combination of 22 with others having similar operational and equipment requirements, and addition of one (Near Surface Temperature Gradient) as a result of a review of these data by personnel of the U.S. Geological Survey Center of Astrogeology.

The identification of the experiments and their associated experiments was greatly aided by the detailed studies that were concurrently being performed in the Lunar Surface Base (LSB) Synthesis Study. As a result of the LSB activity, two additional subobjective categories were added for surface science: (1) lunar surface engineering, technology, and operations, and (2) lunar surface exploitation. These experiments are included in OLS payload considerations because it is assumed that precursor evaluation of the equipment and operational techniqûes would be conducted on space tug sortie missions prior to establishment of the LSB.

There are three experiments associated with engineering, technology, and operations. The most significant equipment is the mobility equipment required. A significant portion of a sortie payload is the propellant required by the mobility equipment. Based upon previous studies of lunar mobility equipment, an allocation of 5500 pounds of propellant is assumed for each tug sortie mission. The mobility equipment is assumed to weigh 3900 pounds.

Ten experiments are identified with precursor lunar exploitation activities. Perhaps the most significant single item in this list of experiments is the water-extracting process equipment. Feasibility studies are currently in process on this type of equipment.

Table 4-7. Experiment and Equipment List - Lunar Surface

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
Bioscience	NSD	4001	Life detection	BI-1	11103	J-Band Spectrophotometer
					11104	Electron Microscope
					14026	Mass Spectr (Lab)
					14018	Gas Chromatograph
					11083	Photomicrographic Camera
					14017	Multivator
					90014	Field Bioscience Kit
					90015	Incubator
		4002	Combined with 4001			
Bioscience	NSD	4003	Terrestrial contamination	BI-2	14018	Gas Chromatograph
					14026	Mass Spec (Lab)
					14022	Organic Carbon Analyzer
		4004	Combined with 4003			
		4005	Combined with 4003			
Bioscience	NSD	4006	Behavior/rhythm	BI-3,4	90016	Time Lapse Camera
					90017	Microscope
		4007	(Deleted)			

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
Aerospace medicine	NSD	4008	Flicker vision	AM-1	90007 90002	Flashing light IMBLMS
Aerospace medicine	NSD	4009	Reduced gravity effects on man	AM-2,3	90002	IMBLMS
		4010	Combined with 4009			
Aerospace medicine	NSD	4011	Vision effects	AM-4	(No experiment peculiar equipment required)	
Astronomy	NSD	4012	X-ray sources	AY-1	11097 11092	X-ray telescope (wide angle) X-ray telescope (grazing incidence)
Astronomy	-	4013	Combined with 4012			
Astronomy	ASD	4014	Flux densities (300 kHz to 1000 kHz)	AY-3	11093	Two-element radio interferometer (300 kHz to 1000 kHz)
Astronomy	ASD	4015	Flux densities (1000 kHz to 15	AY-3	11094	Two-element radio interferometer (1000 kHz to 15 MHz)
Astronomy	NSD	4016	Optical measurements	AY-3	11095	Optical telescope (1.3m)
Astronomy	NSD	4017	Optical effects from environment	AY-3	90004 90005 90007	Convex mirror (12" dia) Flat surface mirror (12" dia) Concave mirror (12" dia)
		4018	Combined with 4051			

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
		4019	Combined with 4051			
		4020	(Deleted)			
Astronomy	ASD	4021	Noise survey	AY-4	15013	RF Noise survey system -surface
Astronomy	NSD	4022	Radio propagation	AY-4	15014 15019	Transmitter and antennas Field strength meter
Astronomy	NSD	4023	Impedance measurements of antennas	AY-4	15015 15016 15017 30005 11091	Dipole antenna (2km) Dipole antenna (20m) Whip antenna (10m) Tape recorder Vector impedance meter
Astronomy	ASD	4024	Lunar plasma effects	AY-4	15018 15020	Plasma probe assembly Electrometer assembly
Astronomy	ASD	4025	Antenna dust accumulation	AY-4	11064 15020	Antenna Electrometer assembly
Astronomy	NSD	4026	Cislunar/wave propagation	AY-5	30008	Transponder - 3 frequency (with antennas)
Astronomy	ASD	4027	Strong discrete sources exhibiting temporal variations	AY-6	11108 30011	Antenna set, 3m crossed loops, 0.6-1.2 MHz, Interferometer
Astronomy	ASD	4028	Observations for correlation with earth observations	AY-6	11109 11110	Antenna set, 5-500 MHz Sweep frequency radiometer
Astronomy	ASD	4029	IR Astronomy	AY-6	11095	Telescope (1.3m)

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
		4030	Combined with 4029			
		4031	(Deleted)			
Geology/ geochemistry	SD	4032	Surface geological mapping and analysis	GG-ALL	11111 90018 90019 90020 14025	IR radiometer (portable) Mapping Kit Geological tool kit UV light-portable Auger spectrometer
Geology/ geochemistry	SD	4033	Subsurface drilling and sampling	GG-ALL	50009 90019 14025 14027 14028	Drill - 30m Geological tool kit Auger spectrometer Portable mass Portable Gas
		4034	(Deleted)			
		4035	Combined with 4032 and 4033			
		4036	(Deleted)			
Geology/ geochemistry	NSD	4037	Petrographic analysis of rocks (in laboratory)	GG-2	90008 50006	Petrographic microscope Sample prep device
Geology/ geochemistry	SD	4038	Mineralogic identification and chemical analysis in situ	GG-2	11086 14025 14026	Neutron activation analysis equipment Auger spectrometer Mass specrometer (laboratory)
Geology/ geochemistry	SD	4039	Investigation: Sites of transient activity	GG-3, 8,1.	14005 12001 11088	Mass spectrometer Ionization pressure sensor Seismometer (4-component Lamont)

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
		4040	Combined with 4032			
		4041	(Deleted)			
		4042	Combined with 4032 and 4033			
		4043	(Deleted)			
Geodesy/ cartography	SD	4044	Geodetic grid construction	GC-1	11112 11082 11081	Absolute gravimeter Photographic astronomical transit Gravimeter (La Coste Romberg)
Geophysics	SD	4045	Gravity profiling	GP-1	11112	Absolute gravimeter
Geophysics	SD	4046	Seismicity active	GP-2,3	40005 11087 50010 50012	Time base generator Seismic amplifier Seismic energy source Geophones
Geophysics	SD	4047	Seismicity passive	GP-2,3 (also GG-3,6, 8)	11088	Seismometer (4 comp. Lamont)
Geology/ geochemistry	SD	4048	Deep drilling and sampling	GG-2,4, 5,6	50008	Drill - 300 m
		4049	(Deleted)			

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
Particles and fields	NSD	4050	Solar wind and energetic particle measurements	PF-1,2,4	14001 14002 14020 11098	Particle counter (low-energy) Particle counter (high-energy) Particle spectrometer Cosmic-ray spectrometer telescope
Particles and fields	NSD	4051	Magnetic field temporal variations	PF-3	15011 15008 15010 15012	Search coil magnetometer (emplaced) Fluxgate magnetometer Helium magnetometer Electric field detector (emplaced)
		4052	Combined with 4051			
Lunar atmosphere	SD	4053	Total pressure	LA-1,3	12001 14005 14019	Ionization pressure sensor Mass spectrometer Mass spec (quadrupole)
		4054	Combined with 4053			
Lunar atmosphere	NSD	4055	Escape and transport rates	LA-2,3	14029 14030	Mass spectrometer (directional) Supra-thermal Ion detector (Apollo-type)
		4056	Combined with 4032			
Geology/ geochemistry	SD	4057	In Situ measurement of natural radiation spectrum	GG-2,4	11005	Gamma ray spectrometer
Geophysics	SD	4058	Magnetic profiling	GP-2 (also GG-1,2,4)	15021 15022	Fluxgate magnetometer Magnetometer - Proton precession

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
Geology/ geochemistry	SD	4059	Subsurface logging	GG-2,6	11079	Downhole geophysical probe
Geology/ geochemistry	NSD	4060	Mineralogic analysis in laboratory	GG-2,4, 6,7,8	11096 90008 50006	X-ray diffractometer Petrographic microscope Sample prep. device
Geology/ geochemistry	NSD	4061	Instrumental chemical analysis in laboratory	GG-2,4, 6,7,8	11096 11086 14018 14026 11114 11115 11113	X-ray diffractometer Neutron Activation analysis equipment Gas Chromatograph Mass spectrometer (laboratory) X-ray spectrometer IR spectrometer UV spectrometer
		4062	(Deleted)			
		4063	Combined with 4032			
Engineering technology and operations	NSD	4064	Biological monitor and Ecosystem Prototype	ET-2	90021	Biology monitor and ecosystem prototype equipment
		4065	(Deleted)			
Engineering technology and operations	NSD	4066	Lunar effects on plants	ET-2	90022	Plant life experiment equipment
		4067	Combined with 4066			

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
		4068	Combined with 4064			
		4069	(Deleted)			
		4070	(Deleted)			
Engineering technology and operations	NSD	4071	Thin film bearings	ET-3	90023	Thin film bearing equipment
		4072	Combined with 4032 and 4033			
		4073	Combined with 4032 and 4033			
Exploitation	SD	4074	Mining/transport equipment	EX-1	--	Mobility equipment
Exploitation	NSD	4075	Water extracting process	EX-1	--	Feasibility stage of development
		4076	Combined with 4075			
		4077	(Deleted)			
Exploitation	NSD	4078	Lunar strata electro-magnetic propagation	EX-3	90024	Lunar strata electromagnetic propagation equipment
Exploitation	NSD	4079	Lunar surface transmission	EX-3	90025	Lunar surface transmission line equipment
		4080	Combined with 4079			

Table 4-7. Experiment and Equipment List - Lunar Surface (Continued)

Discipline	Site Dep	Experiment I/D No.	Experiment Title	Subobjective	Equipment I/D	Equipment Description
Exploitation	NSD	4081	Heat transfer - liquids	EX-3	90026	Liquids heat transfer equipment
Exploitation	NSD	4082	Heat transfer - film	EX-3	90027	Film and drop heat transfer equipment
		4083	Combined with 4046			
Exploitation	NSD	4084	Metals joining	EX-4	90028	Metals joining experiment equipment
Exploitation	NSD	4085	Differential thermal analysis	EX-4	90029	Differential thermal analysis equipment
Exploitation	NSD	4086	Characteristics of lunar ores	EX-4	90030	Ores analysis equipment
Exploitation	NSD	4087	Lunar dry cement and concrete	EX-4	90031	Lunar dry cement and concrete preparation equipment
Geophysics	SD	4088	Near surface temperature gradient	GP-3	11116 40009	Heat flow probe Electronics

4.4 ORBITAL SCIENCE SUPPORT REQUIREMENTS

4.4.1 Orbit Experiment Summary

The experiments defined to accomplish the orbit phase of the post-Apollo lunar exploration program are listed in Table 4-8. They result from applying the Orbit/Surface Slection Criteria defined in Paragraph 4.2 to the Observation Requirements of the Post-Apollo Lunar Exploration Program, defined in Section 3.0. Also listed are the major experiment equipment items. Identification numbers have been assigned to each experiment and equipment item.

The experiments are correlated with the disciplinary subobjectives they principally support. A more complete correlation, including secondary support, is contained in Table 4-9. This final list contains 16 experiments. Earlier lists contained as many as 28. As experiment definitions and descriptions were refined, it became clear that certain experiments were inappropriate for lunar orbit and were deleted. Others were so similar in objectives, operations, and equipment that they could be combined under a single definition. Those deleted were Experiment 5001, Zero Gravity Effects on Man, and Experiment 5012, Selection of Potential Landing or LSB Sites. The first was considered to be fully covered by earth orbiting programs; the second is a major objective of all early OLS activities and need not be called out as a separate experiment.

Many geological remote sensing experiments were combined into a single experiment (5002), after it was realized that great commonality of goals, equipment items, and operational requirements existed. Onboard sample analysis, mineralogic and petrographic were combined into Experiment 5006. Finally, all mapping activities were combined into Experiment 5013, and were based again on equipment and operational commonality.

Although bioscience and aerospace medicine experiments are excluded from the list of orbital experiments, it is assumed that in the basic provisions of the OLS for crew habitability a medical facility will be included. This facility, in conjunction with surface medical and bioscience experiments, will be capable of fulfilling the pertinent science program subobjectives. No special equipment is required in the OLS medical facility.

Only one orbital experiment is the primary source of data for accomplishment of astronomy subobjectives. However, orbital experiments do provide secondary support to all astronomy subobjectives.

Table 4-8. Candidate Experiment/Equipment List - Lunar Orbit

Discipline	Experiment ID	Experiment Title	Subobjective	Equipment ID (Edit)	Equipment Description
Aerospace medicine	5001	(Deleted)			
Geology/ geochemistry	5002	Orbital geological mapping and analysis	GG-1 through 8	11009 11013 11042 11008 11012	Radar reflectometer IR scanning radiometer High-resolution camera UV imager/spectrometer Radar imager
Geology/ geochemistry	5003	Combined with 5002			
Geology/ geochemistry	5004	Combined with 5002			
Geology/ geochemistry	5005	Combined with 5002			
Geology/ geochemistry	5006	Petrographic and mineralogic identification and analysis	GG-2	11096 90008 50006 11086 14026 14018	*X-ray diffractometer *Petrographic microscope *Sample preparation device *Neutron activation analysis equipment *Solids mass spectrometer *Gas chromatograph
Geology/ geochemistry	5007	Combined with 5006			
Geology/ geochemistry	5008	Combined with 5002			

*These equipment items are included in item No. 50011, geochemistry laboratory.

Table 4-8. Candidate Experiment/Equipment List - Lunar Orbit (Continued)

Discipline	Experiment ID	Experiment Title	Subobjective	Equipment ID (Edit)	Equipment Description
Geology/ geochemistry	5009	Combined with 5002			
Geology/ geochemistry	5010	Combined with 5002			
Geology/ geochemistry	5011	Combined with 5002			
Geology/ geochemistry	5012	(Deleted)			
Geodesy/ cartography	5013	Geodetic grid construction and topographic mapping	GC-1, 2	11002 11099	Metric camera, 6 in. Laser altimeter
Geodesy/ cartography	5014	Combined with 5013			
Geophysics	5015	Combined with 5013			
Geology/ geochemistry	5016	High-resolution mapping of selected sites	GG-8	11042	High-resolution camera
Geology/ geochemistry	5017	Remote geochemical analysis	GG-2 and 6	11005 11069 14003 11070	Gamma-ray spectrometer X-ray spectrometer Alpha proton counter Pulse height analyzer

Table 4-8. Candidate Experiment/Equipment List - Lunar Orbit (Continued)

Discipline	Experiment ID	Experiment Title	Subobjective	Equipment ID (Edit)	Equipment Description
Geophysics	5018	Electrical properties of surface and sub-surface	GP-2	11010	EM measurement system (10 khz to 10 MHz)
Geophysics	5019	Thermal anomalies and surface structure	GP-3	11013 11015	IR radiometer Passive microwave imager
Geophysics	5020	Spacecraft orbital perturbations	GP-1, 4	11041 11099	Radar altimeter/scatter-ometer Laser altimeter
Particles and fields	5021	Solar wind and ener-getic particle	PF-1, 2, 4	11098 14020 14001 11070	Cosmic-ray spectrometer tele-scope Particle spectrometer Charged particle counter Pulse-height analyzer
Particles and fields	5022	Magnetic field	PF-3	15010	Helium magnetometer
Particles and fields	5023	Electric field	PF-1, 2, 3	15009	Electric field detector
Lunar atmosphere	5024	Total pressure	LA-1, 3	12001 14005	Ionization pressure sensor Mass spectrometer
Lunar atmosphere	5025	Composition	LA-1, 3	14005 11008	Mass spectrometer UV imager/spectrometer

Table 4-8. Candidate Experiment/Equipment List - Lunar Orbit (Continued)

Discipline	Experiment ID	Experiment Title	Subobjective	Equipment ID (Edit)	Equipment Description
Lunar atmosphere	5026	Escape and transport rates	LA-2, 3	14005	Mass spectrometer
Astronomy	5027	Radio interference from earth	AY-6	30007 30004 11059 11064	Receiver (10 MHz to 3 GHz) Receiver (10 kHz to 10 MHz) Antenna (10 MHz to 100 GHz) Antenna (10 kHz to 10 MHz)
Geophysics	5028	Gravity gradient	GP-1	15007	Gravity gradiometer

Table 4-9. Correlation of Lunar Orbit Experiments and Subobjectives

Experiment \ Subobjectives	GG-1	GG-2	GG-3	GG-4	GG-5	GG-6	GG-7	GG-8	GC-1	GC-2	GP-1	GP-2	GP-3	GP-4	PF-1	PF-2	PF-3	PF-4	LA-1	LA-2	LA-3	AY-1	AY-2	AY-3	AY-4	AY-5	AY-6
5002	X	X	X	X	X	X	X	X	0	0	0		0														
5006	0	X		0								0			0					0	0						
5013	0		0	0	0	0	0	0	X	X	0	0															
5016	0		0	0	0	0	0	X	0	0			0														
5017	0	0	0	0	0			0				X			0				0	0	0	0					
5018	0	0						0			0	X	X				0								0		
5019	0	0	0	0	0		0	0				0	X														
5020	0	0						0			X			X													
5021	0	0	0		0										X	X		X								0	
5022		0															X								0		
5023		0															X							0			
5024			0												0			0	X		X						
5025			0												0			0	X		X						
5026			0												0			0		X	X						
5027																	0							0			X
5028		0									X			0													

X - primary support; 0 - additional support; GG - geology/geochemistry; GC - geodesy/cartography; GP - geophysics; PF - particles and fields; LA - lunar atmosphere; AY - astronomy.

4.4.2 Orbit Experiment Operating Mode Selection

The procedure used to establish the operating mode of the lunar orbit experiments is similar to that employed in the Earth Orbital Space Station Study. An OLS capability model is defined, and experiment requirements are compared to these capabilities. Those experiments incompatible with some aspect of the capability model are assigned to the detached operating mode. Because there is no specific requirement for detached or attached experiment modules (the OLS is considered to be an operational rather than an R&D facility), all detached experiments will be operated on subsatellites, and all compatible experiments will be operated within the OLS, with an airlock utilized as required. Note that the selected mode is the preferred one in all cases; in a low cost program several of the detached experiments could be attached with an accompanying loss in performance. See Table 4-2.

The factors considered in this analysis include contamination, acceleration, attitude and stability, electromagnetic interference, orbit, and safety (Table 4-10). In those cases where OLS capabilities are not yet defined, the appropriately modified EOSS model is used.

Contamination

This environment consists of two components: (1) gases and solids emitted by spacecraft leakage, venting, and propulsion, and (2) nuclear and/or atomic radiation. Experiments susceptible to emitted gases and solids are as follows:

Experiment No.	Experiment Title
5013	Geodetic Grid Construction and Topographic Mapping
5002	Orbital Geological Mapping and Analysis
5019	Thermal Anomalies and Surface Structure
5024	Total Atmospheric Pressure
5025	Atmospheric Composition
5026	Atmospheric Escape and Transfer Rates
5016	High Resolution Mapping of Selected Sites

The EOSS model for these contaminants was as follows:

Leakage - 20 lbm/day total, composed of the following:

O_2:	4.7 lbm/day
N_2:	15.0 lbm/day
CO_2:	0.1 - 0.3 lbm/day
H_2O:	0.0 - 0.2 lbm/day

Table 4-10. Summary - Experiment Requirements/OLS Capability Comparison

Experiment No.	Contamination	Acceleration	Attitude/ Stability	Electromagnetic Interference	Orbit	Safety
5002 *						X
5006						
5013						
5016						
5017 *	X				X	
5018 *						X
5019						
5020 **						
5021 **				X	X	
5022 **				X	X	
5023				X	X	
5024 *	X				X	
5025 *	X				X	
5026 *	X				X	
5027 *						X
5028 ***		X			X	

Key: X - incompatible
Blank - compatible

* Subsatellite No. 1
** Subsatellite No. 2
*** Subsatellite No. 3

Venting - Waste processing and storage products vented overboard are as follows:

4.6 lbm /day of H_2O

9.25 lbm /day of CH_4

Note - Under an emergency situation, a contaminated compartment may require venting to clear contamination. In this case, the vented gases will contain normal atmospheric composition and generated toxic contaminants.

Propulsion - Propellant (H_2/O_2) consumption for attitude control and/or bit makeup is 18.3 lbm /day expended intermittently. Composition of exhaust products is as follows: 80.33% H_2O 19.49% H_2, and 0.09% OH.

Propulsion concept and specific requirements for artificial gravity operations have not been finalized. However, no external viewing experiments would be operated during this period.

(The previous data were reproduced from a Space Division of North American Rockwell document SD 70-155-2-1, page 4-12.)

It should be noted that outgassing is neglected. These gas escape rates result in cumulative degradation of resolution for optical sensors as shown (typically) in Figure 4-5, which was taken from page 4-17 of SD 70-155-2-1.

Figure 4-5 shows that unless exposures to this environment exceed three months, little effect is noted. Therefore, the only experiments incompatible with this environment are the lunar atmosphere experiments 5024, 5025, and 5026, because the pressure near the station for these leak rates could be as high as 10^{-6} torr, which is considerably higher than the expected lunar atmosphere.

The nuclear radiation environment does not necessarily result from a nuclear power source - even with a nonnuclear electrical power subsystem, radiation induced in the large OLS by the natural environment results in values too large to be tolerated by experiment 5017. This experiment is susceptible to radiation doses as small as 10^{-4} mrem/hr. This is smaller than the dose resulting from interaction of the natural environment with the spacecraft material.

Acceleration

The relevant OLS accelerations from various sources are summarized in the following Table 4-11.

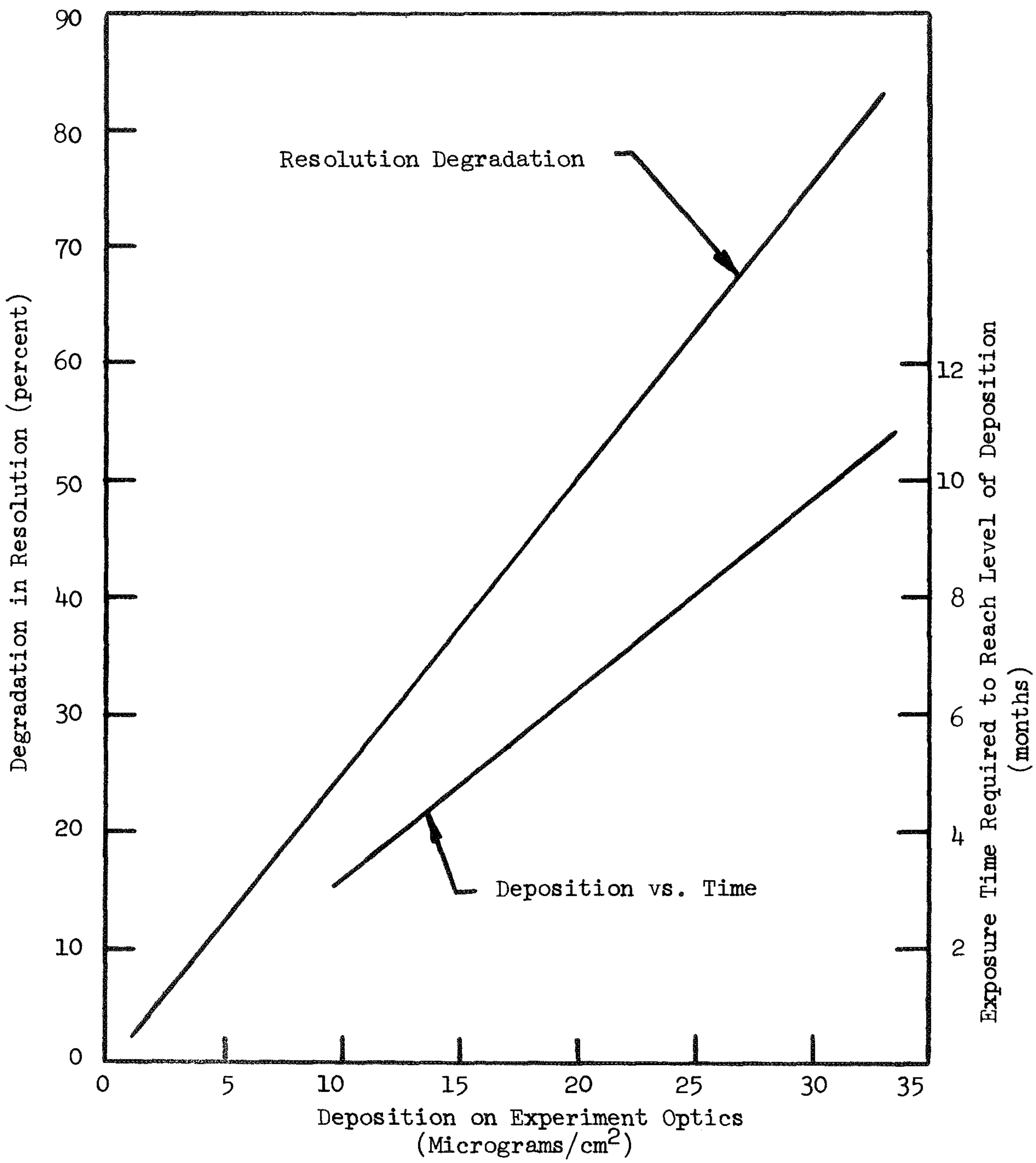


Figure 4-5. Cumulative Degradation of Resolution for Optical Sensors

Table 4-11. Relevant OLS Accelerations from Various Sources

Source	Acceleration	Duration (Seconds)	Frequency
Space tug hard dock	0.02 g	0.3	Once every month
Attitude maneuvers Roll/pitch/yaw (F = 50 lb/axis)	Roll: 4×10^{-4}g Pitch: 7×10^{-4}g Yaw: 6×10^{-4}g (start and stop)	2.0	Each 48 revolutions
Cargo movement	8×10^{-3}g (start and stop)	1.0	Ten-second intervals for 60 minutes once every 6 months
Crew movement	4×10^{-5}g (start and stop)	1.0	Once every 10 minutes
Antenna positioning	10^{-4}g		

The only acceleration-sensitive experiment is 5028, Gravity Gradient, which cannot tolerate accelerations greater than 10^{-6} g. It should be noted that this is completely incompatible with several sources, frequent crew motions in particular.

