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Lunar Base Synthesis Study

FINAL REPORT

VOLUME II

APPENDIXES

Space Division
North American Rockwell

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APPROVED BY

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LUNAR BASE SYNTHESIS

Space Division
North American Rockwell

CONTENTS

APPENDIX A. LSB SCIENCE EQUIPMENT LIST

This section contains the summary descriptions of the individual items of equipment required to conduct the experiments which have been defined. For each item of equipment the following data is presented where applicable:

1. Equipment Number - NR-assigned index number designed to assist future users of these data
2. Equipment Name - brief nomenclature for the item
3. Average Power (watts) - during operating periods
4. Weight (pounds)
5. Volume (cubic feet) - as packaged for shipment
6. Data Rate (bits per second) - peak during operation
7. Experiments Supported - one or more applications for the equipment item
8. Remarks - comments relative to consumables, number required, other interfaces, etc.

LSB Science Equipment List

Equip. No.	Equipment Name	Average Power (watts)	Weight (lb)	Volume *** (cu ft)	Data Rate (bps)	Experiments Supported (numbers)	Remarks
11005*	Gamma ray spectrometer	10.0	85.0	2.0	3000	4057	
11064*	Antenna (750-ft dipole)	**	9.1	3.0	**	4025	
11079	Downhole geophys. probe	34.0	57.0	4.0	1.1×10^4	4059	
11081	Gravimeter (LaCoste Romberg)	5.0	33.0	1.4	0.7	4044	
11082	Photographic astronomical transit	25.0	120.0	1.8	0.3	4044	Consumables: film
11083	Photomicrographic camera	60.0	15.0	2.0	film	4001	Consumables: film
11086*	Neutron activ. anal. eq.	25.0	35.0	0.4	280	4038, 4061	2 req'd; one for each experiment
11087	Seismic amplifier	5.0	4.4	.028	**	4046	
11088	Seismometer (4 Comp. Lamont)	1.0	22.2	.56	230	4039, 4047	2 req'd; one for each experiment
11091	Vector imped. meter	15.0	20.0	.63	7	4023	
11092	X-ray telescope (grazing incidence)	20.0	3564	3106	1×10^5	4012	Consumables: film 1.1 lb/day
11093	Two-element radio interferometer (300 kHz to 1000 kHz)	25.0	11,533	1884	300 with 10^5 peaks	4014	
1094	Two-element radio interferometer (1000 kHz to 15 MHz)	25.0	350	18.0		4015	
11095	Optical telescope (50-inch)	250	11,055	3670	film	4016, 4029	Consumables: photo film 3 lb/day; film proc. mat'l 1.5 lb/day 1 item serves both exps.
11096*	X-ray diffractometer	10.0	20.0	0.7	14	4060, 4061	1 item serves both experiments
11098*	Cosmic ray spectrometer telescope	1.5	7.3	.04	2000	4050	
11099	Optical telescope (100-inch)	4000	33,000	746	3×10^6	4030	Consumables: photo film 3 lb/day; film proc. mat'd, 1.5 lb/day
11103	J-band spectrophotom.	3.0	33.0	1.05	280	4001	Also has paper strip recorder output
11104	Electron microscope	500.0	150.0	55.0	**	4001	
11108	Antenna set (0.6 to 1.2 MHz)	**	440.0	10.5	**	4027	
11109	Antenna set (5 to 500 MHz)	**	100.0	6.3	**	4028	
11110	Sweep freq. radiometer	3.0	15.0	1.5	300.0	4028	
11111	IR radiometer (portable)	**	10.0	0.3	**	4032	Self-contained power supply & data readout
11112	Absolute gravimeter	1.0	22.0	1.8	0.2	4044, 4045	1 item serves both exps.
11113	UV spectrometer	3.0	33.0	1.05	280.0	4061	
11114	X-ray spectrometer	0.5	15.0	0.7	14.0	4061	
11115	IR spectrometer	0.3	33.0	0.9	1.0	4061	
11116	Heat flow probe	**	.3	.01	**	4088	See item 40009 for power and data output
12001*	Ionization pressure sensor	6.0	2.2	.002	10	4039, 4053	4 items req'd for 4053 1 item req'd for 4039

* Items common to LSB and OLS ** Not applicable *** Launch configuration

LSB Science Equipment List (Continued)