Attitude/Stability

No experiment is incompatible with the model OLS capability of 0.25 degree attitude hold (0.1 fine hold) and 0.05 degree-per-second stability (0.01 fine stability). These values provide surface discrimination of 500 meters for nonimaging sensors and resolution of 1 meter for imaging sensors.

Electromagnetic Interference

The OLS has the following EMI sources:

a. Two high-gain 5-foot parabolic steerable or phased array antennas located on each side of the station. The beamwidth is 8 degrees, and the transmitting power is 30 watts at 1.8 GHz.

b. Eight semidirectional antennas with 150-degree beamwidth; power and frequency are the same as those previously mentioned.

In addition, there are low duty cycle approach radars for shuttle and sub-satellites docking. This radiated power, in addition to the induced lower frequency electric and magnetic fields near the OLS resulting from currents, is incompatible with the particle and fields experiments 5021, 5022, and 5023.

Orbit

The nominal OLS orbit is 90 degrees inclination, 60 nautical miles circular. This is incompatible with the requirements of 5017 (Remote Geochemical Analysis), 5021, 5022, 5023 (Particles and Fields), 5024, 5025, 5026 (Lunar Atmosphere), and 5028 (Gravity Gradient). These experiments all require a variety of orbit altitude eccentricities and/or inclinations.

Safety

The EOSS safety guidelines which are equally applicable to the OLS are as follows:

a. Experiments with a potential of biological or toxic contamination of the space station atmosphere shall not be allowed inside the station. Airlocks for decontamination shall be provided for crew and equipment transfer between the experimental areas and the space station.

b. Experiments with an energy content greater than 0.1 pound of TNT equivalent in explosive potential shall not be allowed inside the station while the explosive potential exists.

c. Experiments with any energy content greater than 1.0 pound of TNT equivalent in explosive potential shall not be allowed in attached modules while the explosive potential exists.

No experiment violates these ground rules, provided that normal precautions are observed in the handling of reagent chemicals in the geology/geochemistry laboratory. In addition, special provisions must be made for explosives used in support of the scientific program.

Operational safety considerations require the location of large dipole antennas on subsatellites. These antennas consist of 50, 100, and 750-foot dipole stems in a cross-configuration. Tug maneuvers in the vicinity of the OLS were considered to be too hazardous if these antennas were mounted on the OLS.

4.4.3 Experiment Definitions - Lunar Orbit Experiment Narratives and Master Timelines

Definition Elements

Each experiment shown on the summary list in paragraph 4.4.1 of this report is defined here. A definition consists of the following elements:

a. Disciplinary area

b. Experiment identification number

c. Experiment title

d. Subobjectives primarily supported, together with an assessment of the contribution the experiment makes to the achievement of the subobjectives

e. Observation requirements - A narrative description of the experiment objectives, operations, and equipment (where necessary)

f. Equipment required - A list of the prime items of experiment hardware required to conduct the experiment

g. Master timeline - The principal sections of this element include the following:

   1. Time-phased operations sequence - This shows the duration and relative phasing of major experiment operations (a major experiment operation is defined as one in which the experiment mode changes in a significant way)

   2. Frequency - The desired number (minimum and maximum) of repetitions of the operations sequence (the number of repetitions shown under Frequency is over and above any repetition of operational phases shown on the timeline)

   3. Operational constraints - significant operational requirements for each phase of experiment operation

   4. Equipment - The identification number for equipment used during each experiment phase

Experiment Definitions

Experiment definitions, which include the experiment number, title, description, and master timeline, follow in this section.

Experiment 5002

Discipline: Geology/geochemistry

Experiment ID No.: 5002 (incorporates previously designated experiment numbers 5002, 5003, 5004, 5005, 5008, 5009, 5010, 5011)

Experiment Title: Orbital Geological Mapping and Analysis

Applicable Subobjectives

This experiment, involving the most comprehensive geological mapping and analyses proposed thus far in the UV, visible, IR, and microwave spectral ranges, should make a major contribution to all eight of the geology/geochemistry subobjectives, GG-1 through GG-8 inclusive.

Observation Requirements

This experiment involves the performance of geological surface mapping and analysis with recorded imagery in the UV, visual, IR, and microwave regions of the electromagnetic spectrum over the entire lunar surface from a polar orbit. Emphasis will be placed on analysis of land forms, including the delineation of lithologic contacts, tectonic structures, physiographic and petrographic provinces, and the determination of the morphologic differences between the near and far side of the moon. Particular attention will be given to the investigation of active volcanic areas, stratigraphy where exposed to the surface, and sites of transient activity (e.g., recent impacts of large meteors).

The instrumentation for orbital recording of lunar surface imagery includes a high resolution camera, operable from a 60-nmi altitude with stereo capability, an IR radiometer-scanning imager, UV imager spectrometer, and a radar imager.

The orbital measurement of subsurface properties will involve radar imager soundings at several lunar subsurface depths to determine the extent of the regolith and determine the near-surface stratigraphy. A radar reflectometer will also be used to obtain reflection coefficient data from which subsurface dielectric constants may be determined. High values of dielectric constants may be very guardedly considered as potential indications of water.

Gamma-ray surveys of radiogenic lunar regions will be performed from a subsatellite (NR Equipment 6006) as part of Experiment 5017, Remote Geochemical Analysis. Mass spectrometer survey of atmospheres over active volcanic areas will be performed on the same subsatellite in Experiment 5025.

A master timeline chart for Experiment 5002 is shown in Figure 4-6.

Equipment Required

Equipment No.	Equipment Name
11042	High-resolution camera
11013	IR scanning radiometer
11008	UV imager/spectrometer
11012	Radar imager
11009	Radar reflectometer

Experiment 5006

Discipline: Geology/geochemistry

Experiment ID No.: 5006 (incorporates previously designated experiment numbers 5006 and 5007)

Experiment Title: Petrographic and Mineralogic Identification and Analysis

Applicable Subobjectives

GG-2 - To determine the physical, mineralogic, and chemical properties of lunar materials.

This experiment will probably be a minor contribution to the subobjective, because only a small amount of identification and analysis would be performed on samples brought back to the OLS from a OLS/tug sortie to the lunar surface compared to the amount that would be performed on earth.

Observation Requirements

Petrographic and mineralogic examinations will be made of lunar surface samples returned to the OLS from OLS/tug sorties. Sample preparation for petrographic analysis will provide for thin sectioning of the rocks to typical dimensions of 1cm by 1cm by 0.03mm. Sample preparation for diffraction analysis and mass spectroscopy will provide for production of finely comminuted samples consisting typically of 50 to 100 micron-sized particles.

The X-ray diffractometer involves the irradiation of the powdered rock sample with a monochromatic X-ray beam. The resulting diffraction pattern gives information on mineral or compound structure. The diffraction pattern may be digitized for further interpretation in the OLS or transmission to earth.

FREQUENCY MIN. MAX.	OPERATION NO.	TIME DAYS (0 1 2 3 … 30 33)	CONSTRAINT	EQUIP. NO.
1 4				
Set up, align, calibrate and actuate:			Operate IR sensor only on dark side	
High Resolution Camera	1	0.5	Operate radar on both lunar dark and light sides	11042
IR Scanning Radiometer	2	0.5		11013
UV Imager/Spectrometer	3	0.5		11008
Radar Imager	4	0.5		11012
Radar Reflectometer	5	0.5		11009
Observe and Record	6	30 days	Avoid all sensor attitudes resulting in over-exposure to direct sunlight	All Equipment
Repeat 6 & 7 3 times	7, 8, 9			
Deactivate	10	1 day		

Figure 4-6. Master Timeline Experiment 5002

Neutron activation analysis involves irradiation of lunar material with a source of fast (14 Mev) neutrons and analysis of the secondary radiations with a gamma-ray detector; e.g., with a NaI (Tl) crystal. The characteristic gamma energies for particular lunar materials are detected and their energies determined in a pulse height analyzer. The elemental compositions of lunar minerals containing oxygen, sodium, aluminum, silicon, calcium, and iron are easily assessed. Compositions involving magnesium, titanium, and chromium are less easily identified, and sulfur and cobalt do not appear to be readily identifiable by this system.

A mass spectrometer suitable for chemically analyzing solids will be used to investigate lunar materials with special characteristics, such as lead isotopes, potassium, and argon minerals and minerals bearing possibly organic materials.

A gas chromatograph also will be used for analyzing solid samples that have been volatilized in an oven that is an integral part of the chromatograph. The sample vapors are carried through the absorbing-desorbing column by a carrier gas (inert He). After separation, the components are transported into a glow discharge detector, which identifies the components by the differences in breakdown voltage of the contaminated He carrier gas.

A master timeline chart for Experiment 5006 is shown in Figure 4-7.

Equipment Required

Equipment No.	Equipment Name
50006	Sample preparation device
90008	Petrographic microscope
11096	X-ray diffractometer
11086	Neutron activation analyzer
14018	Gas chromatograph
14026	Solids mass spectrometer

Experiment 5013

Discipline: Geodesy/cartography

Experiment ID No.: 5013

Experiment Title: Geodetic Grid Construction and Topographic Mapping

FREQUENCY MIN. MAX.	OPERATION NO.	TIME	CONSTRAINT	EQUIP. NO.
After each Tug mission to surface		0 2 4 6 12 20		
Preparation of samples and calibrate:				50006
thin slice	1	2 hrs		
powder	2	2 hrs		
pyrolisis in oven	3	1 hr		
Conduct petrographic exam.	4	6 hrs		90008
Conduct diffraction experiment	5	8 hrs		11096
Conduct activation measurements	6	8 hrs		11086
Conduct gas chromatograph measurements	7	8 hrs		14018
Conduct mass spectroscopy experiment	8	8 hrs		14026
Repeat 1 through 8 at least twice and more depending on number of samples				

Figure 4-7. Master Timeline Experiment 5006

Applicable Subobjectives

GC-1 - To establish a three-dimensional geodetic control system over the entire lunar surface in terms of latitude, longitude, and height above the chosen reference figure. This experiment is very nearly a total contribution toward meeting this objective.

GC-2 - To collection photogrammetric data and construct of topographic maps for scientific purposes and base-site evaluation studies.

This experiment is a major contribution toward meeting this subobjective.

Observation Requirements

To construct a geodetic grid on the moon, a metric camera system in an optimum 93-km altitude polar lunar orbit will be used. The completed grid will establish geodetic control by a system of measured positions on the lunar surface. The position and orientation of the camera in the OLS must be known accurately. The position can be obtained from the OLS emphemeris as viewed from the earth. The camera system orientation is obtained from two integral cameras that photograph the star background. The two star cameras are fixed to the same mounting as the 6-in. metric camera, which photographs the lunar surface. Thus, the orientation of the moon in a celestial reference system is established. The accuracy of this system is estimated to be within 15 seconds of arc. The scale of the metric photographs is established from simultaneous measurements with a laser altimeter. The device is the same one used in Experiment 5020. To establish the geoid of the moon, a gravity gradiometer on a subsatellite (Experiment 5028) is used to measure horizontal and vertical gradients in the lunar gravitational acceleration.

Topographic mapping also will be accomplished in this experiment by using the same photographs as taken with the 6-in. metric camera previously mentioned for the geodetic grid construction.

A master timeline chart for Experiment 5013 is shown in Figure 4-8.

Equipment Required

Equipment No.	Equipment Name
11002	Metric camera (6 in.)
11099	Laser altimeter

Experiment 5016

Discipline: Geology/geochemistry

Experiment ID No.: 5016

Experiment Title: High Resolution Mapping of Selected Sites

FREQUENCY MIN. 2 MAX. 6	OPERATION NO.	TIME	CONSTRAINT	EQUIP. NO.
		0 1 … 15 … 31 32		
Set up, calibrate, activate	1	1 day	Photographs are to be taken with sufficient overlap to provide stereoscopic imagery. Laser altimeter to be boresighted with nadir oriented metric camera lens.	11002 11099
Experiment operation	2	30 days		
Deactivate	3	1 day		

REMARKS:

(1) Data from Experiment No. 5028, "Gravity Gradient," required to complete the analysis of this experiment.

(2) Number of repetitions will be determined by lighting (sun angle) requirements for specific purposes.

Figure 4-8. Master Timeline Experiment 5013

Applicable Subobjectives

<u>GG-8</u> - To locate geologically favorable sites for advanced lunar exploration-exploitation scientific facilities. This experiment will be a major contribution to the achievement of this objective. It will provide high fidelity photographic images to be used in conjunction with microwave, IR, and other remote sensing data.

Observation Requirements

After a review of the general topographic lunar maps obtained on previous missions and available photographs from previous and OLS missions, high-resolution photography will be made of areas of geologic interest and selected sites suitable for advanced lunar exploration and exploitation. A high-resolution camera will be used and will be coordinated with the geodetic and topographic mapping medium resolution photography of Experiment 5013 just as is to be accomplished in the Apollo CSM J-series mission experiments.

A master timeline chart for Experiment 5016 is shown in Figure 4-9.

Equipment Required

Equipment No.	Equipment Name
11042	High-resolution camera

<u>Experiment 5017</u>

Discipline: Geology/geochemistry

Experiment ID No.: 5017

Experiment Title: Remote Geochemical Analysis

Applicable Subobjectives

<u>GG-2</u> - To determine the physical, mineralogic, and chemical properties of lunar materials.

<u>GG-6</u> - To construct geologic maps of the lunar surface, delineating lithologic contacts, tectonic structures, physiographic, and petrographic provinces.

This experiment is a major contributor to these subobjectives because much of the lunar surface can be examined by this method from OLS long before surface measurement of such an extensive area can be made.

Observation Requirements

The remote geochemical analysis experiment involves simultaneous observations of three types of high energy radiations (gamma-rays, x-rays, and alpha particles) emanating from the lunar surface.

FREQUENCY MIN. 3 MAX. 12	OPERATION NO.	TIME Hours (0, 24, 34, 754)	CONSTRAINT	EQUIP. NO.
			Daylight only	
Set up, install	1	1 day	Avoid direct sunlight	11042
Warm up	2	10 hrs		
Operate as required	3	Operate intermittently for 30 days as required	Overlap successive exposures to provide stereo imagery	
Deactivate	4	10 hrs		
Repeat 1 thru 4 several different lighting conditions				

Figure 4-9. Master Timeline Experiment 5016

A gamma-ray spectrometer with solid-state (e.g., NaI) detectors, collimators and electronics for measuring coincidence and anticoincidence will be used to measure gamma radiation in the energy range 0.1 to 10 Mev. The lunar gamma radiation is from natural radioactivity (principally isotopes of potassium, uranium, and thorium and daughter products) and from secondary radiation induced by cosmic radiation incident on the lunar surface. The observation of characteristic gamma-ray lines of decay and prompt capture gammas are correlated with isotopic abundances of lunar surface elements. The orbital measurements should be preceded by cislunar space measurements in order to obtain a reference extralunar cosmic background to subtract from the orbital readings.

Equipment Required

Equipment No.	Equipment Name
11005	Gamma-ray spectrometer
11069	X-ray spectrometer
14003	Alpha/proton counter
11070	Pulse height analyzer

An X-ray fluorescence spectrometer is used to measure from lunar orbit the characteristic X-ray fluorescence lines excited in lunar surface materials by incident solar X-rays and charged particles. A sun-oriented X-ray monitor measures the direct solar X-ray contribution in order that differentiation may be made between the fluorescent X-rays and the backscattered solar radiation. Representative identifiable elements are Na, Mg, Al, Si, K, Ca, and Fe from their X-ray K-line radiation yields.

An alpha particle spectrometer is used to measure the alpha fluxes from radon (Rn^{-220} and Rn^{-222}) decay at the lunar surface. The radon decay rate in turn yields information on concentration of uranium and thorium in the surface layer of the moon.

A desirable operational mode is for all three sensors (gamma, X-ray and alpha) to operate simultaneously. A low-altitude 20-nmi polar orbiting sub-satellite is recommended. The pointing accuracy is ± 5^{o}.

A master timeline chart for Experiment 5017 is shown in Figure 4-10.

Experiment 5018

Discipline: Geophysics

Experiment ID No.: 5018

Experiment Title: Electrical Properties of Surface and Subsurface

FREQUENCY MIN. Twice / MAX. Four Times	OPERATION NO.	TIME (Hours: 0, 8, 16, 368)	CONSTRAINT	EQUIP. NO.
Set up, align, calibrate and actuate all three sensors	1	8 hrs	Screen sunlight from X-ray detector	11005 11069 14003 11070
Observe & record	2	360 hrs		11005
				11069
				14003
Deactivate	3	1 hr		

Figure 4-10. Master Timeline Experiment 5017

Applicable Subobjectives

GP-2 - To evaluate physical state and composition of lunar interior. The orbital microwave measurement of dielectric constants of materials near the lunar surface and subsequent inference as to the presence or absence of water will be a major contribution to this subobjective.

Observation Requirements

Radar scattering and reflection measurements are to be made from the lunar orbiter to the lunar surface. A radar transmitter will provide a polarized source of microwaves that while being partially reflected, has a penetration depth that increases as the conductivity of the lunar soil decreases. Average backscattering reflection coefficients will be obtained from the relative intensity of the echo signal, whose Fresnel reflection coefficient at normal incidence and the complex dielectric constant of the lunar surface may subsequently be computed. The state of polarization of the echo signal also will be measured.

A master timeline chart for Experiment 5018 is shown in Figure 4-11.

Equipment Required

Equipment No.	Equipment Name
11010	EM measurement system (10kHz to 10mHz)

Experiment 5019

Discipline: Geophysics

Experiment ID No.: 5019

Experiment Title: Thermal Anomalies and Surface Structure

Applicable Subobjectives

GP-3 - To evaluate the internal dynamics of the moon. Identification and infrared measurements of certain additional thermal anomalies, particularly those at high latitudes in near permanent solar shade, may make a major contribution to knowledge of internal heat sources and lunar energy budget. Radar imaging will provide a minor contribution toward meeting this subobjective.

FREQUENCY OF OPERATIONS	OPERATION NO.	TIME	CONSTRAINT	EQUIP. NO.
MIN. 2 · MAX. 4		0 1 2 73 74		
Deploy, calibrate and operate	1	1.0 hr (0–1)	Polar Orbit	11010
Operate	2	72 hrs (1–73)	60 NM	
Deactivate	3	1.0 hr (73–74)		
Repeat operations nos. 1 and 2 four more times within 15 days for full coverage	4			

Figure 4-11. Master Timeline Experiment 5018

Observation Requirements

Infrared Observations - An infrared scanning radiometer will be used in lunar polar orbit to identify and evaluate anomalously hot or cold regions on the portions of the lunar surface not illuminated by the sun-particularly craters in high latitudes. The result will be a temperature map of the lunar surface.

The instrumentation might typically consist of a thermister bolometer immersed in silicon, a cross-track scanner, signal-conditioning electronics package, and a beryllium heat sink. The field of view is 150 degrees (with 7.5 degrees overlap above each lunar horizon for calibration). The results should be correlated with photographic and microwave data over same field of view.

Microwave Observations - Microwave imaging of the lunar surface is to be accomplished concurrently with the IR scans described previously as well as on the sunlit side of the terminator for several angles of inclination of sunlight. Microwave emissions may indicate substructure under surface rubble to depths of 1m.

A master timeline chart for Experiment 5019 is shown in Figure 4-12.

Equipment Required

Equipment No.	Equipment Name
11013	IR radiometer
11015	Passive microwave imager (7 to 19 GHz)

Experiment 5020

Discipline: Geophysics

Experiment ID No.: 5020

Experiment Title: Spacecraft Orbital Perturbations

Applicable Subobjectives

GP-1 - To determine mass distribution and figure of the moon. This experiment, by defining spacecraft trajectories more accurately, will be a major contributor in describing mass concentrations below the lunar surface.

GP-4 - To determine the Earth-Moon mechanical interactions. Observations of amplitude of deviations from a Keplerian orbit in these experiments may yield a minor contribution toward this objective.

FREQUENCY MIN.	FREQUENCY MAX.	OPERATION NO.	TIME (0 2 4 6 8 10 … 32 34)	CONSTRAINT	EQUIP. NO.
Twice	Six times				
Set up, align, calibrate, and actuate		1	4 hrs	Observe IR only on dark side Observe microwave on dark & sunlit side	11013 & 11015
Observe and record IR & microwave on dark side 1st pass		2	1 hr	Avoid all attitudes in which radiometer is exposed to sunlight	11013 & 11015
Microwave only on sunlit side		3	1 hr		11015
IR & microwave on dark side 2nd pass		4	1 hr		11013 & 11015
Microwave only on sunlit side		5	1 hr		11015
IR & microwave on dark side 3rd pass		6	1 hr		11013 & 11015
Non-recording period		7	24 hrs		
Repeat op. no. 2 thru 7 at least 15 times		8			
Deactivate experiment			2 hrs		

Figure 4-12. Master Timeline Experiment 5019

Observation Requirements

Measurements of radar altitude and range rate will be made with a high degree of time synchronization with a radar altimeter. Altitudes will be measured to better than 10-m resolution. (Accuracy attainable will depend upon the nature of surface at subsatellite point.)

A laser altimeter (similar to that intended for later Apollo J-missions) also will be used to provide time-correlated altitude data. Laser data will also be correlated with the cartographic record from a metric camera and with spacecraft attitude obtained from a stellar camera. Field of view (protected from sun) is 200 microradians. The transmitted beam is 300 microradians. Light source is 6943-angstrom pulsed ruby laser with 200-millijoule pulses of 10-nanosecond duration at repetition rates up to 3.75 pulses per minute. Laser will be boresighted with metric camera.

A master timeline chart for Experiment 5020 is shown in Figure 4-13.

Equipment Required

Equipment No.	Equipment Name
11041	Radar Altimeter and Scatterometer
11099	Laser altimeter

Experiment 5021

Discipline: Particles and fields

Experiment ID No.: 5021

Experiment Title: Solar Wind and Energetic Particles

Applicable Subobjectives

PF-1 - To evaluate solar wind-moon interaction. The measurement of solar wind at extremly low orbital altitudes from a subsatellite is a major contribution toward meeting this objective.

PF-2 - To evaluate fundamental physics of plasma interactions. Measurement of solar wind ditributions in the vicinity of the Moon provides a major contribution to the accomplishment of this objective.

PF-4 - To measure lunar particle environment. Measurement in the near lunar space incident, reflected and secondary muclei, electrons, and radiations is a minor contribution to this objective.

FREQUENCY OF OPERATIONS MIN. Three MAX. Eight	OPERATION NO.	TIME Hours 0 3 6 9 12 24	CONSTRAINTS	EQUIP. NO.
Set up, actuate	1	3 hrs		
Warmup	2	15 min.	Pointing accuracy ±2°	11041 11099
Observe & record	3	8 hrs	Cover laser altimeter optics to prevent contamination. Avoid direct sun. Temperatures: Non-operating, 30 to 257 F; Operating, 65 to 160 F	
Non-Operating Period	4	12.75 hrs		
Deactivate	5	15 min.	Laser altimeter bore-sighted with and operated in conjunction with metric camera	
Repeat daily for 15 days	6			

Figure 4-13. Master Timeline Experiment 5020

Observation Requirements

The solar wind and energetic particles experiment is to be conducted from subsatellites launched from the OLS. The subsatellite is intended to orbit at much lower altitude than would be considered operationally safe for the OLS. Orbital altitudes should be at 10, 15, and 20 nmi and an elliptical orbit, beginning at 60 nmi and descending within 5 nmi of lunar surface. The subsatellite also provides a sensor platform with less geometrical and nuclear radiation interference to the experiment than would be possible on the OLS.

The solar wind (low-energy nuclei) will be measured by a Faraday cup plasma spectrometer viewing two directions simultaneously with wide angle cones. Simultaneous measurements from subsatellites flying at same orbital longitude at two different low lunar altitudes are proposed. A curved plate analyzer with a multisegment collector for angular resolution in polar angle of low flux higher energy solar wind particles (> 100 ev) is recommended to supplement the Faraday cup measurements.

The medium and high-energy solar and galactic nuclei will be measured by charged particle spectrometer telescopes. Each telescope consists of two or more silicon detectors operating with coincidence circuitry to establish angular distribution of particles. Absorbers placed between detectors allow energy loss measurements and discrimination among particle types. Pulse height analysis is used to determine particle energies.

Equipment Required

Equipment No.	Equipment Name
14001	Charged particle counter (Faraday cup plasma spectrometer)
14020	Medium energy-charged particle spectrometer telescope
11098	Cosmic-ray spectrometer telescope
11070	Pulse-height analyzer

A master timeline chart for Experiment 5021 is shown in Figure 4-14.

Experiment 5022

Discipline: Particles and fields

Experiment ID No.: 5022

Experiment Title: Magnetic Field

FREQUENCY OF OPERATIONS MIN. / MAX.	OPERATION NO.	TIME Hours (0, 24, 48, 820, 824, 1496)	CONSTRAINT	EQUIP. NO.
Twice per 6 mo. / Six per 6 mo.				
Experiment Preparation	1	24 hrs		
Initialization and Verification	2	8 hr		
Subsatellite Separation	3	4 hr	Measurements of charged particles are conducted simultaneously on the same sub-satellite with magnetic & electric field measurements	14001, 14020, 11098, 11070
Activation	4	4 hr		
Experiment Operation	5	4 wk		
Deploy subsatellite to new altitude	6	4 hr		
Repeat operations no. 5 & 6 at least once	7	4 wk, 4 hr		
Retrieve subsatellite & deactivate	8	5 hr		

Figure 4-14. Master Timeline Experiment 5021

Applicable Subobjectives

PF-3 - To measure the magnetic and electric field around, on, and within the Moon. Direct measurement of the magnetic field at lower altitudes than previous lunar orbiters and with higher resolution from a subsatellite will fulfill a major part of the subobjective concerned with electric fields in near lunar space.

Observation Requirements

The measurement of the magnetic field is to be conducted from the same subsatellite that carries the instrumentation for charged particle and electric field measurements. The subsatellite is intended to orbit at much lower altitudes than would normally be considered for the OLS. Magnetic field measurements at several subsatellite constant orbital altitudes of 10, 15, and 20 nmi are of interest. Also, an elliptical orbit with the subsatellite launched at a OLS orbital altitude of 60 nmi and descending to a minimum altitude of 5 nmi would provide the magnetic field values as a continuing function of altitude.

The total magnitude of the external magnetic field is to be measured by a helium magnetometer system. The heart of the system is a cell of helium vapor excited to a long-lived metastable state by irradiation with polarized infrared 1.8 micron radiation from a helium lamp and deexcited by a single from an RF source at the Larmor procession frequency in the external magnetic field. The absorption in the cell is monitored with a lead sulfide detector. The density of excited He atoms, and consequently the absorption, varies with a frequency directly proportional to the magnetic field (23 Hz per gamma of field intensity).

Because the vector magnetic field is required and the helium magnetometer is a scalar device, the cell is surrounded by a set of three orthogonal Helmholtz coils carrying currents that are varied to nullify the total external field. The nullifying coil currents constitute the output of the instrument and are a measure of the components of the total magnetic field vector.

Equipment Required

Equipment No.	Equipment Name
15010	Helium magnetometer

Master Timeline

Because the magnetic field measurements in near lunar space are made on the same subsatellite that carries the instrumentation to measure the particles and fields and are to be made simultaneously with the latter measurements, the master timeline will be similar to that for the particles and fields measurements (Experiment 5021).

Constraints

The extraneous magnetic fields from the subsatellite will be minimized, while ensuring that the Helmholtz coils adequately compensate for any remaining extraneous fields in a known manner.

Experiment 5023

Discipline: Particles and Fields

Experiment ID No.: 5023

Experiment Title: Electric Field

Applicable Subobjectives

PF-1 - To measure solar wind--moon interaction. Electric field measurements in near lunar space provides a major contribution to the achievement of this objective.

PF-2 - To evaluate fundamental physics of plasma interactions. Electric field measurements provide a major contribution to the achievement of this objective.

PF-3 - To determine magnetic and electric fields. This subobjective is partially met by measurement of electric field in lunar space.

Observation Requirements

The measurement of the electric field is to be conducted from the same subsatellite that carries the instrumentation for charged particles and magnetic field measurements. The subsatellite is intended to orbit at much lower altitudes than would normally be considered for the OLS. Electric field measurements at several subsatellite constant orbital altitudes of 10, 15, and 20 nmi are of interest. Also, an elliptical orbit with the subsatellite launched at a OLS orbital altitude of 60 nmi and descending to a minimum altitude of 5 nmi could provide electric field values as a continuous function of altitude.

The electric field measurements may be made by a dipole antenna-type electric field detector. Provision is made to filter out the unwanted high-frequency noise (e.g., above 20 kHz) before preamplification followed by further signal conditioning in the form of several narrow-band filters with rectified outputs to a recorder and/or telemetry. Provision also should be made to correlate the electric field measurements simultaneously with the measured magnetic field.

Equipment Required

Equipment No.	Equipment Name
15009	Electric field detector

Master Timeline

Because the electric field measurements in near lunar space are made on the same subsatellite that carries the instrumentation to measure the magnetic field and charged particles and are made simultaneously with the latter measurements, the master timeline will be similar to that for the particles and fields measurements (Experiment 5021).

Constraints

Isolation from spacecraft electric fields and wake effects will be provided by mounting the electric field dipole on the far side of a 6 foot boom.

Experiment 5024

Discipline: Lunar Atmosphere

Experiment ID No.: 5024

Experiment Title: Total Pressure

Applicable Subobjectives

LA-1 - To determine the total quantity and distribution of the component species of the lunar atmosphere. The measurement of the total pressure will be a major contribution toward meeting this subobjective.

LA-3 - To monitor atmospheric contamination resulting from lunar missions, including transport and escape rates. After the unperturbed total pressure values for the lunar atmosphere have been obtained, measurements of increased total pressure levels, if present, as a function of time after contamination from lunar missions will be a major contribution toward meeting this subobjective.

Observation Requirements

Total pressure measurements are required from an anticipated lunar surface atmospheric value of 10^{-10} torr to that in interplanetary space of 10^{-14} torr with ability to sense variations of 10^{-15} torr at lunar orbital altitudes. To obtain altitude profiles as well as any longitudinal variations from solar influences, the total pressure should be measured from a subsatellite at several lunar circular orbital altitudes (e.g., 10, 15, and

20 nmi) as well as an elliptical orbit, the latter initiated from the OLS orbital altitude (e.g., 60 nmi) and having the lowest possible perigee (e.g., 5 nmi).

The Redhead cold-cathode ionization gauge has been recommended for measurement of lunar atmospheres. Present gauge sensitivities require improvement in sensitivities of 2 to 3 orders of magnitude to yield the desired 10^{-15} torr sensitivity figure.

The total pressure measurements are intended to be performed simultaneously with measurements of composition of the lunar atmosphere and measurements of escape and transport rates. A mass spectrometer, primarily intended for composition measurements, also may provide partial pressure data for each species and when used with an electron multiplier as a detector will yield 10^{-13} to 10^{-14} torr for scan times of several minutes (according to the Santa Cruz report). The summation of the partial pressure data over all species should, in principle, give a measure of the total pressure.

Equipment Required

Equipment No.	Equipment Name
12001	Ionization pressure sensor
14005	Mass Spectrometer

A master timeline chart of Experiment 5024 is shown in Figure 4-15.

Experiment 5025

Discipline: Lunar atmosphere

Experiment ID No.: 5025

Experiment Title: Composition of Lunar Atmosphere

Applicable Subobjectives

LA-1 - To determine the total quantity and distribution of the component species of the lunar atmosphere. The measurement of the composition of the lunar atmosphere is a major contribution toward this subobjective.

LA-3 - To monitor atmospheric contamination resulting from lunar missions, including transport and escape rates. The measurement of atmospheric composition in contaminated regions as a function of time after lunar operations and comparison with measurements in the same or similar regions before contamination (if possible), will be a major contribution to this subobjective.

FREQUENCY OF OPERATIONS MIN. MAX.	OPERATION NO.	TIME Hours (0, 24, 48, 760, 1484)	CONSTRAINT	EQUIP. NO.
Experiment Preparation	1	24		
Initialization and Verification	2	8	The lunar atmosphere subsatellite will also measure composition and transport rates simultaneously	
Subsatellite Separation	3	4		
Activation	4	4		
Experiment Operation	5	720		12001 14005
Deploy satellite to a new altitude	6	4		
Repeat operations nos. 5 and 6 three times	7	720		
Retrieve subsatellite and deactivate	8	5		

Figure 4-15. Master Timeline Experiment 5024

Observation Requirements

The identification and measurement of major and minor lunar atmospheric components up to 150 mass units and resolvable to the nearest mass unit are required. A mass spectrometer includes a sample introduction system, an ion source (in which positive atomic or molecular ions are created from the sample gas by electron impact), a mass analyzer (quadrupole type), and a detector.

The quadrapole type mass analyzer is preferred over the simpler sector magnetic analyzer to avoid magnetic field interference with other systems. However, radio frequency shielding is required.

The mass spectrometer is to be flown on a subsatellite and operated concurrently with the total pressure and transport rate experiments as well as with the remote geochemical analysis experiment.

Measurements of UV spectral emissions from lunar atmosphere by resonance reradiation of absorbed solar flux in the 1000 to 4000 angstrom range are also required. Representative instrumentation is a Far UV Ebert spectrometer (grating type) with collecting optics, photomultiplier tube and pulse-counting circuitry.

Equipment Required

Equipment No.	Equipment Name
14005	Mass spectrometer
11008	UV imager/spectrometer

Master Timeline

Master timeline is identical with that for measurement of total pressure (Experiment 5024).

Experiment 5026

Discipline: Lunar Atmosphere

Experiment ID No.: 5026

Experiment Title: Escape and Transport Rates in Lunar Atmosphere

Applicable Subobjectives

LA-2 - To determine the principal natural atmospheric source, loss and transport mechanisms and their rates. The measurement of escape and transport rates is a total contribution to this subobjective.

LA-3 - To monitor atmospheric contamination resulting from lunar missions, including transport and escape rates. The measurement of escape and transport rates will, in the presence of contamination from lunar mission, provide data on the more rapid transport processes and will be a major contribution to this subobjective.

Observation Requirements

Measurements are to be made of the escape and transport rates of the components of the lunar atmosphere. Attempts should be made to measure the escape of both the natural atmospheric components and the contaminants from lunar mission operations. A collimated mass spectrometer can be used, in principle, to provide directional discrimination. Because the velocity of escape of an atom or molecule is independent of its mass, velocity selection by a chopper can be used to separate escaping from trapped particles. Species (i.e., mass) separation can then be accomplished inside the mass spectrometer. Measurements should be taken on both the sunlit and dark hemispheres during periods of both high and low solar activity. Also, in conjunction with orbital overflights of manned surface activity, releases of 100 mole volumes of gaseous mixtures (e.g., He, Ne, and Ar) from the lunar surface should be made and the escaping flux monitored at orbital altitudes.

Equipment Required

Equipment No.	Equipment Name
14005	Mass spectrometer

Master Timeline

Master timeline for this experiment is the same as that for the total pressure experiment (5024), with the additional operational constraint in the present experiment that two additional directions of reception of escaping lunar particles by the collimated mass spectrometer be introduced within the same time shcedule.

Experiment 5027

Discipline: Astronomy

Experiment ID No.: 5027

Experiment Title: Radio Interference from Earth

Applicable Subobjectives

AY-6 - To conduct radio and optical observations of solar system sources. Because the earth is believed to be one of the more important radio sources, this experiment is a major contributor toward meeting the subobjective.

Observation Requirements

One or more wide-band receivers covering the 100-kHz to 3-GHz interval will be used in conjunction with an extensible wide-band antenna system to evaluate earth radio noise and compare it with contributions from other principal radio sources. Occultation by the lunar horizon will be used to differentiate among sources. Of particular interest will be frequencies below terrestrial ionospheric cutoff at 10 MHz. Lunar surface also should be scanned to ascertain competition of earth radiation with lunar surface noise in subsequent surface based measurements.

A master timeline chart for Experiment 5027 is shown in Figure 4-16.

Equipment Required

Equipment No.	Equipment Name
30004	Wide-band receiver (10 kHz to 10
30007	Wide-band receiver (10 MHz to 3 GHz)
11064	Antenna system (10 kHz to 10 MHz)
11059	Antenna system (10 MHz) to 100 GHz)

Experiment 5028

Discipline: Geophysics

Experiment ID No.: 5028

Experiment Title: Gravity Gradient

Applicable Subobjectives

GP-1 - To determine mass distribution and figure of the moon. The use of a gravity gradiometer to determine a more detailed description of the lunar gravitational field will be a major contribution toward meeting this subobjective.

Observation Requirements

The measurement of the vertical component of the lunar gravity gradient, with a nominal value of 3×10^{-10} sec^{-2}, is required to an estimated accuracy of one part in 10^4. To define lunar internal mass anomalies with dimensions of less than 40 km, an orbital gravity gradiometer system is required. An instrument capable of this sensitivity is technically feasible, but previous development work has been minimal. At least two types of instruments are known to be under development: the seismometer type (Grumman) and vibrating string accelerometer type (Hughes). The seismometer type appears at this time to show more promise.

FREQUENCY MIN.	FREQUENCY MAX.	OPERATION NO.	TIME Hours (0 1 2 3 4 5 6 7 8 9 10 11 12 13)	CONSTRAINT	EQUIP. NO.
5 times per 3 days	9 times per 6 days				
Deploy antennas in anti-lunar direction.		1	1 hr		30007 11059 30004 11064
Actuation, warmup, alignment & calibration		2	4 hrs		
Repeat op. no. 1 to view lunar surface		3	1 hr		
Repeat op. no. 2 to view lunar surface at least		4	4 hrs		
Observe and record Repeat at least 4 times per 3 days		5	1 hr, 1 hr	Adjust repeated observation periods to view desired occultation differentiated sources and desired lunar surface elements	
Deactivate experiment		6	2 hrs		

Figure 4-16. Master Timeline Experiment 5027

To produce high-resolution (approximately 20 km) gravity anomaly maps an orbital altitude of 20 nmi is suggested. Experiment should be performed from an unmanned subsatellite employing gravity gradient stabilization. Orbit eccentricity must be held to less than 0.01, and initial oscillations of attitude must be damped out before measurements begin. Readings should be correlated with laser altimeter and time.

A master timeline chart for Experiment 5028 is shown in Figure 4-17.

Equipment Required

Equipment No.	Equipment Name
15007	Gravity Gradiometer

FREQUENCY MIN.	FREQUENCY MAX.	OPERATION NO.	TIME (Hours: 0, 6, 12, 14, 734)	CONSTRAINT	EQUIP. NO.
Once	Four times				
Set up, align and calibrate		1	8 hrs		
Launch subsatellite and stabilize		2	6 hrs	Circular orbit - Eccentricity less than 0.01	15007
Observe and record		3	720 hrs		
Deactivate		4	2 hrs		
Alternate: Retrieve & inject into new orbit, repeat items 2, 3 and 4					

Figure 4-17. Master Timeline Experiment 5028

4.4.4 Lunar Orbit Experiment Equipment Summary

Table 4-12 presents the required lunar orbit experiment equipment together with the electrical power requirements and the weights and volumes of each major piece of equipment. The items marked (SS) will be carried on subsatellites in this model program as a consequence of the mode selection presented previously.

Individual lunar orbit experiment sensor/equipment descriptor sheets are also presented in this section. The equipment descriptor sheets present equipment technical and physical characteristics as well as recording the consumables required, electrical power requirements, calibration, and maintenance requirements, OLS attitude stabilization requirements, data requirements that include command and control signals, and special operational and environmental requirements if any. All integrated OLS scientific support requirements are derived from this tabulation of data.

Table 4-12. Experiment Equipment List

Equipment No.	Equipment Name	Average, Power (Watts)	Weight (lb)	Volume (cu ft)	Experiments Supported (Experiment Nos.)
10000 SENSORS					
11000 ELECTROMAGNETIC SENSORS					
11002	Metric camera (6-inch)	250.0	250.0	14.0	5013, 5014
11005	Gamma-ray spectrometer	10.0	85.0	2.0	5017 (SS)
11007	Microwave radiometer	30.0	40.0	1.5	5019
11008	UV imager/spectrometer	14.0	50.0	1.5	5002, 5025 (SS)
11009	Radar reflectometer	50.0	30.0	2.6	5002 (SS)
11010	EM measurement system	50.0	180.0	1.6	5018 (SS)
11012	Radar imager	800.0	400.0	22.0	5002
11013	IR radiometer	100.0	100.0	2.0	5002, 5019
11015	Passive microwave imager	150.0	100.0	2.7	5019
11041	Radar altimeter/scatterometer	80.0	52.0	3.4	5020
11042	High Res. camera	25.0	300.0	6.0	5002, 5014, 5016
11059	Antenna (10-MHz to 100-GHz)	Subassembly of 11009			5027 (SS)
11064	Antenna (10-kHz to 10-MHz)	Subassembly of 11010			5027

Table 4-12. Experiment Equipment List (Continued)

Equipment No.	Equipment Name	Average, Power (Watts)	Weight (lb)	Volume (cu ft)	Experiments Supported (Experiment Nos.)
11043	Metric camera (3-inch)	10.0	110.0	7.0	5013, 5014, 5015
*11086	Neutron activation analysis equipment	25.0	35.2	0.42	5006
*11096	X-ray diffractometer	10.0	20.0	0.70	5006
11069	X-ray spectrometer	12.0	18.0	0.3	5017 (SS)
11070	Pulse height analyzer	8.0	6.0	0.1	5017 (SS), 5021 (SS)
11099	Laser altimeter	54.0	35.0	2.0	5013, 5020
11098	Cosmic ray spectrometer telescope	1.5	7.3	0.04	5021 (SS)
12000 PRESSURE SENSORS					
12001	Ionization pressure sensor	6.0	2.2	0.002	5024 (SS)
14000 PARTICLE SENSORS					
14001	Charged particle counter (low-energy)	0.5	10.0	0.4	5021 (SS)
14003	Alpha proton counter	2.0	20.0	1.0	5017 (SS)
14005	RF mass spectrometer	12.0	15.0	0.9	5024 (SS), 5025 (SS), 5026 (SS)
*14018	Gas chromatograph	15.0	55.0	2.15	5006

Table 4-12. Experiment Equipment List (Continued)

Equipment No.	Equipment Name	Average, Power (Watts)	Weight (lb)	Volume (cu ft)	Experiments Supported (Experiment Nos.)
14020	Particle spectrometer	3.0	10.0	0.2	5021 (SS)
*14026	Solids mass spectrometer	3.0	50.0	0.6	5006
	15000 FIELD SENSORS				
15007	Gravity gradiometer	10.0	21.0	0.36	5028 (SS)
15009	Electric field detector	3.0	5.0	1.0	5023 (SS)
15010	Helium magnetometer	5.0	11.0	0.1	5022 (SS)
	30000 STORAGE/TRANSMISSION/RECEIVING EQUIPMENT				
30004	Receiver (10-kHz to 10-MHz	Neg.	20.0	0.25	5027
30007	Receiver (10-MHz to 3-GHz)	Neg.	20.0	0.25	5027
	40000 PROCESSING EQUIPMENT				
40006	Signal conditioning equipment	20.0	20.0	1.0	All
40007	Data analysis laboratory	450.0	117.0	500.0	All
40008	Photography laboratory	200.0	1500.0	500.0	All

Table 4-12. Experiment Equipment List (Continued)

Equipment No.	Equipment Name	Average, Power (Watts)	Weight (lb)	Volume (cu ft)	Experiments Supported (Experiment Nos.)
50000 GENERAL SUPPORT EQUIPMENT					
*50006	Sample preparation device	500.0	52.6	23.0	5006
50011	Geochemistry laboratory	1200.0	2500.0	75.0	5006
60000 SMALL SATELLITES					
60004	P & F subsatellite	10.0	140.0	20.0	5021 (SS), 5022 (SS), 5023 (SS)
60005	Gravity gradiometer subsatellite	10.0	140.0	20.0	5028 (SS)
60006	Geochemical and atmospheric subsatellite	50.0	950.0	150.0	5017 (SS), 5024 (SS), 5025 (SS), 5026 (SS)
90000 MISCELLANEOUS EQUIPMENT					
*90008	Petrographic microscope	100.0	5.0	0.35	5006

(SS) - subsatellite experiment

*Items included in 50011 geochemistry laboratory
(SS)Items constituting parts of subsatellite payloads

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11002
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Metric Camera (6 inches)

General Characteristics:

Terrain Camera: Hycon HC 489, 6-inch focal length; 74° field of view, 9 x 9-inch film; shutter speed 1/100 to 1/1000 second.

Stellar Camera (2): 9-inch focal length, 14° field of view, 70 x 70 M/M film; 95° to 100° line of sight from terrain and 40° to 90° to each other; exposure sequence such as to provide 60% overlap.

Supports Experiments 5013 and 5014.

2. PHYSICAL CHARACTERISTICS

Weight: 250 pounds

Power: 250 watts average, 400 watts maximum

Volume: 14.0 cubic feet

3. CONSUMABLES

Film 9 x 9 inch; 14 lb/mission
Film 70 x 70 M/M; 8 lb/mission

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

±10 feet in altitude (attitude provided by integral Stellar camera)

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degrees (continuous while mapping)

Equipment No. 11002
Page No. 2

5. DATA DESCRIPTION

Film (cassettes); 33 lb film/cassette

5 analog channels; 1 BPS

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF/STANDBY Switch - one

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Temperature 5° to 30 C (film limitations)

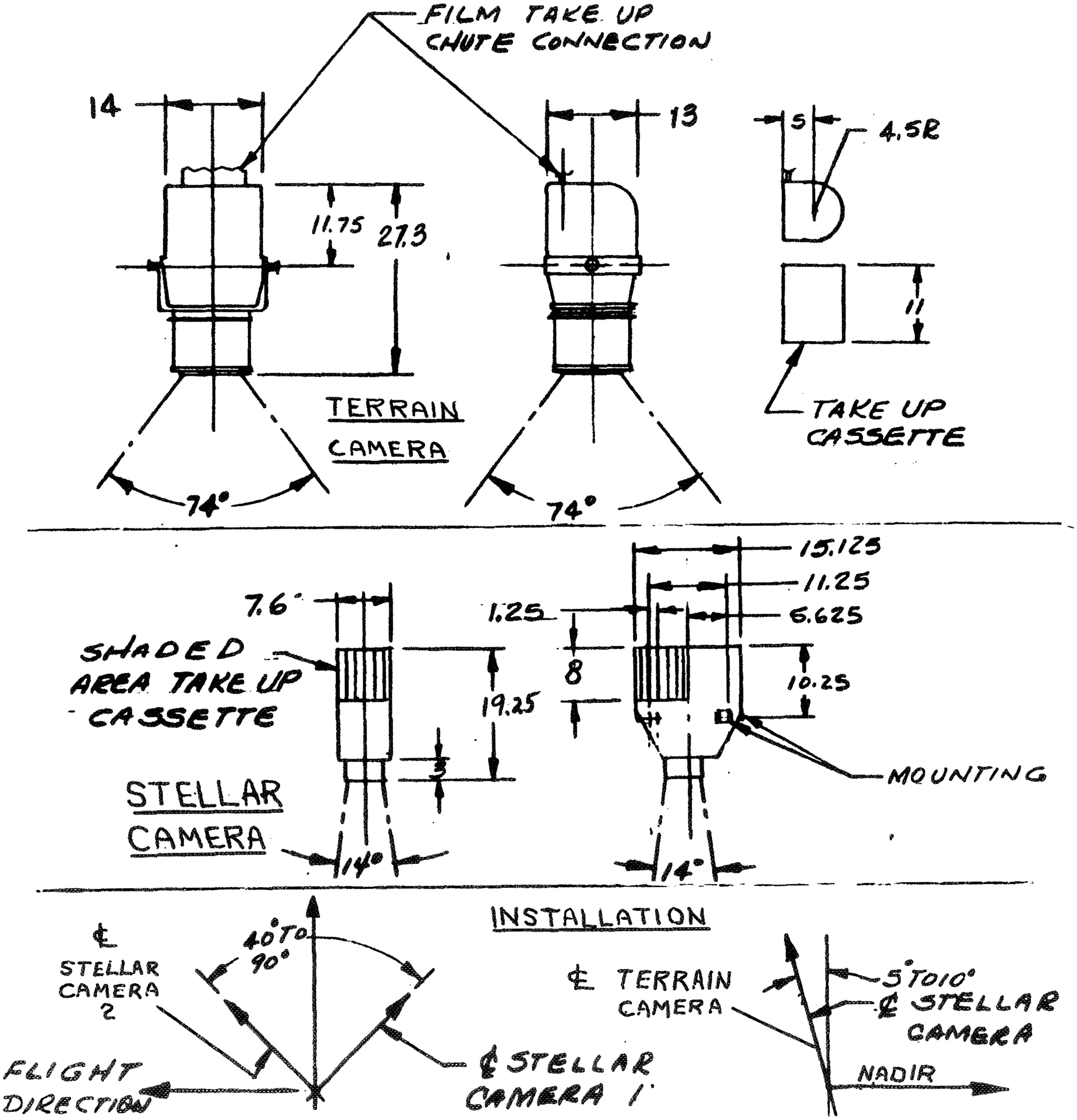
Operates only on sunlit side of moon (15 to 40°)

8. REMARKS

1. Average thermal output 900 Btu/hr
2. Power required: 28 vdc
3. Cycle camera once each 24 hours to prevent film set

Equipment No. 11002
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11005
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Gamma Ray Spectrometer

General Characteristics:

Range 0.3 to 1.0 x 10^{10} Mev/gamma

Supports Experiment 5017
Contained in geochem and atmospheric subsatellite (Equipment 60006)

2. PHYSICAL CHARACTERISTICS

Weight : 85.0 pounds   Power: 10 watts

Volume : 2.0 cubic feet

Support equipment required: Pulse height analyzer 11070

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

See subsatellite equipment #60006 for data output

Analog, 10 samples per second

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment #60006

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Temperature +20 C to +30 C

Not to be exposed to magnetic flux > 2 Gauss

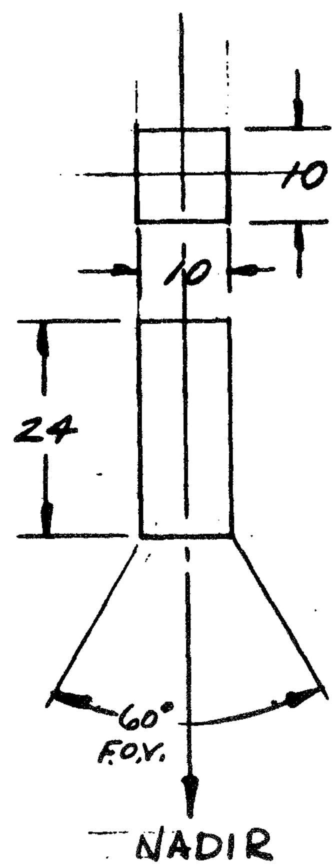
8. REMARKS

1. Average thermal output 36 Btu/hr
2. Power source: 28 vdc
3. Must be boom mounted 12 feet from S/C

Equipment No. 11005
Page No. 3

9. CONFIGURATION SKETCHES

GAMMA RAY SPECTROMETER



MOUNTED ON BOOM 12FT FROM SPACE CRAFT

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11007
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Microwave Radiometer