Equip. No.	Equipment Name	Average Power (watts)	Weight (lb)	Volume *** (cu ft)	Data Rate (bps)	Experiments Supported (numbers)	Remarks
14001*	Particle counter (low energy)	0.5	10.0	0.4	1000	4050	
14002	Particle counter (high energy)	5.0	10.0	0.3	1000	4050	
14005*	Mass spectrometer	12.0	15.0	0.9	1000	4039, 4053	4 items req'd for 4053 1 item req1d for 4039
14017	Multivator	5.0	30.0	2.0	10	4001	
14018*	Gas chromatograph	15.0	55.0	2.15	**	4001, 4003, 4061	Consumables: helium 2 items req'd: 1 for 4001 and 4003; 1 for 4061
14019	Mass spectrometer (quadrupole)	3.0	44.0	.53	560	4053	4 items required
14020*	Particle spectrometer	3.0	10.0	0.2	200	4050	
14022	Organic carbon analyzer	10.0	50.0	0.5	**	4003	Consumables: O_2,H_2,He
14025	Auger spectrometer	**	40.0	1.0	**	4032, 4033, 4038	Self-contained power supply & data recorder
14026*	Mass spectr. (lab)	3.0	50.0	0.6	**	4001, 4038, 4061, 4003	
14027	Mass spectr. (portable)	**	30.0	0.6	**	4033	Self-contained power supply & data recorder. Consumables: paper
14028	Gas chromatograph (port)	**	55.0	2.0	**	4033	"
14029	Mass spect. (directional)	12.0	15.0	0.9	1000	4055	
14030	Suprathermal ion detec.	10.0	25.0	2.5	1000	4055	
15010*	Magnetometer-helium	5.0	11.0	0.1	2	4051	
15011	Magnetometer - search coil (emplaced)	10.0	13.0	0.5	320	4051	Consists of magnetometer 15002 and data buffer analyzer 15020.
15012	Electric field detector (emplaced)	0.4	4.4	.03	14	4051	
15013	RF noise survey system - surface	35.0	800.0	150.0	**	4021	
15014	Transmitter & antennas	40.0	22.0	.56	30	4022	
15008	Magnetometer-fluxgate	3.0	15.0	0.2	10	4051	
15015	Dipole ant. (2 km)	**	388	110	**	4023	
15016	Dipole ant. (20-meter)	**	6.1	2	**	4023	
15017	Whip antenna (10-meter)	**	30.0	1.0	**	4023	
15018	Plasma probe assembly	**	30.0	3.0	**	4024	
15019	Field strength meter	5.0	11.0	.35	50	4022	
15020	Electrometer assembly	3.0	32.0	4.0	300	4024, 4025	2 items required - one for each experiment
15021	Magnetometer - fluxgate (traverse)	5.0	4.0	.25	3	4058	
15022	Magnetometer - proton precession	5.0	13.2	0.7	20	4058	
30005	Tape recorder	6.0	10.0	.15	**	4023	Consumables: magnetic tape
30008	Transponder (3 freq.) with antennas	25.0	128	12.0	**	4026	3 items required
30011	Interferometer	12.0	55.0	7.0	1560	4027	

* Items common to LSB and OLS ** Not applicable *** Launch configuration

LSB Science Equipment List (Continued)