General Characteristics:

Supports Experiment 5019

Measures microwave frequency over range 19.25 to 19.45 GHz

2. PHYSICAL CHARACTERISTICS

Weight: 40.0 pounds

Power: 30 watts

Volume: 1.5 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:
± 2000 feet; ± 0.25 degree

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degree (continuous while operating)

5. DATA DESCRIPTION

Digital; 150 BPS (altitude dependent)

Analog (5 channels); 8 bits/word at 1 SPS/channel

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Switch (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

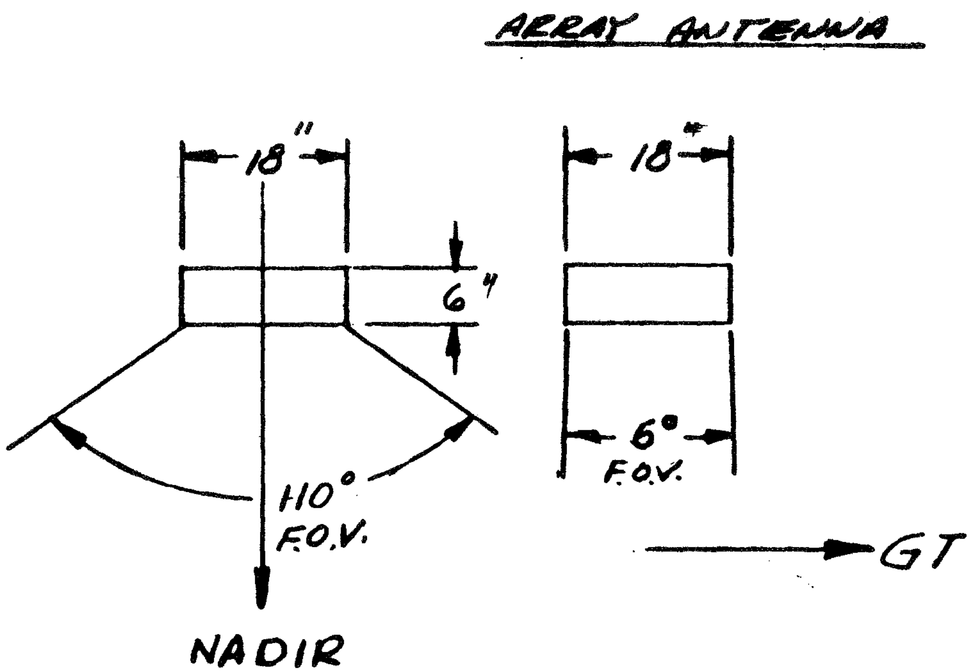
No EM waves 0.8 microns or longer

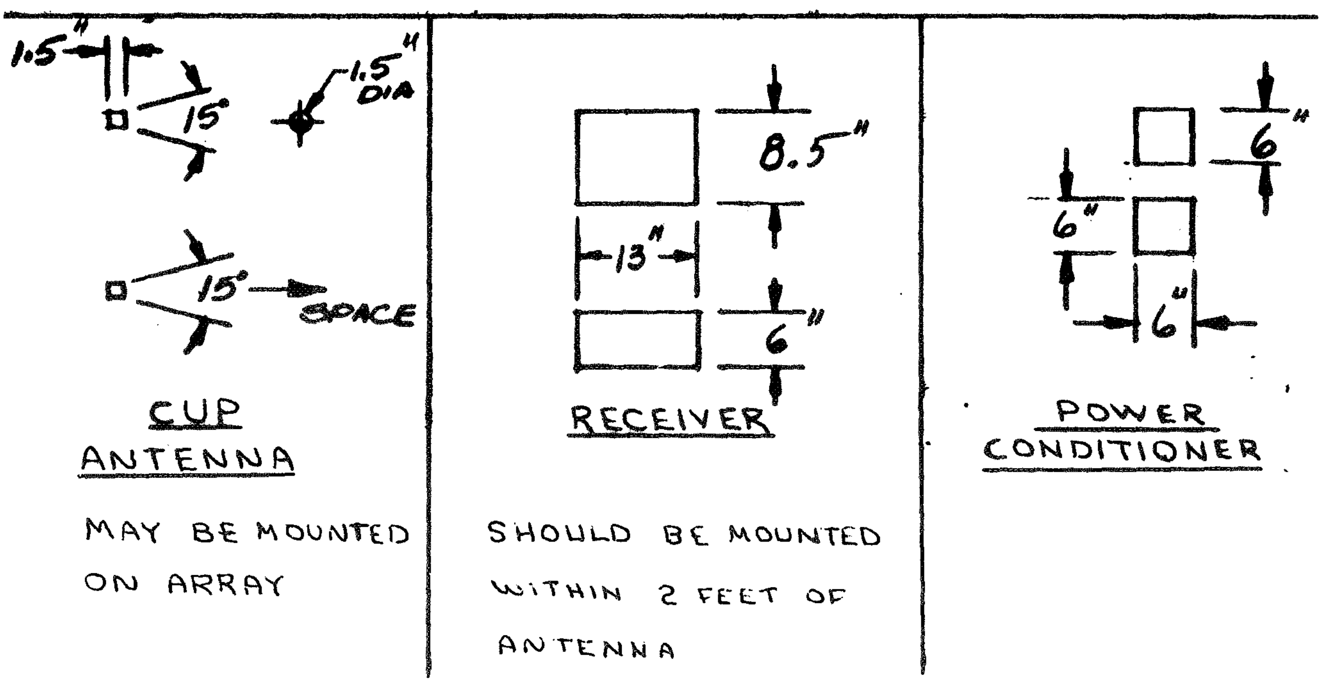
8. REMARKS

1. Average thermal output 51 Btu/hr
2. Power source required: 28 vdc
3. Power conditioner converts 28 vdc to 24.5 vdc by electronics

9. CONFIGURATION SKETCHES

MICROWAVE RADIOMETER





SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11008
Page No. 1

1. GENERAL INFORMATION

Equipment Name: UV Imager/Spectrometer

General Characteristics:

Supports Experiments 5002 and 5025

Measures reflected and emitted power over the range 1800 to 4000 angstroms

2. PHYSICAL CHARACTERISTICS

Weight : 50.0 pounds

Power: 14 watts

Volume : 1.5 cubic feet

Support equipment required: 35 mm film in cassettes (10 lb each)

3. CONSUMABLES

35 mm film; 20 lb/mission

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

± 2000 feet; ± 0.25 degree

Attitude Reference: Nadir; inertial; horizon

Attitude Hold Limit: ± 0.25 degree

Equipment No. 11008
Page No. 2

5. DATA DESCRIPTION

35 mm film

5 analog channels; 1 sample per second

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Control Switch (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Equipment to be free from high ionizing flux; free from dust

Temperature limits: Imager -10 to 50 C
Film recorder +5 to +30 C

Equipment operates only on sunlit side of moon

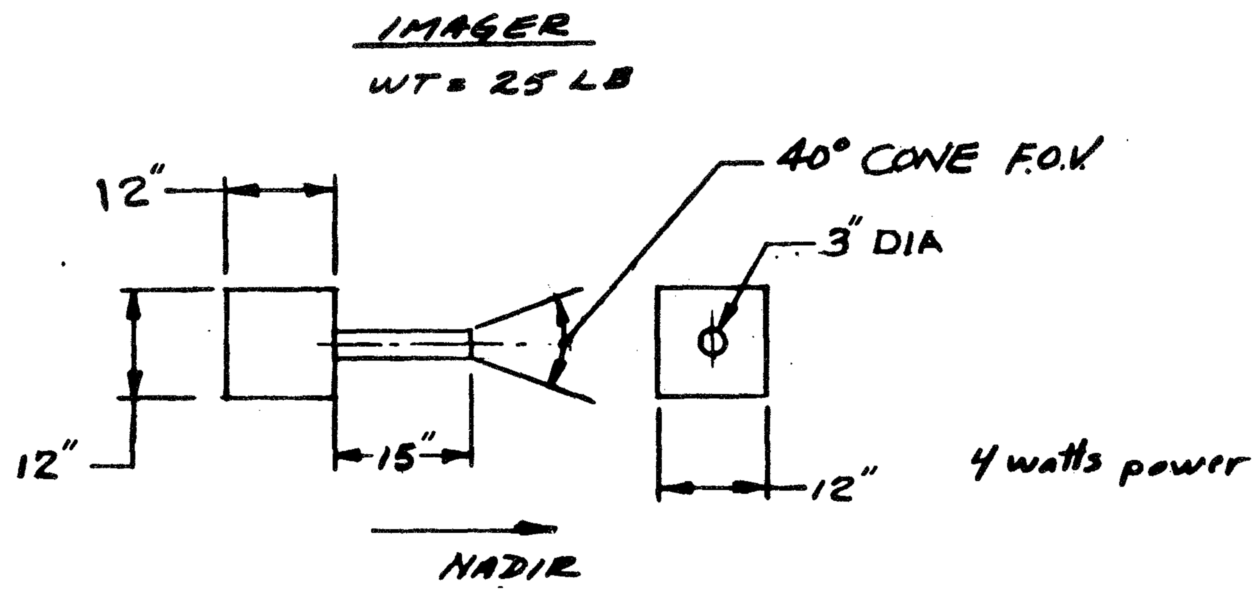
8. REMARKS

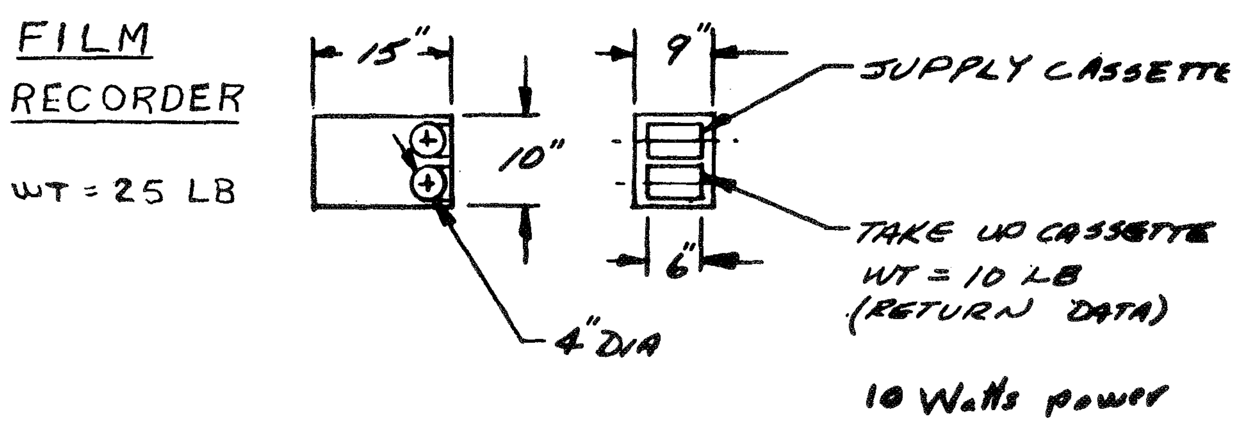
1. Average thermal output 30 Btu/hr
2. Power source required: 28 vdc
3. Unit includes 35 mm film recorder

Equipment No. 11008
Page No. 3

9. CONFIGURATION SKETCHES

UV IMAGER / SPECTROMETER





SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11009
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Radar Reflectometer

General Characteristics:

Supports Experiments 5002 and 5027

Measures frequency over range 10 MHz to 10 GHz (equipment operates in three particular frequencies in this range - 10 MHz, 1 GHz, and 100 GHz)

2. PHYSICAL CHARACTERISTICS

Weight: 30.0 pounds

Power: 50 watts

Volume: 2.6 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track ± 2000 feet;
Cross-track ± 2000 feet

± 0.2 degree

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.5 degree

5. DATA DESCRIPTION

3 digitial channels; 10,000 bits/channel

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Switch; Frequency mode select SW (3 Pos) (two)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

No EM waves 0.8 microns or longer

Temperature -10 C to +65 C

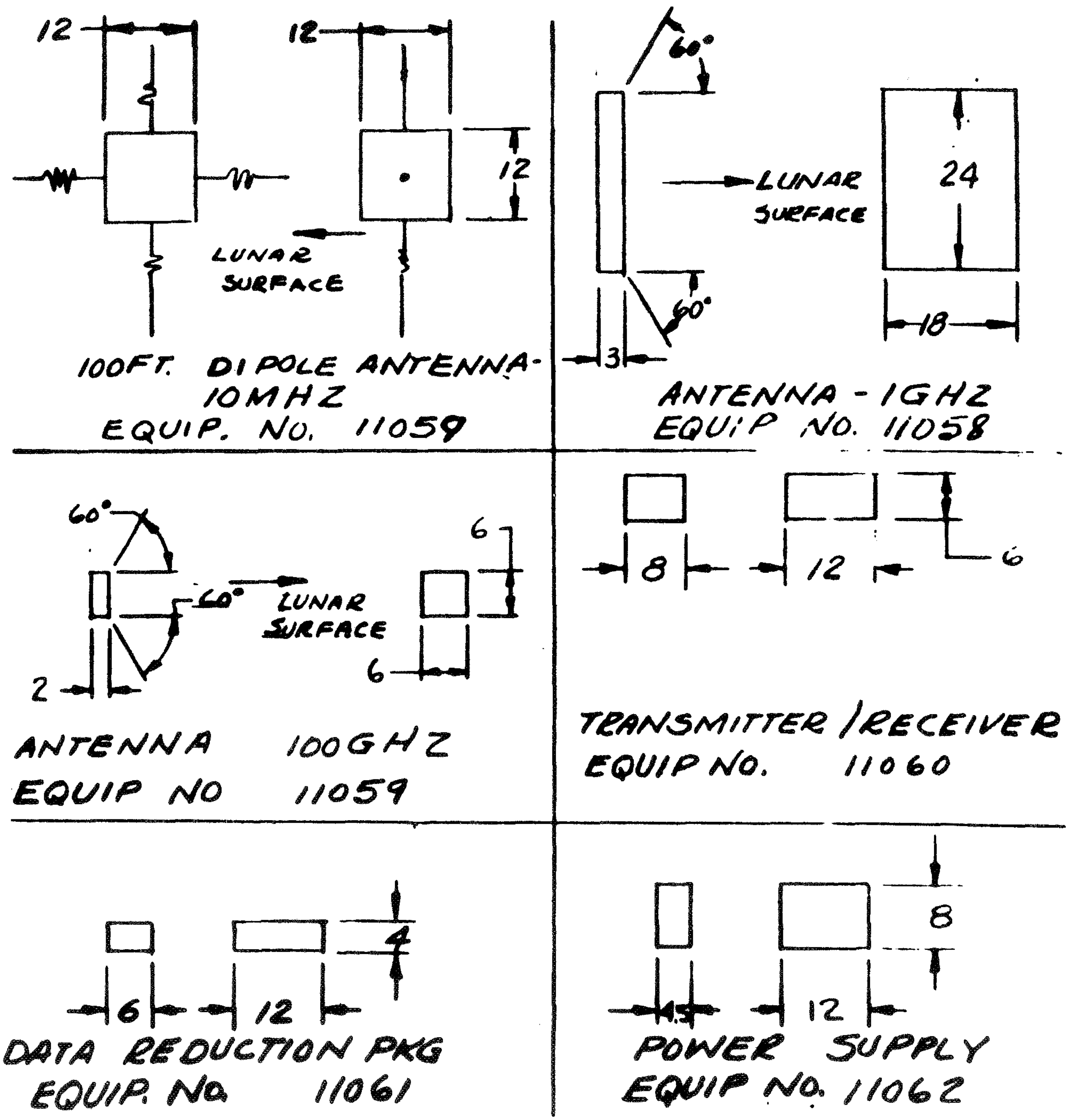
8. REMARKS

1. Average thermal output 120 Btu/hr
2. Power source required: 28 vdc
3. This equipment item consists of the following subassemblies: 11057, 11058, 11059, 11060, 11061, and 11062

Equipment No. 11009
Page No. 3

9. CONFIGURATION SKETCHES

RF REFLECTOMETER



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11010
Page No. 1

1. GENERAL INFORMATION

Equipment Name: EM Measurement System

General Characteristics:

Supports Experiments 5018 and 5027

Range 10 kHz to 10 MHz

2. PHYSICAL CHARACTERISTICS

Weight : 180.0 pounds

Power: 50 watts (self contained)

Volume : 1.6 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

± 1 nautical mile; ± 5 degrees

Attitude Reference: Nadir

Attitude Hold Limit: ± 5 degrees (while operating)

5. DATA DESCRIPTION

Digital; 1000 BPS

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Switch; Frequency mode select SW (2 Freq) (two)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

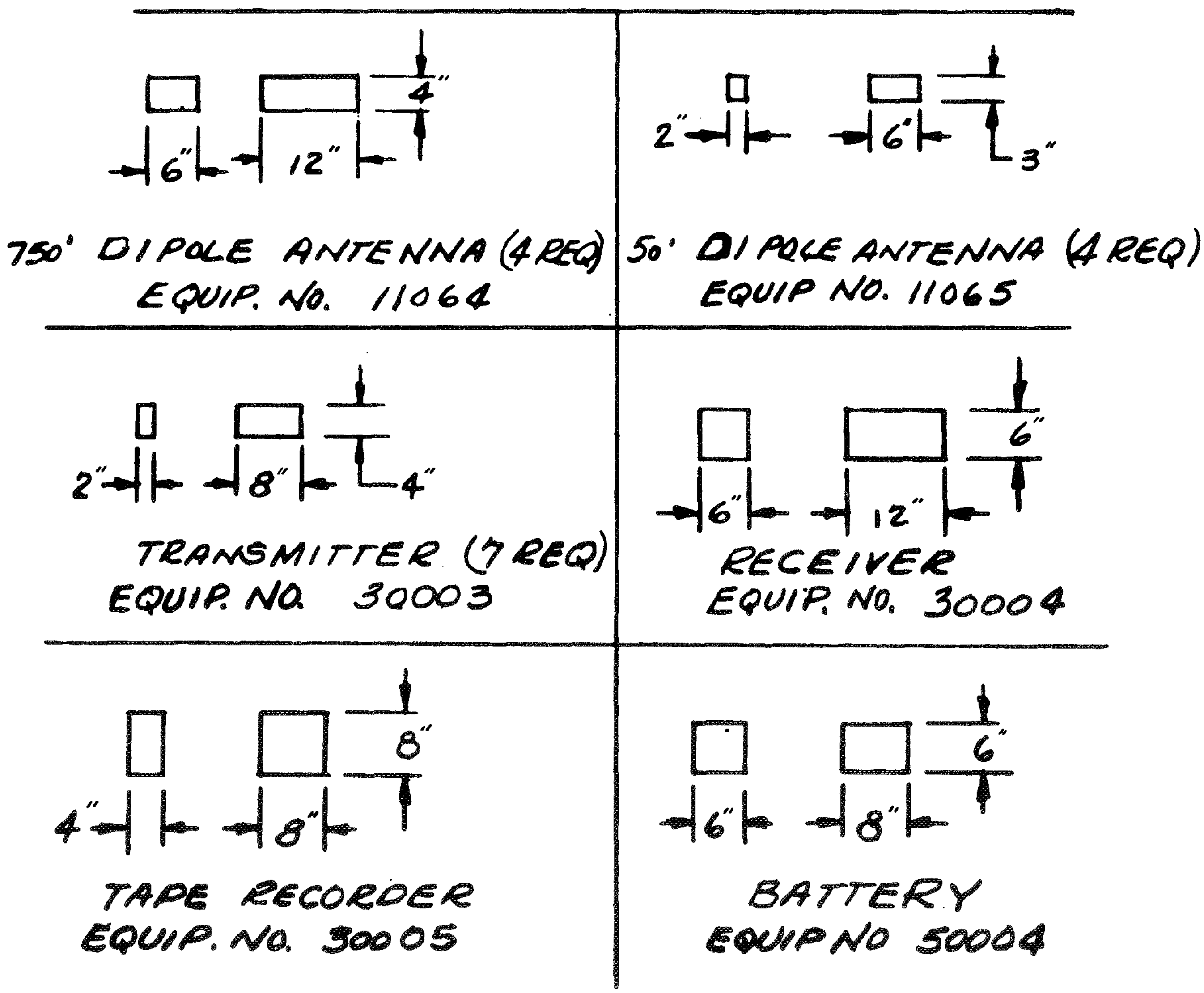
8. REMARKS

1. Average thermal output 180 Btu/hr
2. This equipment item consists of the following subassemblies: 11064, 11065, 30003, 30004, 30005, 50004
3. Power source required: None - self contained

Equipment No. 11010
Page No. 3

9. CONFIGURATION SKETCHES

ELECTRO MAGNETIC MEASUREMENTS



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11012
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Radar Imager

General Characteristics:

Supports Experiment 5002

Range 8.0 to 10.0 GHz

2. PHYSICAL CHARACTERISTICS

Weight : 400.0 pounds

Power: 800 watts

Volume : 22.0 cubic feet

Support equipment required: Film cassettes (10 lb each)

3. CONSUMABLES

70 mm film; 20 lb/mission

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track ± 1000 feet;
Cross-track ± 1000 feet
(Altitude provided by experiment data)

± 0.2 degree

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.5 degree

Equipment No. 11012
Page No. 2

5. DATA DESCRIPTION

Film (cassettes); 20 lb/mission

20 channels; 0.1 sample per second

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Control Switch; Frequency mode SW (two)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

No EM waves 0.8 microns or longer

Antenna and Electronics: -20 C to +75 C; Recorder: +5 C to +30 C

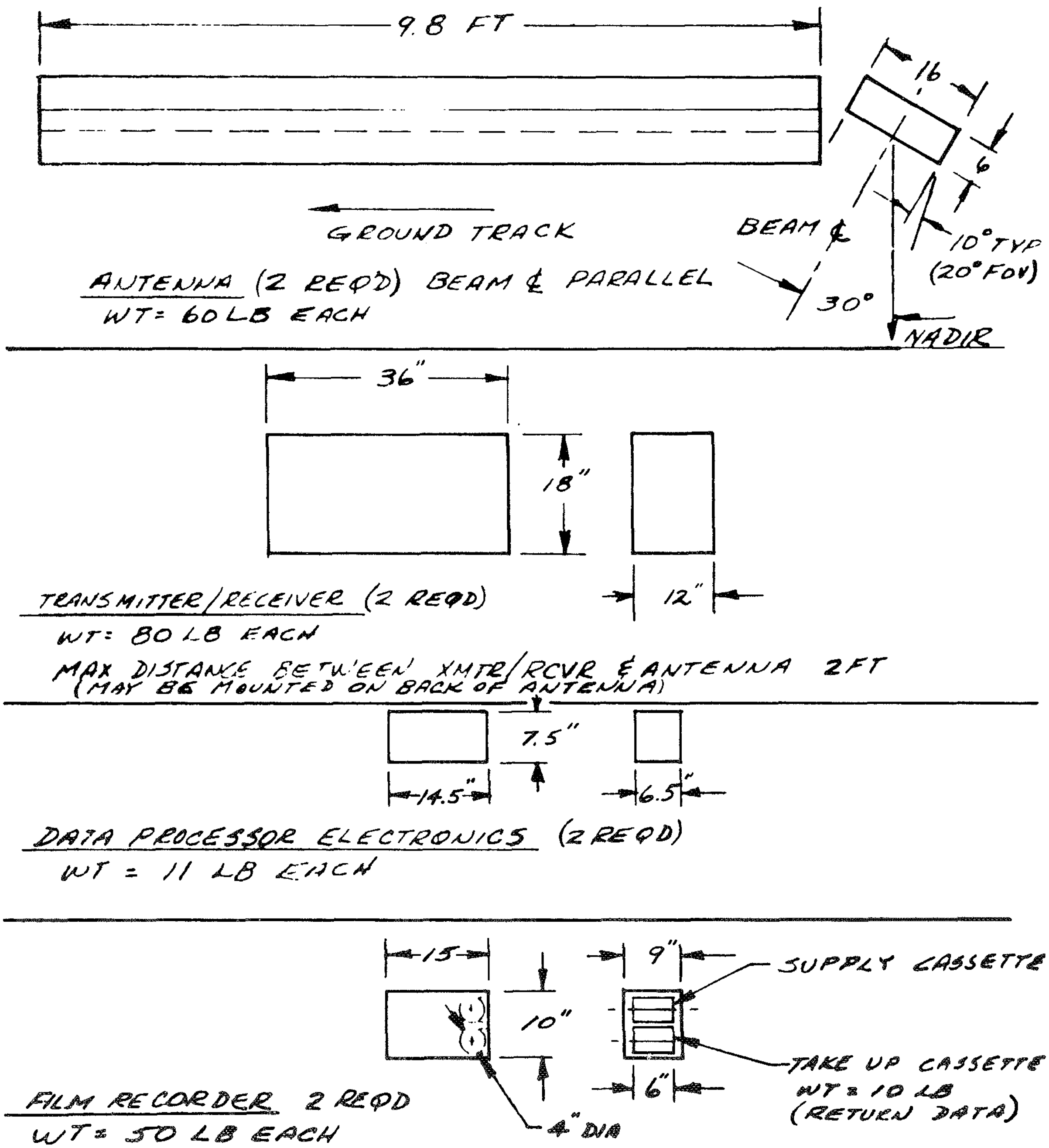
8. REMARKS

Power supply required: 28 vdc

Equipment No. 11012
Page No. 3

9. CONFIGURATION SKETCHES

RADAR IMAGER



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11013
Page No. 1

1. GENERAL INFORMATION

Equipment Name: IR Radiometer

General Characteristics:

Supports Experiments 5002 and 5019

Measures emitted energy in wavelength region 1.0 to 50.0 microns

2. PHYSICAL CHARACTERISTICS

Weight: 100.0 pounds

Power: 100 watts

Volume: 2.0 cubic feet

3. CONSUMABLES

Film, .17 ft^2/200 x 200 km surface coverage

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track 0.5 nautical miles;
Cross-track 0.5 nautical miles
Altitude ± 1000 feet

± 0.25 degree

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degree

5. DATA DESCRIPTION

Film; .17 ft^2/40,000 sq. km at 120 n mi altitude

Analog; 20 samples per second

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Control SW (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Low temperature ($<$ 30 C)

Frequency from high ionizing radiation flux and dust

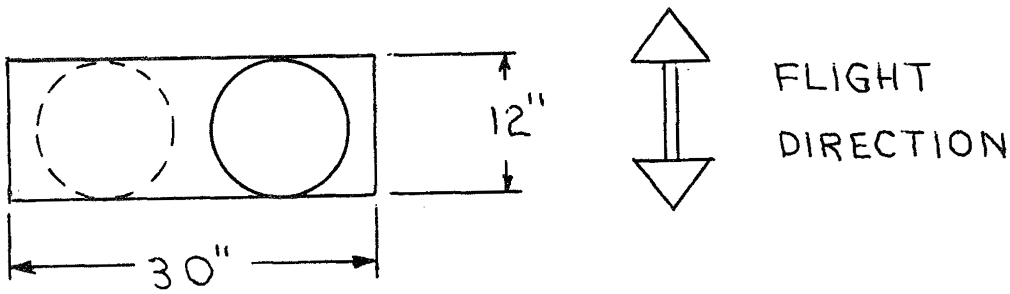
Darkness or low illumination required

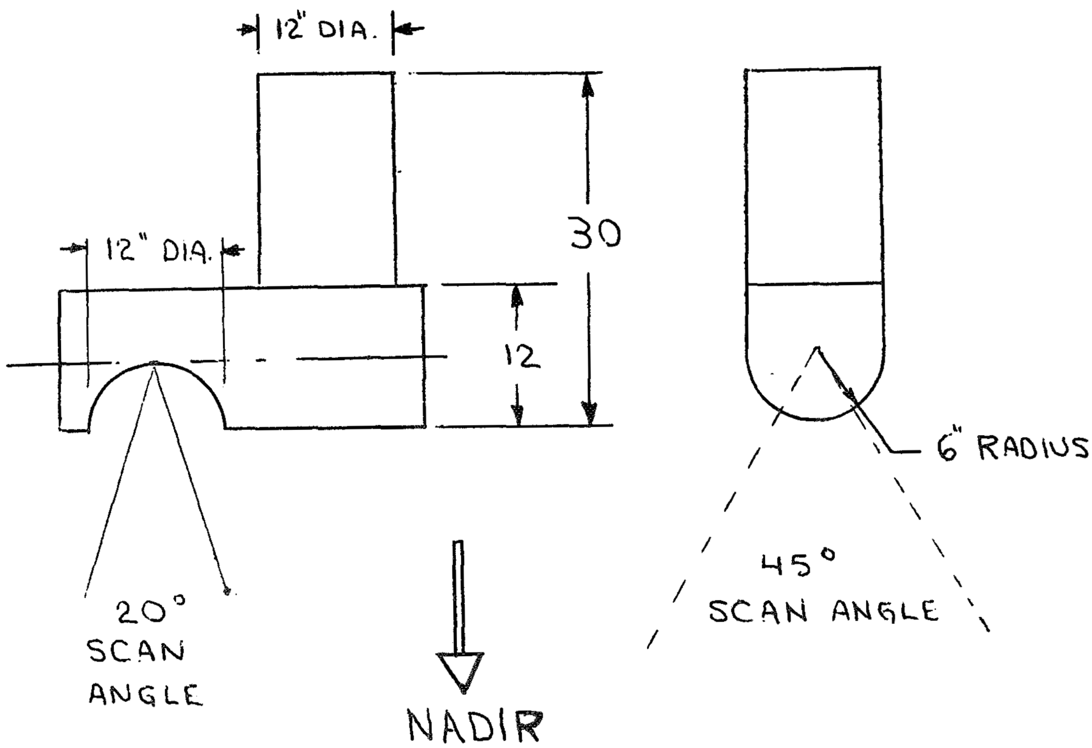
8. REMARKS

1. Average thermal output 3400 Btu/hr
2. Power source required: 28 vdc
3. Detector sensitivity dependent on required delta t and imaging time
4. Data recorded on film from CRT or laser modulation
5. Focal length 3.6 feet Cassegrain folded; f = 14
6. Detector packing density 1000, requires considerable analysis
7. Swath 100 n mi at 120 km altitude
8. Beam occupies 1.4 n mi x 1.4 n mi
9. Integration time .02 second

Equipment No. 11013
Page No. 3

9. CONFIGURATION SKETCHES





SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11015
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Passive Microwave Imager

General Characteristics:

Supports Experiment 5019

Operating Range 7 GHz to 19 GHz

2. PHYSICAL CHARACTERISTICS

Weight: 100 pounds

Volume: 2.7 cubic feet

Power: 150 watts average, 180 watts maximum

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:
± 2000 feet (all axes; ± 2 degrees)

Attitude Reference: Nadir

Attitude Hold Limit: ± 2 degrees

Equipment No. 11015
Page No. 2

5. DATA DESCRIPTION

Digital

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Control Switch (one)

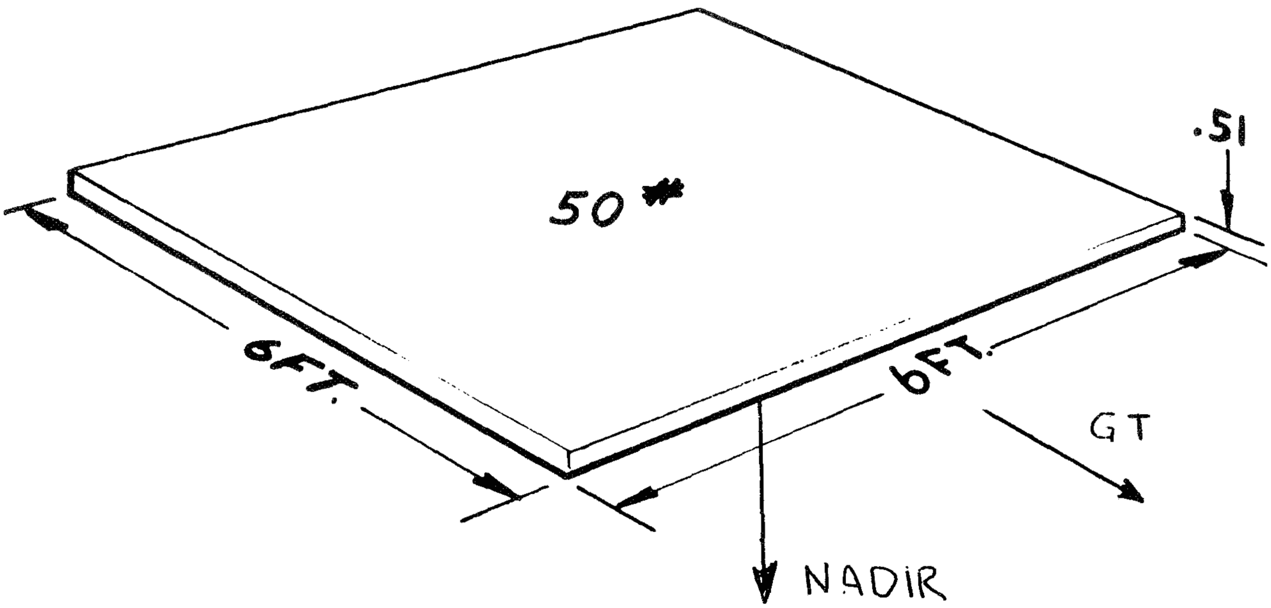
7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Free from magnetic fields EM waves (> 0.8 microns)

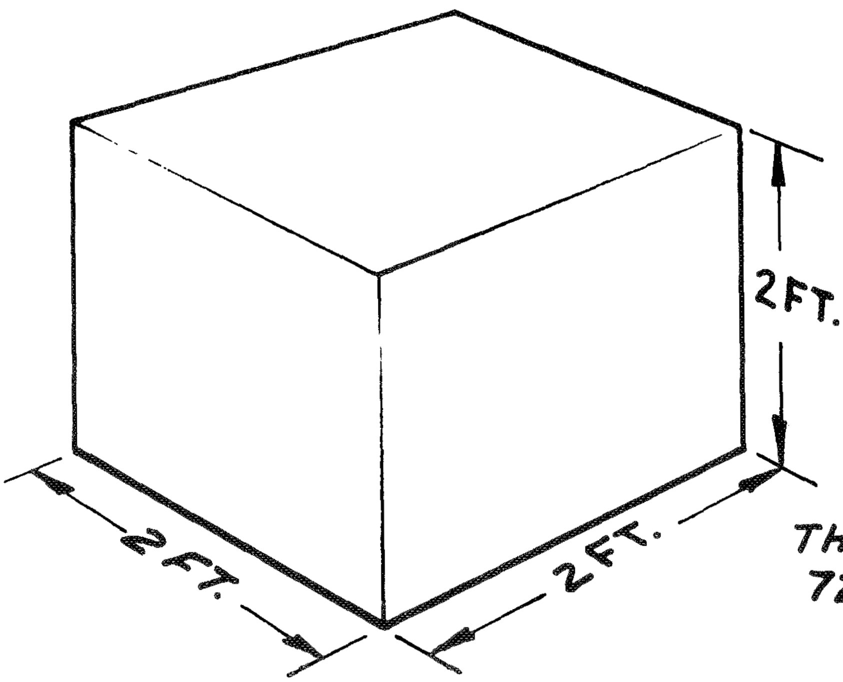
8. REMARKS

Average thermal output 720 Btu/hour

9. CONFIGURATION SKETCHES



11016 ANTENNA



THERMAL OUTPUT
720 BTU/HR

11017 ELECT PKG

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11041
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Altimeter/Scatterometer, Radar

General Characteristics:
Supports Experiment 5020

2. PHYSICAL CHARACTERISTICS

Weight: 52 pounds

Power: 80 watts

Volume: 3.4 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track ± 1000 feet;
Cross-track ± 1000 feet
(Altitude provided by experiment)

± 0.25 degree

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degree

5. DATA DESCRIPTION

Altimeter - Digital; 70 BPS

Scatterometer - Digital; 500 BPS

Housekeeping 20 channels; 8 BPS (total)

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Control Switch (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Temperature limits -20 to +70 C

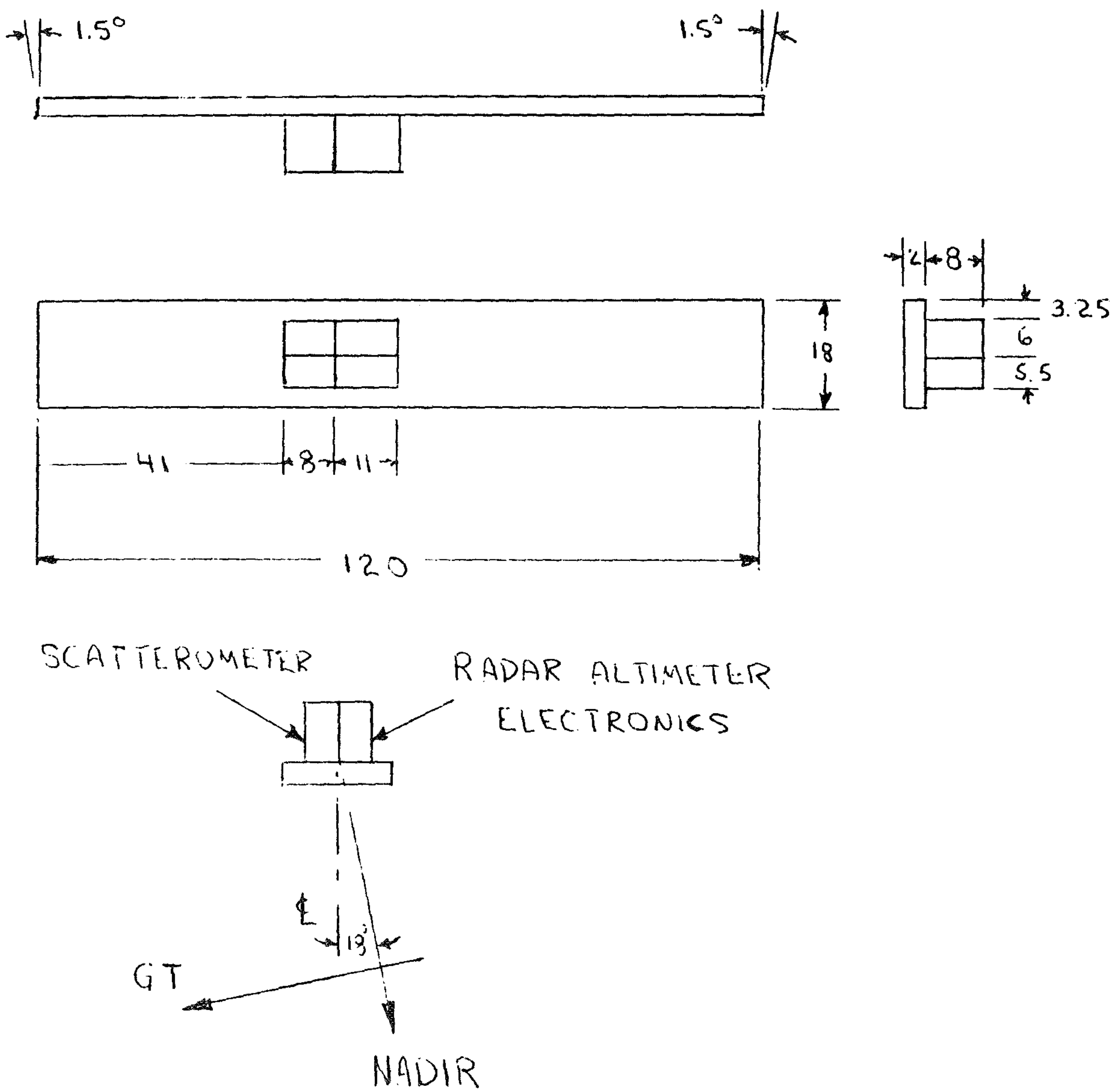
8. REMARKS

1. Power source required: 28 vdc
2. Average thermal output 290 Btu/hour

Equipment No. 11041
Page No. 3

9. CONFIGURATION SKETCHES

RADAR ALTIMETER SCATTEROMETER



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11042
Page No. 1

1. GENERAL INFORMATION

Equipment Name: High Resolution Camera

General Characteristics:

Supports Experiments 5002, 5014 and 5016

0.3 to 0.7 microns
5" x 5" film format
8 feet focal length, Cassegrain optics
25 n mi sq. field of view at 120 n mi altitude

2. PHYSICAL CHARACTERISTICS

Weight : 300 pounds

Power: 25 watts

Volume : 6 cubic feet

3. CONSUMABLES

Film; 1.7 ft^2/sec

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track ± 0.35 nautical miles;
Cross-track ± 0.34 nautical miles
Altitude ± 100 feet

± 0.25 degree

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degree

5. DATA DESCRIPTION

Film; 1.7 ft^2/sec

Analog; 10 samples per second

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Control Switch (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Bright illumination required

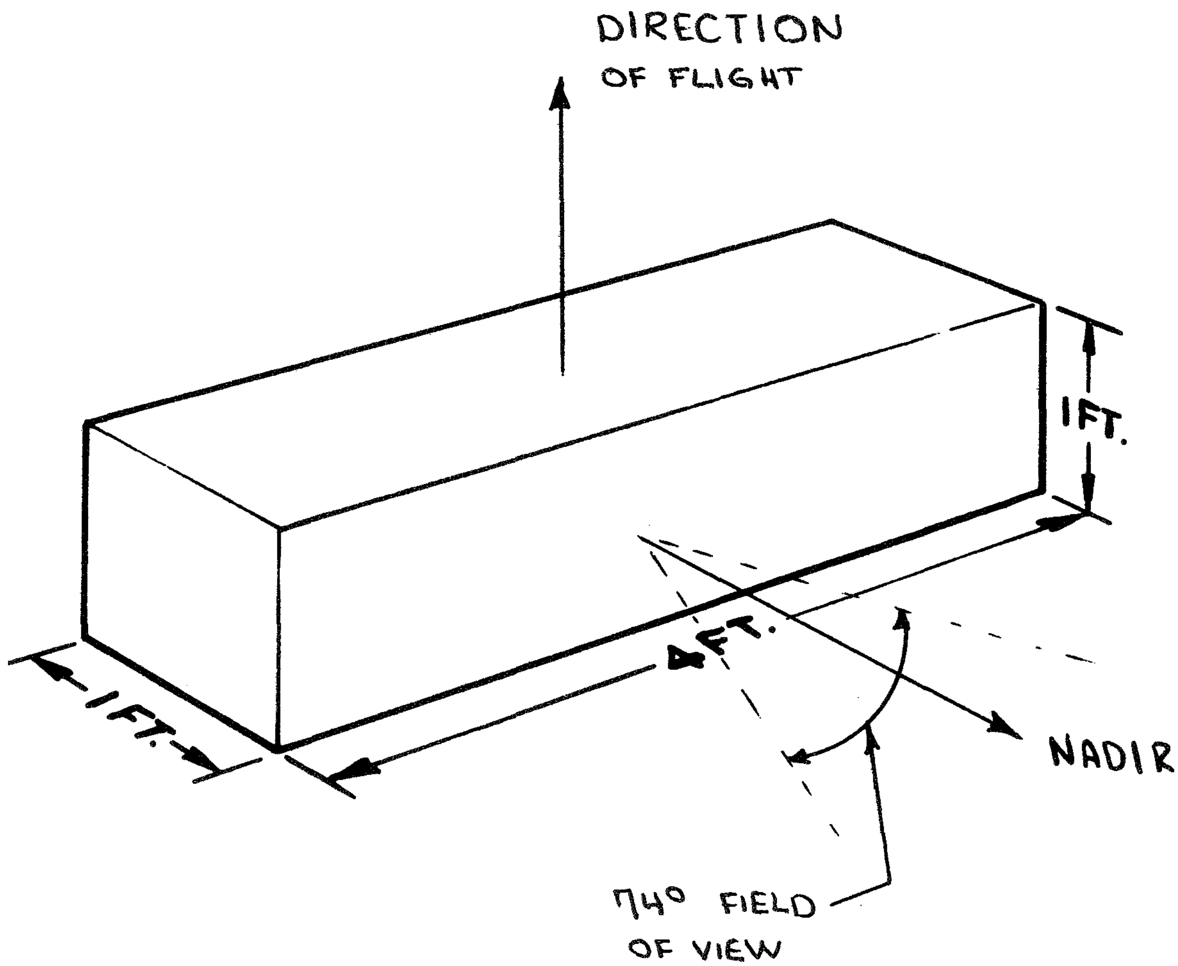
Free from high ionizing radiation flux and dust

8. REMARKS

1. Average thermal output 620 Btu/hour
2. Power source required: 28 vdc
3. Operates at altitudes from 30 to 120 km
4. 1 meter resolution at 120 km altitude

Equipment No. 11042
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11043
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Camera, Metric, 3-inch Focal Length

General Characteristics:

Supports Experiments 5013, 5014, and 5015

0.3 to 0.7 microns; 9" x 9" film format; 3-inch focal length
360 km square field of view @ 120 km altitude
Ground resolution = 100 feet @ 120 KM altitude

2. PHYSICAL CHARACTERISTICS

Weight: 110 pounds

Power: 10 watts

Volume: 7.0 cubic feet

3. CONSUMABLES

Film (.5 inch); 28 ft^2 per orbit

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

Altitude ± 100 feet (attitude provided by integral stellar camera)

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degree

5. DATA DESCRIPTION

Film; 28 ft^2/orbit

Digital serial; 10 BPS

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF Operation Switch (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Bright illumination required

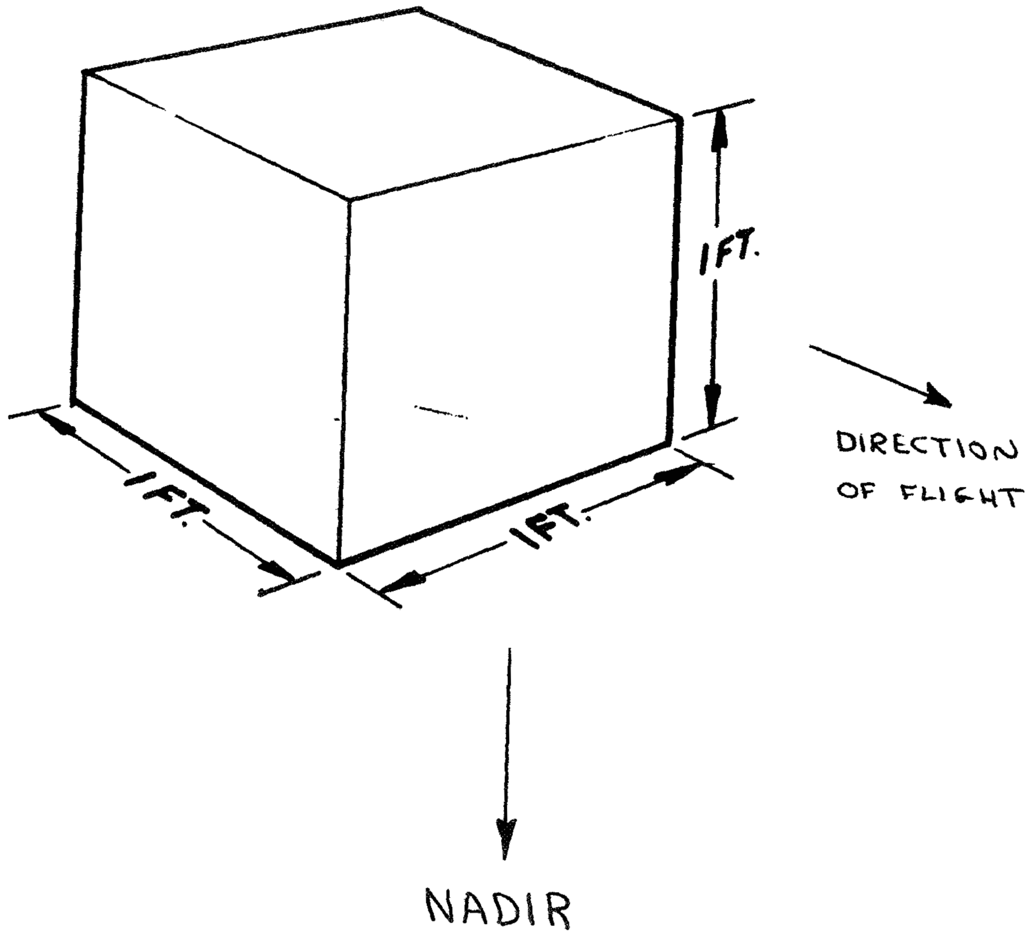
Free from high ionizing radiation flux and dust

8. REMARKS

Average thermal output 36 Btu/hour

Equipment No. 11043
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11069
Page No. 1

1. GENERAL INFORMATION

Equipment Name: X-Ray Spectrometer

General Characteristics:

Supports Experiment 5017 contained in geochem. and atmospheric subsatellite (Equipment #60006).

Determines energy spectrum of fluorescent X-rays and incident solar flux within range 0.1 to 30 Kev/photon

2. PHYSICAL CHARACTERISTICS

Weight: 18.0 pounds

Power: 12 watts

Volume: 0.3 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

See subsatellite equipment #60006 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See equipment #60006 (subsatellite)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Must be free from low ionizing flux

Darkness or low illumination required

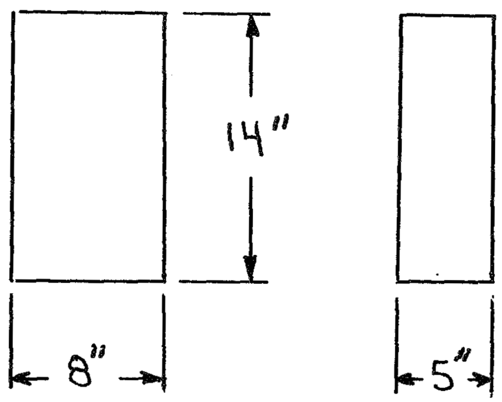
Free from dust

8. REMARKS

1. Average thermal output 43 Btu/hour
2. Power source required: 28 vdc

Equipment No. 11069
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11070
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Pulse Height Analyzer

General Characteristics:

Supports Experiments 5017 and 5021

Contained in particles and fields subsatellite (Equipment #60004)

2. PHYSICAL CHARACTERISTICS

Weight : 6.0 pounds

Power: 8 watts

Volume : 0.1 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): None

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Temperature limits 0 to 50 C

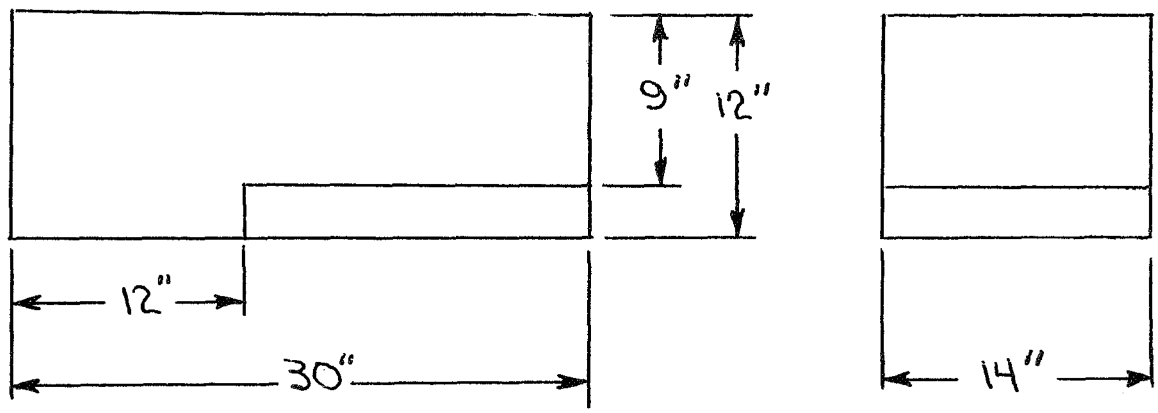
No EM waves 0.8 microns or longer

8. REMARKS

1. Average thermal output 29 Btu/hr
2. 256 channel capacity

Equipment No. 11070
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11086
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Neutron Activation Analysis Equipment

General Characteristics:

Supports Experiment 5006

2. PHYSICAL CHARACTERISTICS

Weight : 35.2 pounds

Power: 25 watts

Volume : 0.42 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 11086
Page No. 2

5. DATA DESCRIPTION

Voice; 28×10^2 BPS stored

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

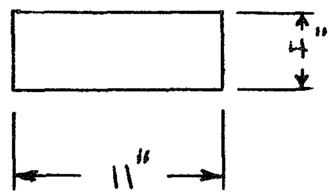
Requires protection from severe thermal cycling

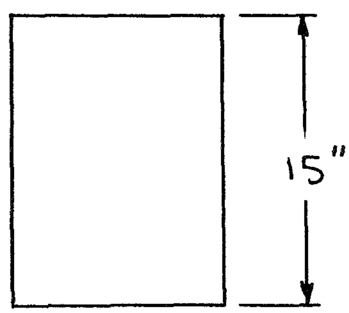
8. REMARKS

Geochem laboratory equipment

Equipment No. 11086
Page No. 3

9. CONFIGURATION SKETCHES





Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11096
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Diffractometer, X-Ray

General Characteristics:

Supports Experiment 5006

2. PHYSICAL CHARACTERISTICS

Weight: 20.0 pounds

Volume: 0.7 cubic feet

Power: 10 watts average, 60 watts maximum

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

Digital; 14 BPS stored

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

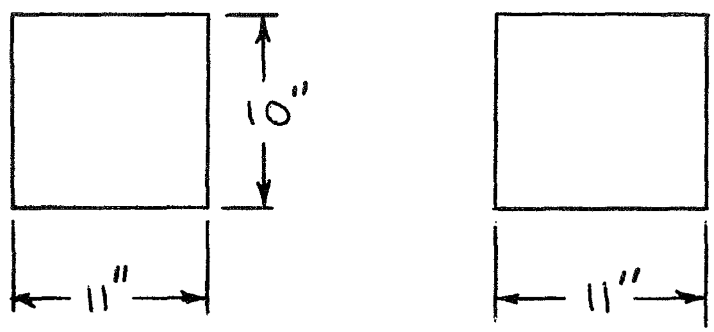
Requires protection from radiation exposure

8. REMARKS

Geochem laboratory equipment

Equipment No. 11096
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11098
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Telescope, Cosmic Ray Spectrometer

General Characteristics:

Supports Experiment 5021

Contained in particles and fields subsatellite (equipment #60004)

2. PHYSICAL CHARACTERISTICS

Weight : 7.3 pounds Power: 1.5 watts

Volume : 0.04 cubic feet

Support equipment required: Pulse height analyzer

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 11098
Page No. 2

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

6. EQUIPMENT COMMAND/CONTROL

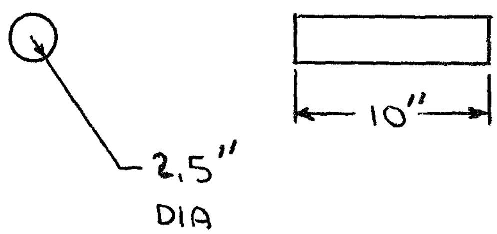
Control Function Type(s): See subsatellite equipment #60004

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Free from radiation exposure

8. REMARKS - None

9. CONFIGURATION SKETCHES



NOTE: DOES NOT INCLUDE PULSE ANALYZER

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 11099
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Altimeter, Laser

General Characteristics:

Supports Experiments 5013 and 5020

2. PHYSICAL CHARACTERISTICS

Weight : 35 pounds

Volume : 2.0 cubic feet

Power: 54 watts average, 97 watts maximum

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track 1000 feet;
Cross-track 1000 feet
(altitude provided by equipment)

± 10 arc minutes

Attitude Reference: Nadir

Attitude Hold Limit: ± 0.25 degree

5. DATA DESCRIPTION

Digital serial; 24 bit/word
18 bit altitude word; 2.75 rpm
6 event - 1 bit

4 analog channels; 6 bit stat word at 1 S/S

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): ON/OFF/STANDBY Switch (one)

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Non-operating: -40 F to 160 F

Operating: 30 F to 130 F

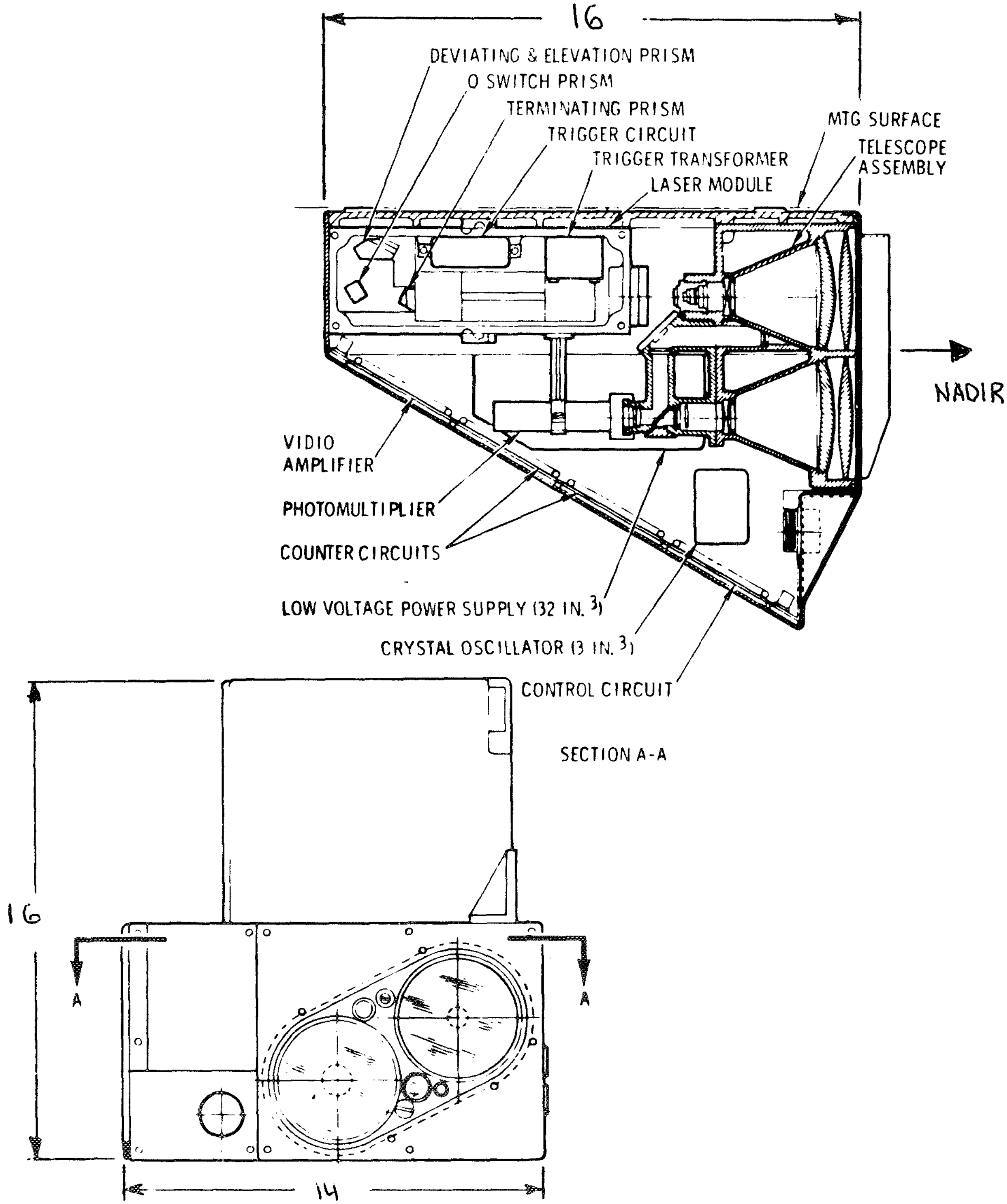
Protect from direct solar radiation

8. REMARKS

May be mounted on common chassis with metric camera (3-inch focal length, Fairchild)
(Reference paragraph 6.0) has direct output to metric camera and 24 bit parallel TM or recorded output

Equipment No. 11099
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 12001
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Ionization Pressure Sensor

General Characteristics:

Supports Experiment 5024

Contained in geochem. and atmospheric subsatellite (Equipment #60004)

Range 1.0×10^{-6} to 1.0×10^{-13} torr

2. PHYSICAL CHARACTERISTICS

Weight: 2.2 pounds

Power: 6 watts

Volume: 0.002 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Temp. Fm. AP-83, Exp. 5-1-71

Equipment No. 12001
Page No. 2

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment #60004

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

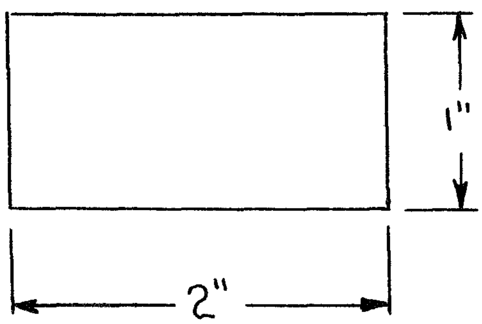
Keep free from high ionizing flux

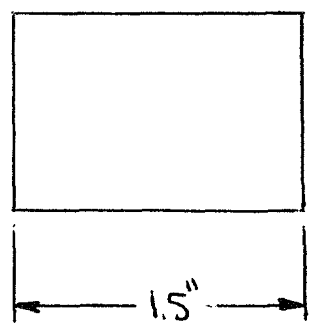
Keep free from magnetic fields

8. REMARKS - None

Equipment No. 12001
Page No. 3

9. CONFIGURATION SKETCHES





SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 14001
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Counter, Charged Particle, Low Energy

General Characteristics:

Supports Experiment 5021

Contained in geochem. and atmospheric subsatellite (Equipment #60004)

1.0 to 40 kev

2. PHYSICAL CHARACTERISTICS

Weight : 10.0 pounds

Power: 0.5 watts

Volume : 0.4 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

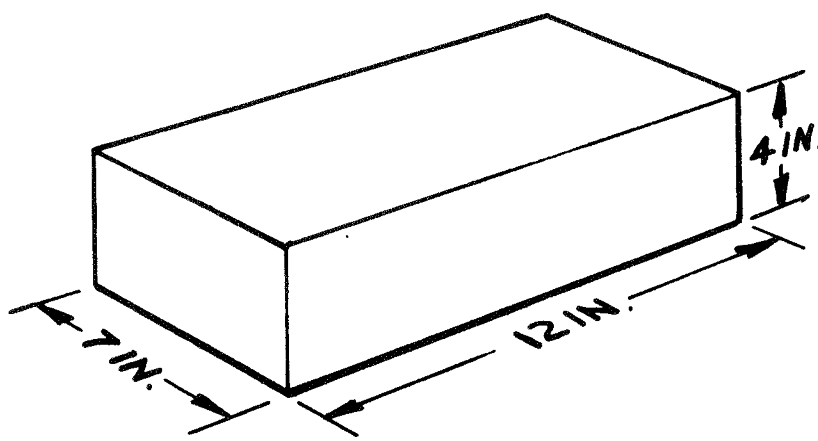
6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment #60004

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 14003
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Alpha Proton Counter

General Characteristics:

Supports Experiment 5017

Contained in geochem. and atmospheric subsatellite (Equipment #60006)

Measures radiation over the range 1.0 to 10.0 Mev/alpha

2. PHYSICAL CHARACTERISTICS

Weight : 20.0 pounds

Power: 2 watts

Volume : 1.0 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 14003
Page No. 2

5. DATA DESCRIPTION

See subsatellite equipment #60006 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment $60006

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

Temperature 15 to 35 C

8. REMARKS

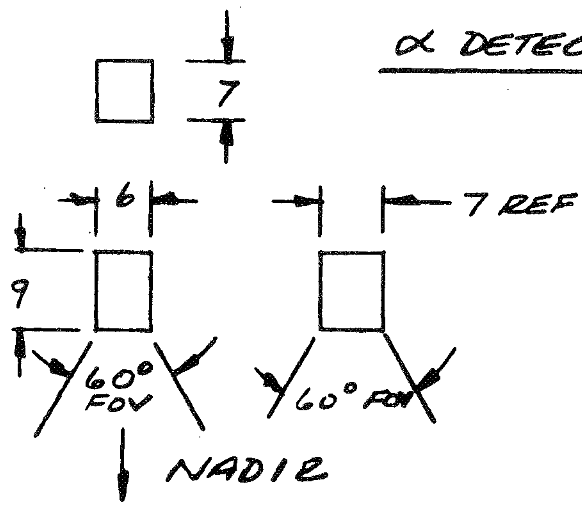
1. Average thermal output 7.2 Btu/hour
2. Power source required: 28 vdc

9. CONFIGURATION SKETCHES

ALPHA PROTON COUNTER

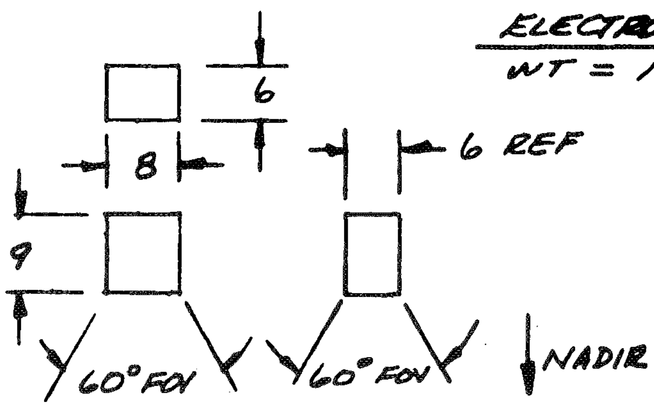
WT = 10 LB.

α DETECTOR*



ELECTRON MULTIPLIER*

WT = 10 LB



*NOTE: MUST BE USED WITH SIGNAL CONDITIONER AND MULTICHANNEL ANALYZER COMMON TO:
γ RAY SPECTROMETER, X-RAY FLUORESCENCE,
ALPHA PROTON COUNTER

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 14005
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Mass Spectrometer

General Characteristics:

Supports Experiments 5024, 5025 and 5026

Contained in geochem. and atmospheric subsatellite (Equipment #60006)

amu range 1.0 to 150.0

2. PHYSICAL CHARACTERISTICS

Weight : 15.0 pounds   Power: 12 watts

Volume : 0.9 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - None

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 14005
Page No. 2

5. DATA DESCRIPTION

See subsatellite equipment #60006 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment #60006

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

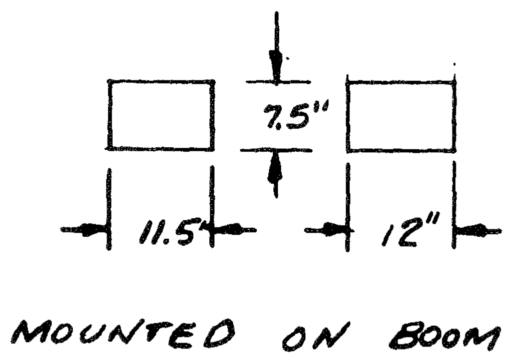
8. REMARKS

1. Average thermal output 43 Btu/hour
2. Power source required: 28 vdc

Equipment No. 14005
Page No. 3

9. CONFIGURATION SKETCHES

MASS SPECTROMETER



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 14018
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Gas Chromatograph

General Characteristics:

Supports Experiment 5006

2. PHYSICAL CHARACTERISTICS

Weight : 55.0 pounds

Power: 15 watts

Volume : 2.15 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 14018
Page No. 2

5. DATA DESCRIPTION

Data printout in graph format

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

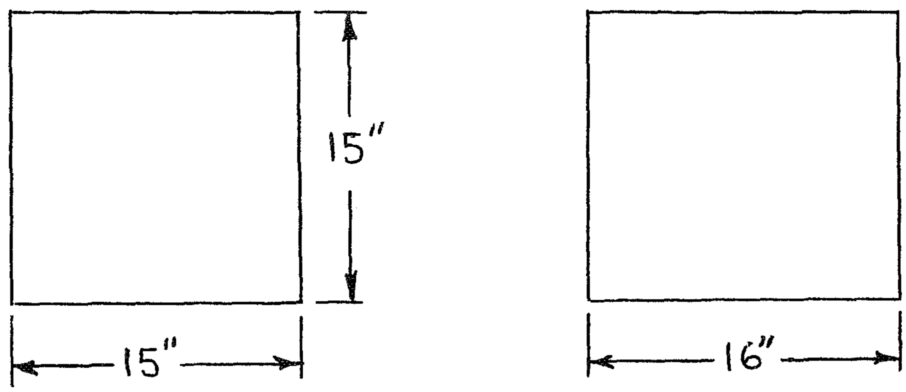
Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 14018
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 14020
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Spectrometer, Charged Particle

General Characteristics:

Supports Experiment 5021

Contained in particles and fields subsatellite (Equipment #60004)

Electrons to Z = 20

Energy from 0.01 to 0.5 Mev

2. PHYSICAL CHARACTERISTICS

Weight: 10.0 pounds

Power: 3.0 watts

Volume: 0.2 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Temp. Fm. AP-83, Exp. 5-1-71

Equipment No. 14020
Page No. 2

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

6. EQUIPMENT COMMAND/CONTROL

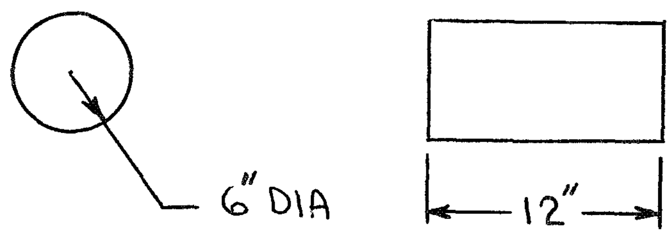
Control Function Type(s): See subsatellite equipment #60004

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 14020
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 14026
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Solid Mass Spectrometer

General Characteristics:

Supports Experiment 5006

2. PHYSICAL CHARACTERISTICS

Weight : 50.0 pounds

Power: 3.0 watts

Volume : 0.6 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 14026
Page No. 2

5. DATA DESCRIPTION

Not applicable - lab equipment

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

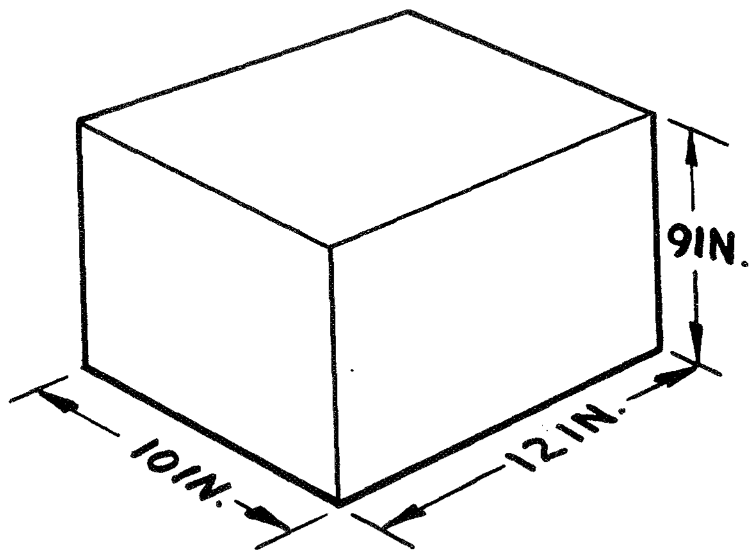
Avoid severe thermal cycling

8. REMARKS

Self contained power supply

Equipment No. 14026
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 15007
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Gravity Gradiometer

General Characteristics:

Supports Experiment 5028

Contained in gravity graient subsatellite (Equipment #60005)

Measures gravity gradient 1.0 x 10^{-7} to 3.0 x 10^{10} gal/cm

2. PHYSICAL CHARACTERISTICS

Weight : 21.0 pounds

Power: 10 watts

Volume : 0.36 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Temp. Fm. AP-83, Exp. 5-1-71

5. DATA DESCRIPTION

See subsatellite equipment #60005 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment #60005

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

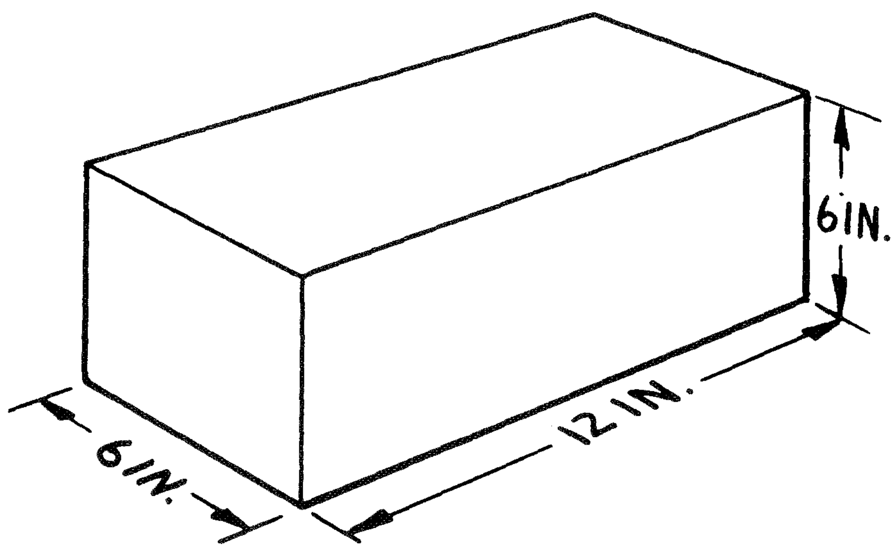
8. REMARKS

1. Average thermal output 36 Btu/hour
2. Power source required: 28 vdc
3. Station must be extremely stable during instrument operation

Temp. Fm. AP-83, Exp. 5-1-71

Equipment No. 15007
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 15009
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Detector, Electric Field

General Characteristics:

Supports Experiment 5023

Contained in particles and fields subsatellite (Equipment #60004)

100 to 0.01 millivolts/meter

0 to 30 kHz

2. PHYSICAL CHARACTERISTICS

Weight : 5.0 pounds   Power: 3.0 watts

Volume : 0.5 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s): See subsatellite equipment #60004

7. SPECIAL ENVIRONMENTAL REQUIREMENTS

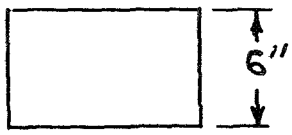
Free from electric fields

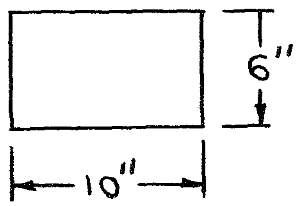
8. REMARKS

Can be used with data buffer analyzer to reduce data rate to 70 BPS

Equipment No. 15009
Page No. 3

9. CONFIGURATION SKETCHES





SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 15010
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Helium Magnetometer

General Characteristics:

Supports Experiment 5022

Contained in particles and fields subsatellite (Equipment #60004)

2. PHYSICAL CHARACTERISTICS

Weight : 11.0 pounds

Power: 5.0 watts

Volume: 0.1 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION

See subsatellite equipment #60004 for data output

6. EQUIPMENT COMMAND/CONTROL

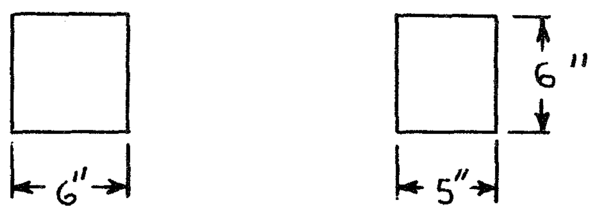
Control Function Type(s): See subsatellite equipment #60004

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 15010
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 30004
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Receiver

General Characteristics:

Supports Experiment 5027

Operates over frequency range 10 kHz to 10 MHz

2. PHYSICAL CHARACTERISTICS

Weight: 20.0 pounds

Power: Negligible

Volume: 0.25 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 30004
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable - Self Contained

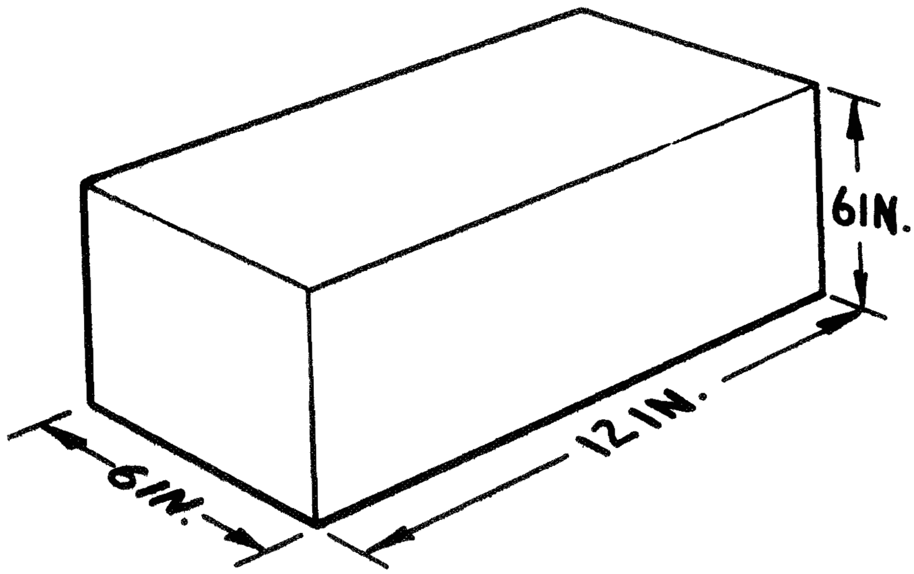
Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 30004
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 30007
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Receiver

General Characteristics:

Supports Experiment 5027

Operates over frequency range 10 MHz to 3 GHz

2. PHYSICAL CHARACTERISTICS

Weight : 20.0 pounds

Power: Negligible

Volume : .25 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 30007
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable - Self Contained

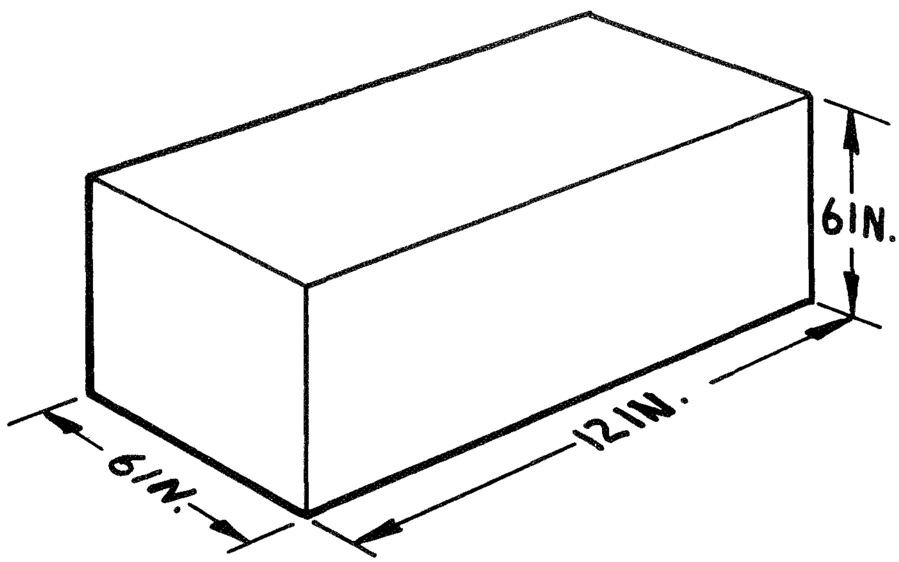
Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 30007
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 40006
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Signal Conditioning Equipment

General Characteristics:

Supports the signal conditioning requirements of all experiments

2. PHYSICAL CHARACTERISTICS

Weight : 20 pounds

Power: 20 watts

Volume : 1.0 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 40006
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - None

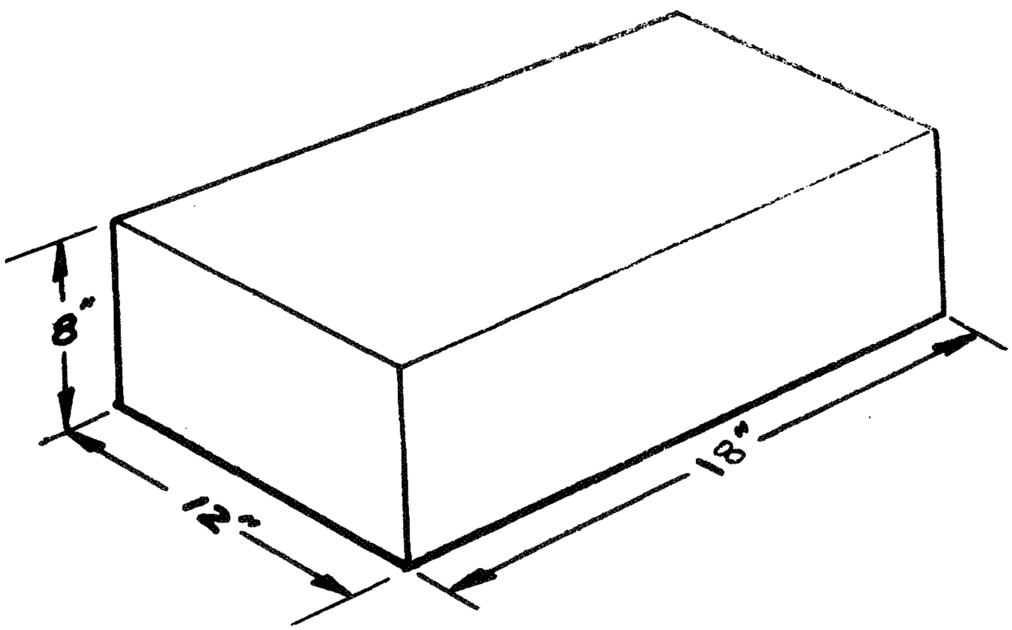
Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 40006
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 40007
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Data Analysis Laboratory (Typical)

General Characteristics:

Supports the data viewing and analysis requirements of all experiments

Lab contains: desk/2 restr (chairs); light board; plotting board; desk top viewers; file storage; microfilm viewer; RACU; supplies

2. PHYSICAL CHARACTERISTICS

Weight : 117.0 pounds

Power: 450 watts

Volume : 500.0 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

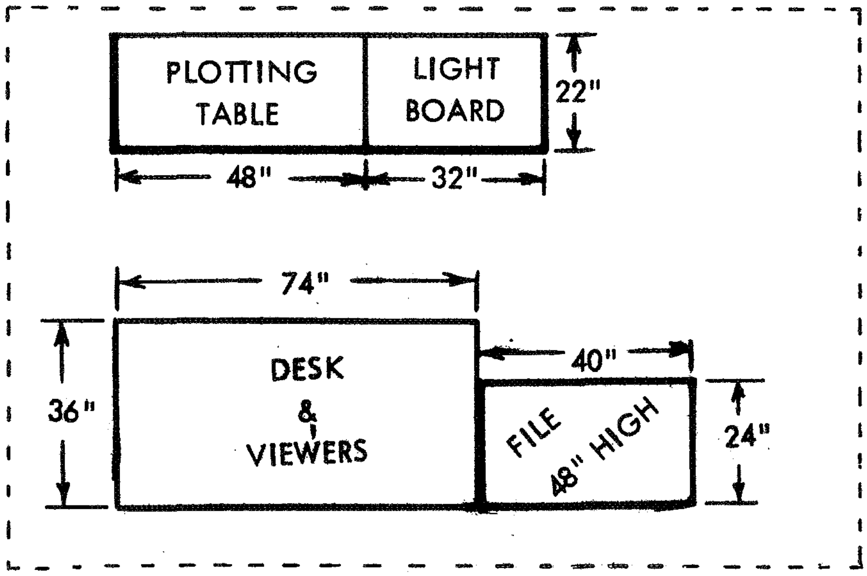
8. REMARKS

Equipment volume 69 cubic feet

Equipment No. 40007
Page No. 3

9. CONFIGURATION SKETCHES

DATA ANALYSIS LAB



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 40008
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Photographic Laboratory

General Characteristics:

Supports the photographic processing requirements of all experiments

2. PHYSICAL CHARACTERISTICS

Weight : 1500 pounds

Power: 200 watts

Volume : 500 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 40008
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

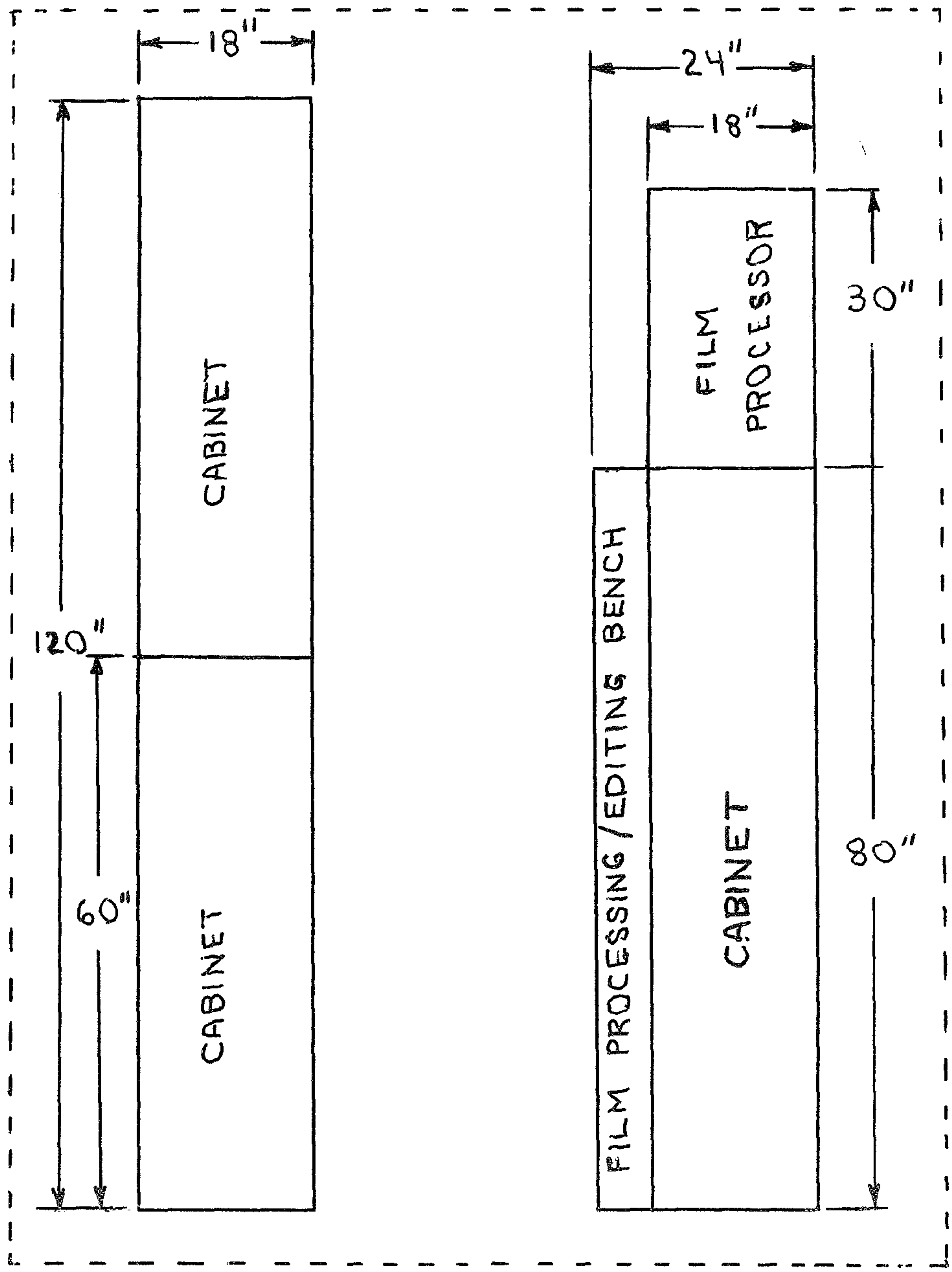
7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 40008
Page No. 3

9. CONFIGURATION SKETCHES

PHOTOGRAPHY LABORATORY



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 50006
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Sample Preparation Device

General Characteristics:

Supports Experiment 5006

This equipment consists of the following:
- cutter and sectioner
- polisher
- pulverizer

2. PHYSICAL CHARACTERISTICS

Weight: 53 pounds

Power: 500 watts

Volume: 23.5 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 50006
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

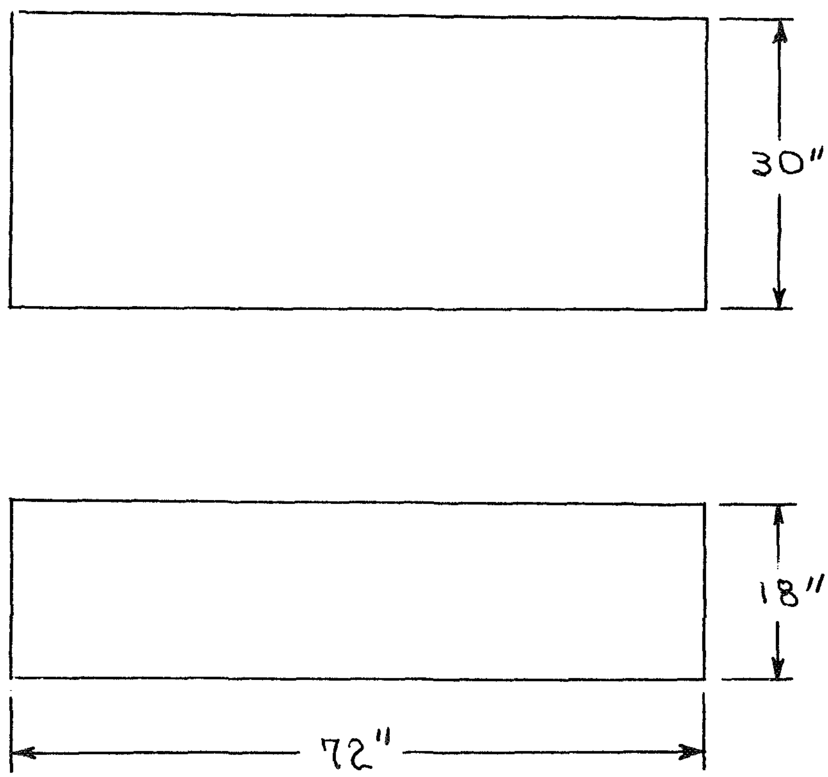
7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS

Used for sectioning and preparing rocks prior to microscopic examination

Equipment No. 50006
Page No. 3

9. CONFIGURATION SKETCHES



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 50011
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Geochemistry Laboratory

General Characteristics:

Supports geochemical analysis requirements of Experiment 5006

This laboratory contains the following equipment items in addition to general support equipment: 90008 - Petrographic Microscope; 50006 - Sample Preparation Device; 14018 - Gas Chromatograph; 14086 - Neutron Activation Analysis Equipment; 14026 - Mass Spectrometer; and 11096 - X-Ray Diffractometer

2. PHYSICAL CHARACTERISTICS

Weight: 2500 pounds

Power: 1200 watts

Volume: 700 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 50011
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

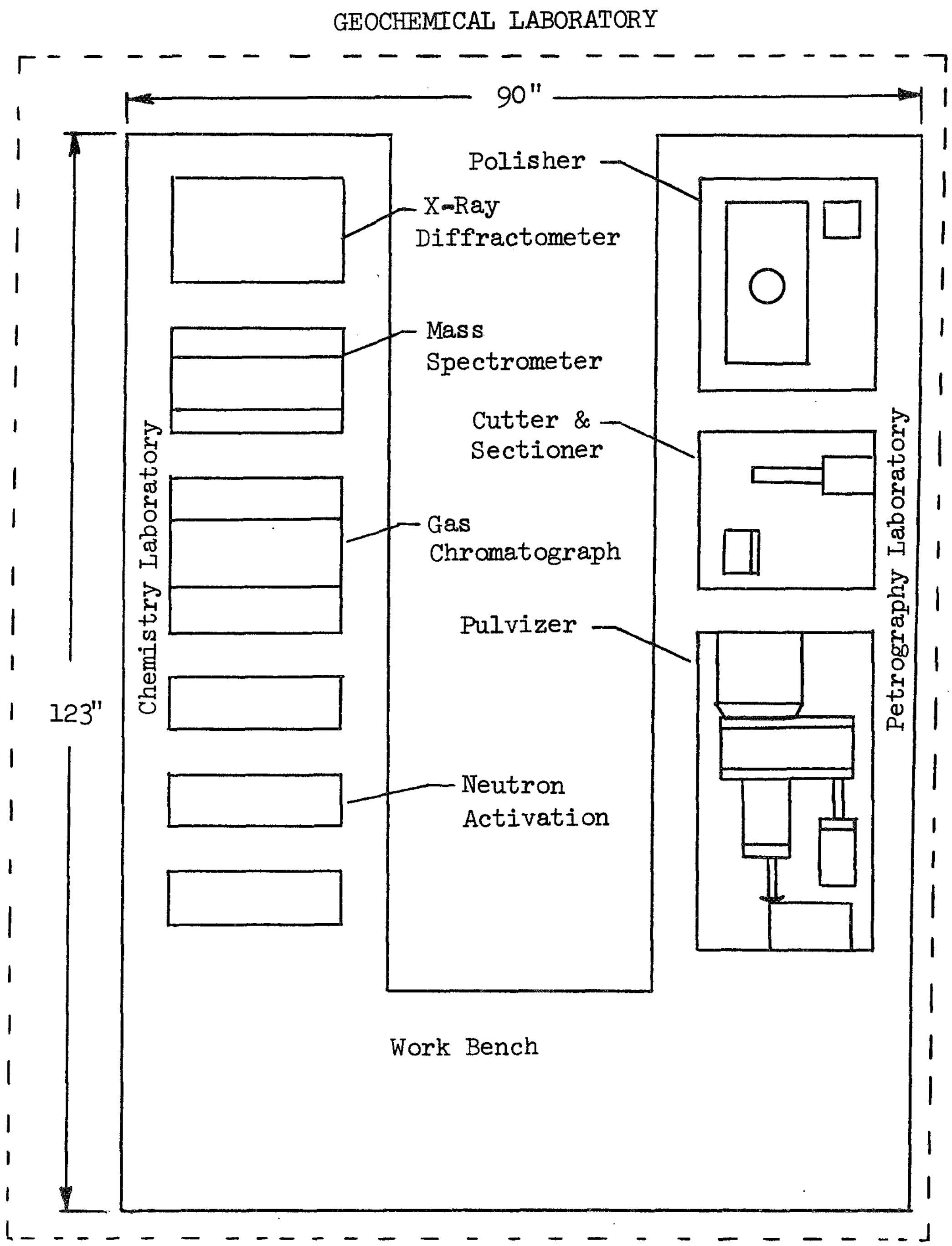
Control Function Type(s):

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS - None

Equipment No. 50011
Page No. 3

9. CONFIGURATION SKETCHES



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SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 60004
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Particles and Fields Subsatellite

General Characteristics:

Supports Experiments 5021, 5022, and 5023

Contains the following scientific equipment payload: 15010 - Helium Magnetometer; 14001 - Low Energy Charged Particle Counter; 14020 - Particle Spectrometer; 11098 - Cosmic Ray Spectrometer Telescope; 11070 - Pulse Height Analyzer; and 15009 - Electric Field Detector

2. PHYSICAL CHARACTERISTICS

Weight: 140.0 pounds

Power: 10 watts

Volume: 20.0 cubic feet

3. CONSUMABLES

N_2 - 70 lb/mission

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:
In-track $\pm$ 1 nautical mile
Cross-track $\pm$ 1 nautical mile
Altitude $\pm$ 1 nautical mile

Attitude Reference: Integral to subsatellite

Attitude Hold Limit: Integral to subsatellite

Equipment No. 60004
Page No. 2

5. DATA DESCRIPTION

Digital; 512 BPS

Digital; 1000 BPS for 10 hours prior to ejection

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s):

57 commands (S/S has 2 decorders), command message 23 bit word

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

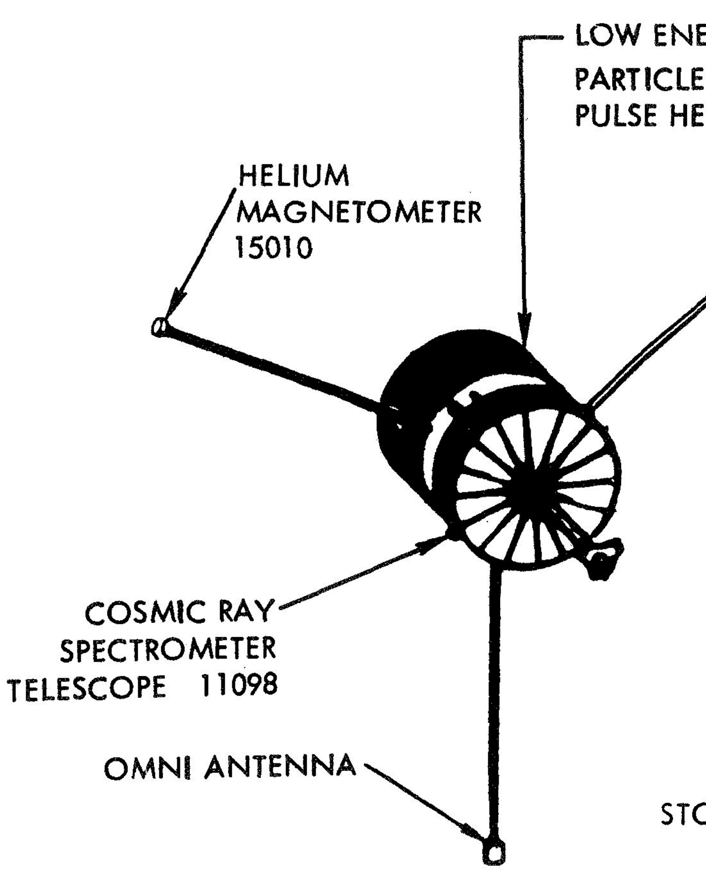
8. REMARKS

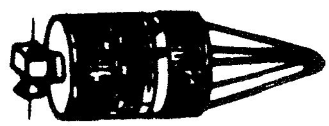
1. Satellite must be spun up to 70 rpm and ejected at 4 fps
2. Delta V capability for orbit changes available
3. Power required: 28 vdc
4. Subsatellite at 10, 15, and 20-nautical mile altitude circular orbit; 60 x 5 nautical mile elliptical equatorial orbit.

Equipment No. 60004
Page No. 3

9. CONFIGURATION SKETCHES

PARTICLES & FIELDS SUBSATELLITE (MODIFIED PIONEER SATELLITE)





STOWED CONFIGURATION

Temp. Fm. AP-83, Exp. 5-1-71

SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 60005
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Gravity Gradient Subsatellite

General Characteristics:

Supports Experiment 5028

Contains the following scientific equipment payload: 15007 - Gravity Gradiometer

2. PHYSICAL CHARACTERISTICS

Weight: 140.0 pounds

Power: 10 watts

Volume: 20.0 cubic feet

3. CONSUMABLES

N_2 - 70 lb/mission

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track ± 1 nautical mile
Cross-track ± 1 nautical mile
Altitude ± 1 nautical mile

Attitude Reference: Integral to subsatellite

Attitude Hold Limit: Integral to subsatellite

Equipment No. 60005
Page No. 2

5. DATA DESCRIPTION

Digital; 512 BPS

Digital; 1000 BPS for 10 hours prior to ejection

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s):

57 commands (S/S has 2 decorders), command message 23 bit word

7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

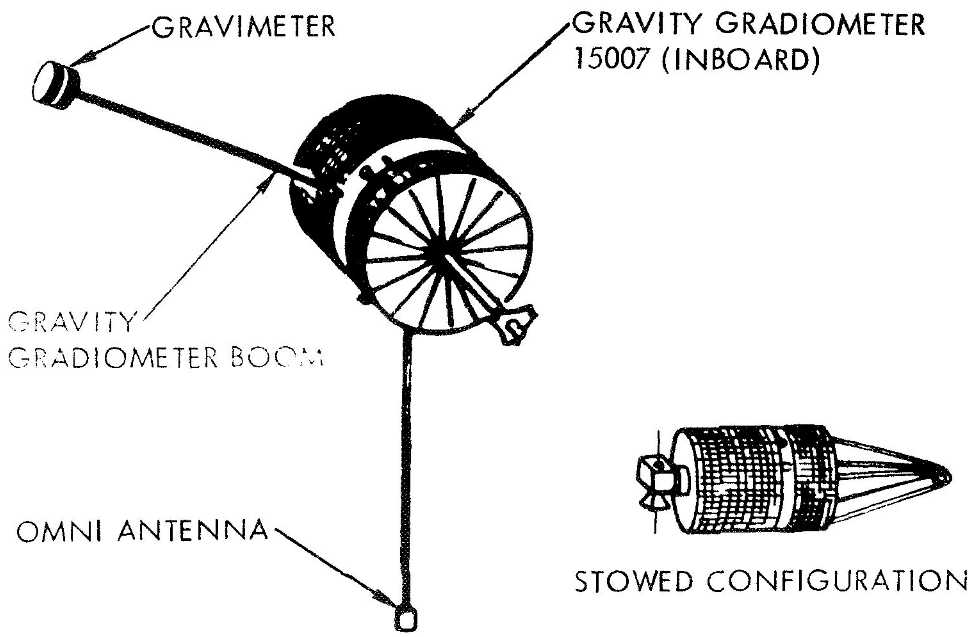
8. REMARKS

1. Delta V capability for orbit changes available
2. Power required: 28 vdc
3. Subsatellite at 20-nautical mile altitude (circular orbit)

Equipment No. 60005
Page No. 3

9. CONFIGURATION SKETCHES

GRAVITY GRADIOMETER SUBSATELLITE
(MODIFIED PIONEER SATELLITE)



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 60006
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Geochemical and Atmospheric Subsatellite

General Characteristics:

Supports Experiments 5017, 5024, 5025 and 5026

Contains the following scientific equipment payload: 11005 - Gamma Ray Spectrometer; 11069 - X-Ray Spectrometer; 14003 - Alpha Proton Counter; 11070 - Pulse Height Analyzer; 12001 - Ionization Pressure Sensor; 14005 - Mass Spectrometer; and 11008 - Uvimager/Spectrometer

2. PHYSICAL CHARACTERISTICS

Weight: 950.0 pounds

Power: 50 watts

Volume: 150.0 cubic feet

3. CONSUMABLES

N_2H_4 - 80 lb/mission

4. GUIDANCE ATTITUDE AND CONTROL

Instantaneous Position/Attitude:

In-track $\pm$ 1 nautical mile
Cross-track $\pm$ 1 nautical mile
Altitude $\pm$ 1 nautical mile

Attitude Reference: Integral to subsatellite

Attitude Hold Limit: Integral to subsatellite

Equipment No. 60006
Page No. 2

5. DATA DESCRIPTION

Digital; 4.5×10^6 BPS

Digital; 875 BPS for 10 hours prior to ejection of subsatellite

6. EQUIPMENT COMMAND/CONTROL

Control Function Type(s):

S/S flight programmer can store 128 words - command word 26 bits

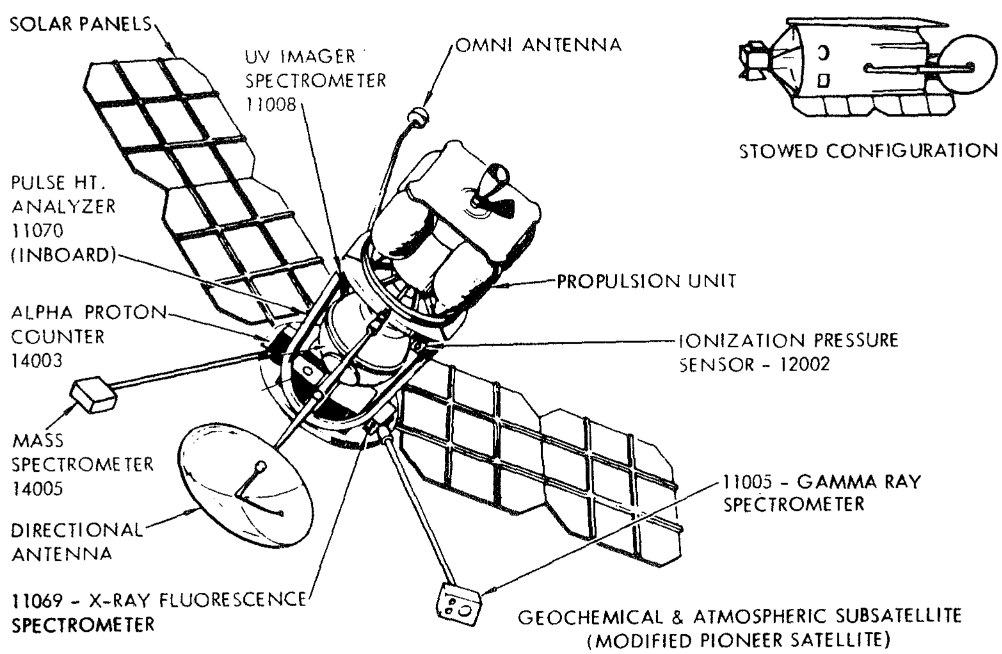
7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS

1. Subsatellite is 3 axis gyro stabilized
2. Delta V capability available for orbit changes, 1020 meters/seconds
3. Power required: 28 vdc
4. Subsatellite at 10, 15, and 20-nautical mile altitude (circular orbit)

9. CONFIGURATION SKETCHES

GEOCHEMICAL AND ATMOSPHERIC SUBSATELLITE (MODIFIED LUNAR ORBITER)



SENSOR/EQUIPMENT DESCRIPTION SHEET

Equipment No. 90008
Page No. 1

1. GENERAL INFORMATION

Equipment Name: Microscope, Petrographic

General Characteristics:

Supports Experiment 5006

2. PHYSICAL CHARACTERISTICS

Weight : 5.0 pounds

Power: 100 watts

Volume : 0.4 cubic feet

3. CONSUMABLES - None

4. GUIDANCE ATTITUDE AND CONTROL - Not Applicable

Instantaneous Position/Attitude:

Attitude Reference:

Attitude Hold Limit:

Equipment No. 90008
Page No. 2

5. DATA DESCRIPTION - Not Applicable

6. EQUIPMENT COMMAND/CONTROL - Not Applicable

Control Function Type(s):

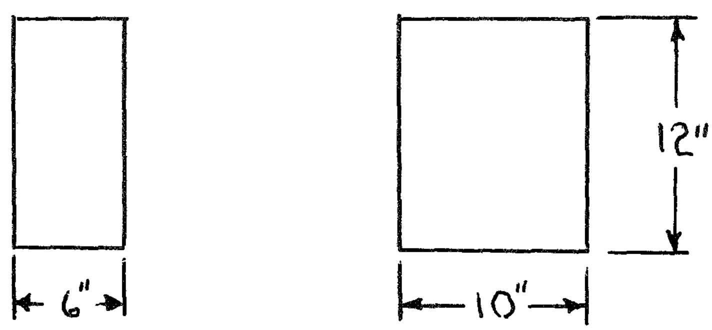
7. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

8. REMARKS

Used with 50006 sectioning equipment

Equipment No. 90008
Page No. 3

9. CONFIGURATION SKETCHES



Temp. Fm. AP-83, Exp. 5-1-71

4.5 INTEGRATED SUPPORT REQUIREMENTS

4.5.1 Ground Rules

Presented in this section are the integrated OLS experiment support profiles including experiment schedule, power profile, data profile, and crew skill requirements.

This OLS Experiment Operating Plan has been prepared based on the following ground rules:

1. Experiments are not planned during the crew transfer duration (16 days) or during the tug sorties to the surface of the moon (30 days).

2. The experiments require exclusive operating time during the assigned presortie time span to enable acquisition of a non-interference data base for that experiment.

3. The experiments do not use a sensor for more than 30 consecutive operating days.

4. One subsatellite was considered to be operating (transmitting data to the OLS) at a time.

5. The photographic experiments were assigned the initial performance spot to enable analysis of data for the verification of the candidate tug sites.

6. Astronomy was scheduled early to enable accumulation of the man-made radiowave data in the lunar vicinity before there are emplaced lunar stations left on the lunar surface by the tug sorties.

7. The atmospheric subsatellite was selected as the first one because its experiments' objectives can be affected by the projected propulsive activity in the vicinity of the moon. That subsatellite has also been purposely scheduled to coincide with the full duration of a tug sortie to enable determination of the effect of their presence on the atmosphere.

The geophysics experiment to determine the orbital perturbations of the station was scheduled to occur before the gravity gradient subsatellite to enable a verification of gravity effects.

4.5.2 Experiments Schedule

The power, data, and crew skills profiles are based upon the experiments' schedule shown in Figure 4-18.

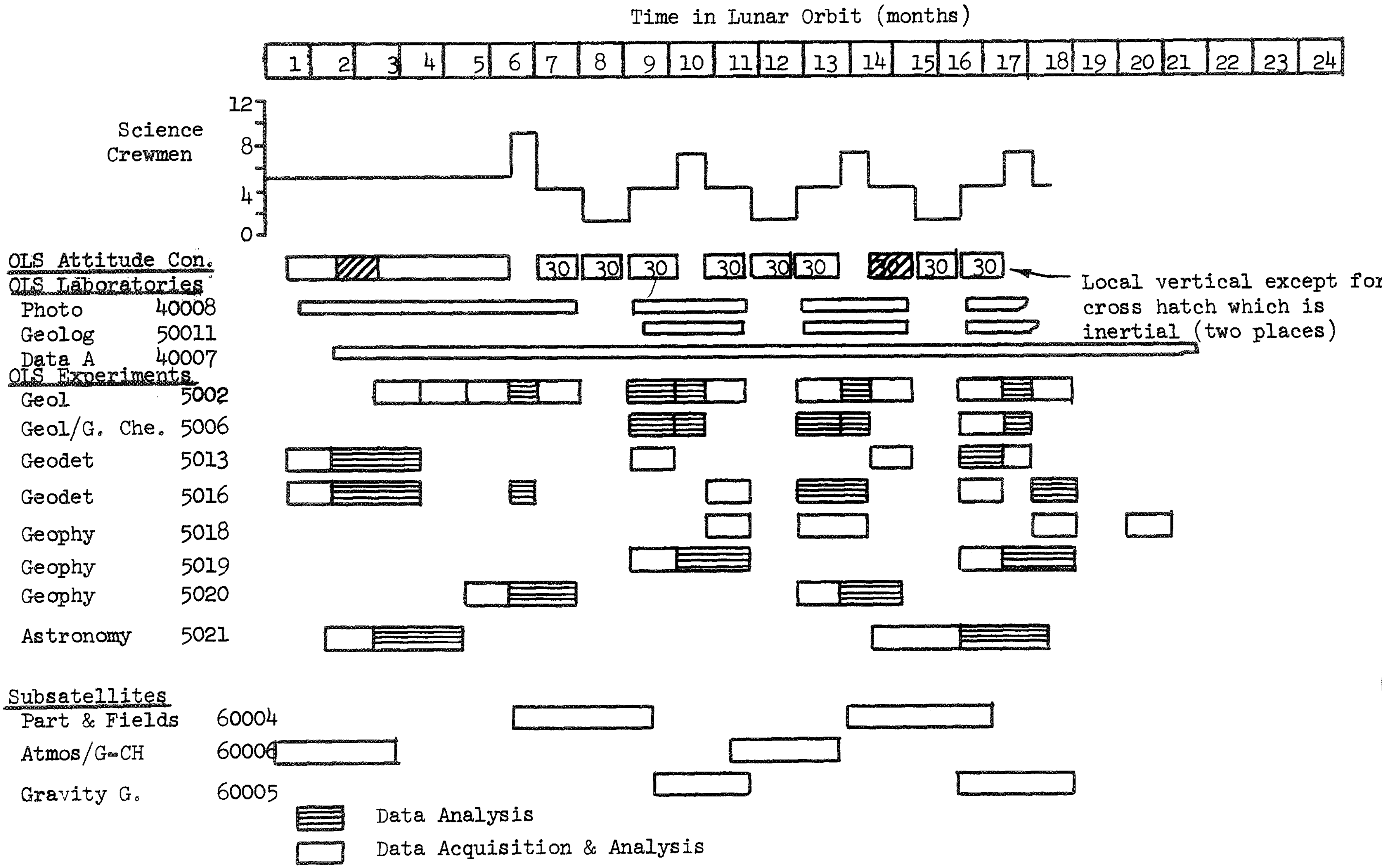


Figure 4-18. OLS Experiments Operating Plan

The quantitative data which were used to construct the power and data profiles are based upon the profiles for the individual experiments presented in paragraph 4.4.3 and the equipment descriptors presented in paragraph 4.4.5.

Power

The power profile for experiments shown in Figure 4-19 includes the equipment required to perform the experiment and that required in direct support of the experiment (photo laboratory, data analysis lab, and geology/geochemistry laboratory). Power variations within an experiment can occur because of the 30-day equipment operating limit.

Data

The data requirements shown in Figure 4-20 in bits per second, are dominated by the requirements of the atmospheric-geochemical experiment subsatellite as presented in the profile. The high bit rate for the subsatellite is caused by a combination of the data to be recorded and the time available for transmitting back to the station. The transmitting window will be reduced because of lower operating altitudes for the subsatellite.

Crew Skills

The OLS scientific crew skills requirements as a function of time are shown in Figure 4-21. The initial experimental period of the OLS (months one through six) was considered as one of preparation of the reference data for the remainder of the mission; thus, within the skills distribution, the emphasis should be placed upon the analytical and remote sensing experiments while for subsequent periods, the field skills would receive major emphasis.

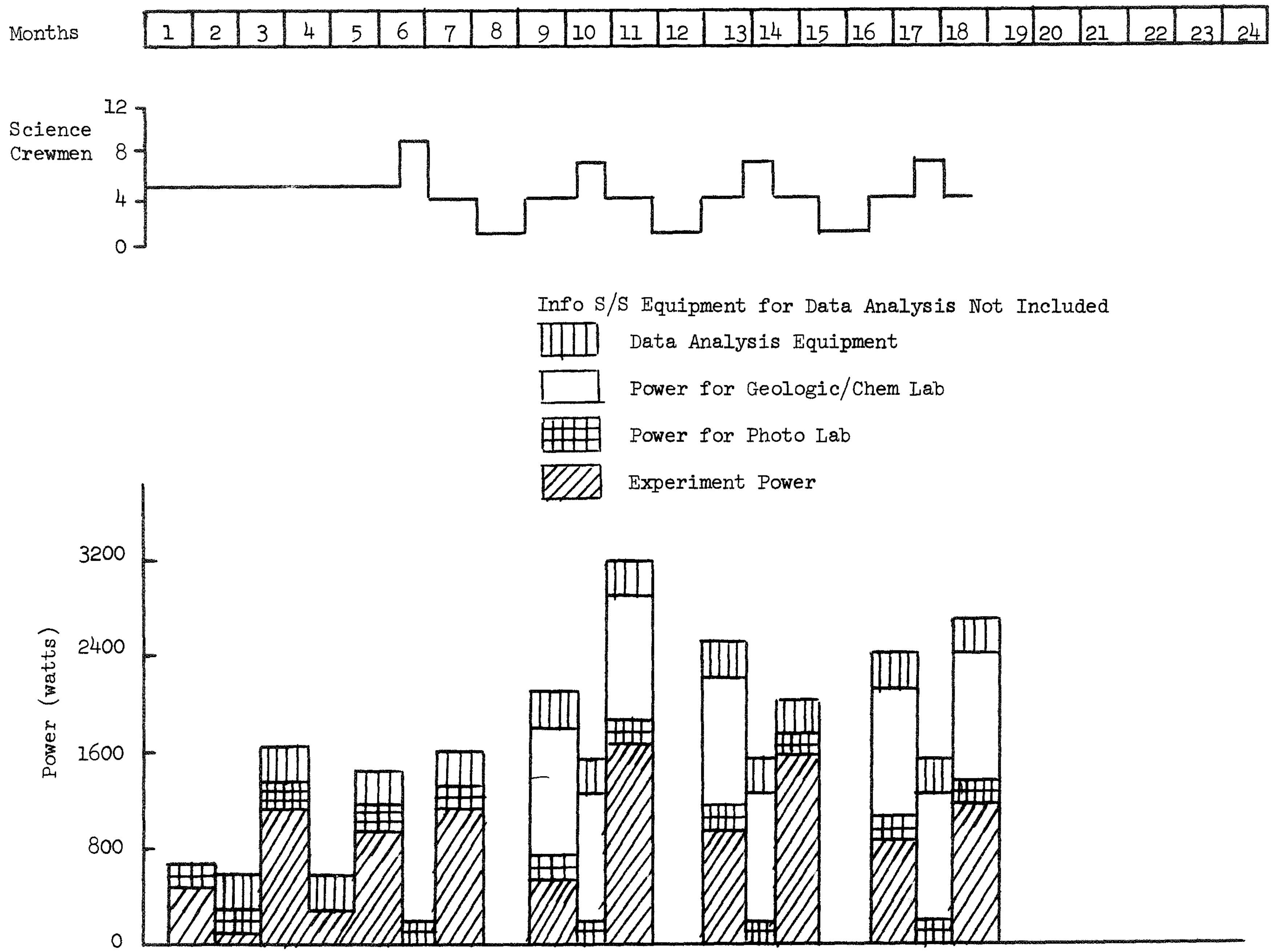


Figure 4-19. OLS Experiments Power Profile

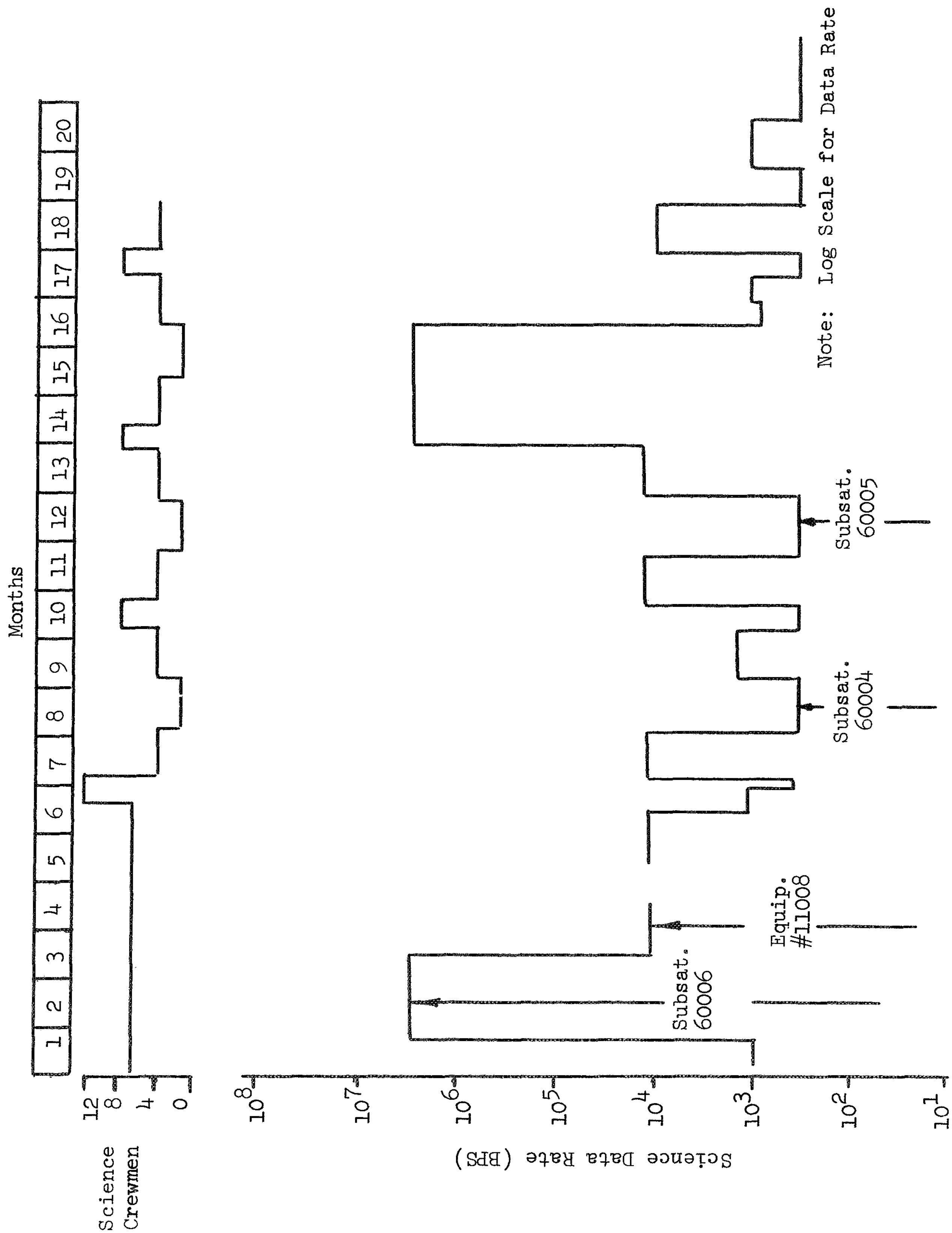


Figure 4-20. OLS Scientific Data Requirements

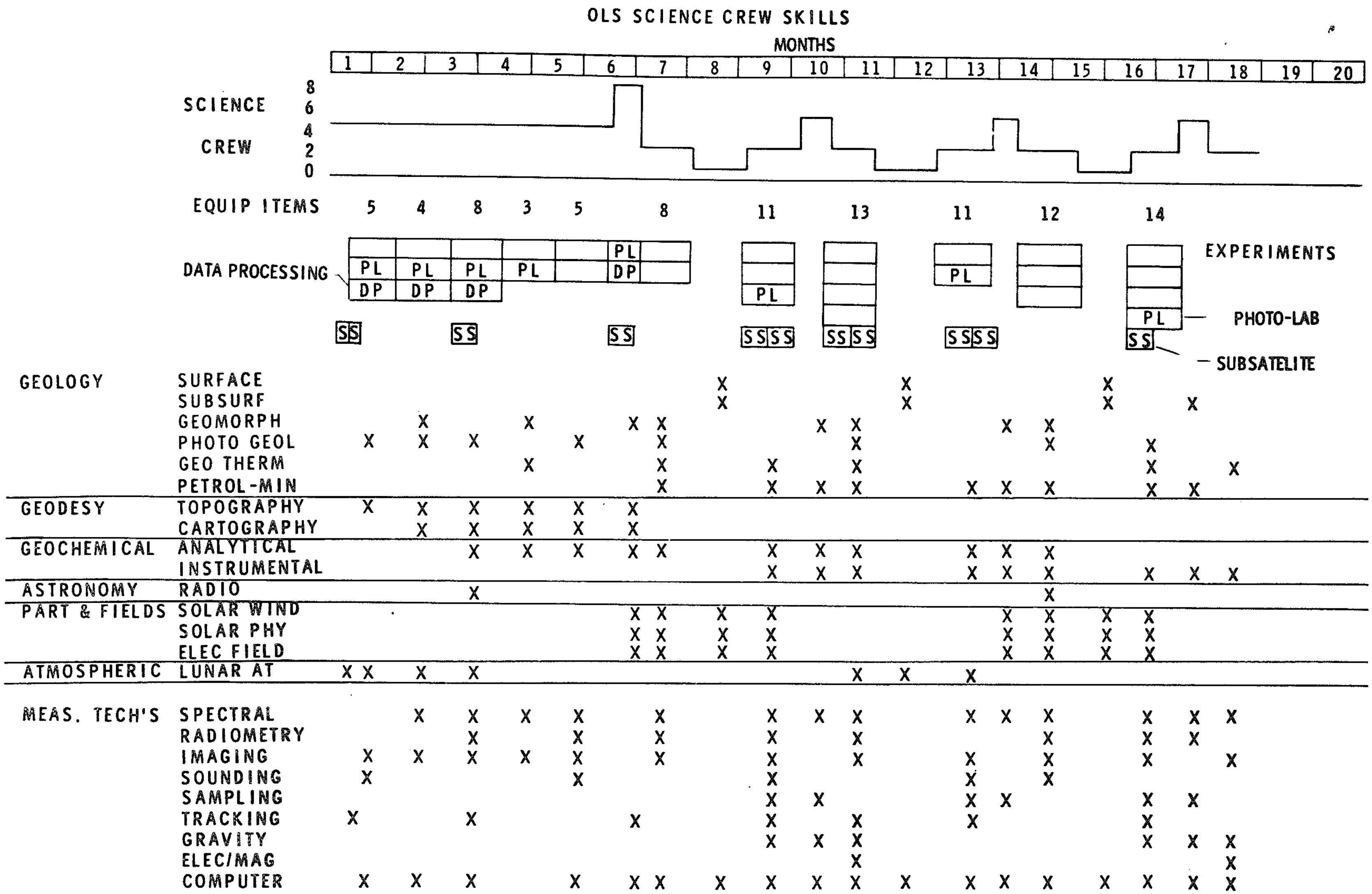


Figure 4-21. OLS Science Crew Skills

4.6 SUMMARY OF OLS SCIENCE SUPPORT REQUIREMENTS

The following data is a condensed summary of the scientific support requirements of the OLS.

Integral Floor Space	
Data Analysis Laboratory	70 square feet
Geochemistry Laboratory	100 square feet
Photography Laboratory	70 square feet
Control Center	45 square feet
Sensor Nadir Viewing Surface Area	110 square feet
Airlock Requirements	
Satellite Servicing	5 foot diameter x 10 feet long
Sensors	110 square feet of surface area
Servicing	
Cameras and tape recorders	Continuous shirtsleeve
All other sensors	Periodic shirtsleeve
Consumables (per 109 days)	
Orbital Science	
Nitrogen (subsatellite)	455 pounds
Hydrazine (subsatellite)	3460 pounds
Spares and replacements	108 pounds
Film	252 pounds
Displays	Control Console
Guidance and Stability	
Ephemeris Accuracy	
Altitude	± 330 feet
In-track	± 850 feet
Cross-track	± 490 feet
Orbit velocity	± 25 feet per second
Angular Rate Control	
Continuous	± 0.05 degrees per second
Fine pointing	± 0.01 degrees per second

Attitude Control	
Inertial	± 0.25 degree
Relative, continuous	± 0.25 degree
Relative, fine pointing	± 0.1 degree
Surface Science (per sortie)	
Mobility equipment propellant	5500 pounds
Expended scientific equipment (emplaced sensors, film, tapes, etc.)	725 pounds

Electrical Power

Average	4 kw
Surge	6 kw - 1 hour
Peak	7 kw - 1 minute

Data Requirements

Digital	
Peak (instantaneous)	6×10^6 bps
Daily (maximum)	3.5×10^{11} bpd
Daily (average)	1×10^5 bps
Television	
Closed circuit on OLS	3 channels
OLS to surface	1 channel
Storage Capacity	
Operating Memory	
Mass storage	1×10^6 words
Command and Control (including subsatellites)	
Discrete	1500
Variable	80 eight-bit commands
Data Processing	1×10^{10} bpd