Equip. No.	Equipment Name	Average Power (watts)	Weight (lb)	Volume *** (cu ft)	Data Rate (bps)	Experiments Supported (number)	Remarks
40005	Time base generator	5.0	1.1	.18	4000	4046	
40006*	Signal conditioning equipment	20.0	20.0	1.0	**	All astronomy and atmospheric	
40009	Electronics unit (heat flow)	3.0	8.8	.14	2000	4088	Used with heat flow probe, item 11116
50006*	Sampe preparation device	500	52.6	23.0	**	4037, 4060	One item required - serves both experiments
50008	Drill - 300-meter	14,000	4200	360	**	4048	
50009	Drill - 30-meter	3000	200.0	36.0	**	4033	
50010	Seismic energy source	**	500.0	14.0	**	4046	500 one lb increments
50012	Geophones	**	50.0	.50	**	4046	
90004	Convex mirror (12-in diameter)	**	5.0	.50	**	4017	
90005	Flat surface mirror (12-in diameter)	**	5.0	.50	**	4017	
90006	Concave mirror (12-in diameter)	**	5.0	.50	**	4017	
90007	Flashing light	neg.	10.0	.30	**	4008	
90008*	Petrographic microscope	100.0	5.0	.35	**	4037, 4060	One item serves both experiments
90014	Field bioscience kit	**	33.0	.40	**	4001	
90015	Incubator	20.0	26.0	17.0	**	4001	
90016	Time lapse camera	neg.	2.0	.20	**	4006	Consum.: 35 mm film
90017	Microscope	10.0	4.4	.50	**	4006	
90018	Mapping kit	2.0	52.7	6.8	**	4032	Incl. survey staff
90019	Geological tool kit	**	8.8	.2	**	4032, 4033	One item serves both experiments
90020	UV light - portable	**	15.0	.5	**	4032	Self-contained power supply
90021	Biomon. & ecology exp. equip.	50.0	22.0	1.7	**	4064	
90022	Plant life exp. equip.	10.0	1034	4.0	**	4066	
90023	Thin film bearing experiment equip.	200	22.0	.35	**	4071	
90024	Lunar strata EM prop. experiment equip.	250.0	6.6	0.5	TBD	4078	
90025	Lunar surface trans line exper. equipment	0	4.4	.17	**	4079	
90026	Liquids heat transfer exper. equipment	neg.	15.4	.17	**	4081	
90027	Film and drop heat transfer exp. equip.	neg.	6.6	0.7	**	4082	
90028	Metals joining exp. eq.	1800	44.0	1.70	**	4084	
90029	Diff. thermal anal. exper. equip.	2.0	11.0	3.50	**	4085	
90030	Ore analysis equipment	0	11.0	0.1	**	4086	
90031	Lunar dry cement and concrete prep. equip.	350.0	240.0	35.0	**	4087	

* Items common to LSB and OLS   ** Not applicable   *** Launch configuration

APPENDIX B. LUNAR SURFACE EXPERIMENT DEFINITIONS

This section consists of individual lunar surface experiment narrative descriptions and timelines. Each experiment definition consists of the following elements:

1. Discipline - the broad category of activity which the experiment principally supports

2. Experiment Identification Number - an NR-assigned index number designed to assist future users of these data

3. Experiment Title - a concise description of the experiment

4. Applicable Subobjectives - a tabulation of the disciplinary subobjectives primarily supported by the experiment together with an assessment of the contribution the experiment makes to the achievement of the subobjectives

5. Observation Requirements - a narrative description of the experiment objectives, operations and (where necessary) equipment

6. Equipment Required - a list of the prime items of experiment hardware required to conduct the experiment, together with a summary of (integrated) support requirements

7. Master Timeline - a summary of experiment operations in timeline format including the following data:

    a. Time-phased operations sequence - a bar chart identifying each significant experiment operation and showing their durations and relative phasing

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

    c. Constraints - significant operational limitations for each phase of experiment operation

    d. Equipment number - the NR-assigned index number for the equipment used during each experiment phase

    e. Manpower requirements - the number of crew man-hours required to conduct one operations sequence (except as noted)

The following listing provides an index to the experiment descriptions which are contained in this Appendix.

DISCIPLINE	EXP. NO.	TITLE
BIOSCIENCE	4001	Life Detection
BIOSCIENCE	4003	Terrestial Contamination
BIOSCIENCE	4006	Behavior and Rythms of Plants
AEROSPACE MEDICINE	4008	Flicker Vision
AEROSPACE MEDICINE	4009	Reduced Gravity and Behavior Effects
AEROSPACE MEDICINE	4011	Vision Effects
ASTRONOMY	4012	X-Ray Astronomy
	4014	Radio Astronomy - .3 to 1.0 MHz
	4015	Radio Astronomy - 1.0 to 15 MHz
	4016	Optical Astronomy - 50-inch
	4021	Radio Noise Survey
	4022	Radio Propagation
	4023	Impedance Measurements
	4024	Lunar Plasma Effects
	4025	Antenna Dust Accumulation
	4026	Cislunar Wave Propagation
	4027	Temporal Variations - .6 to 1.2 MHz
	4028	Temporal Variations - 5 to 500 MHz
	4029	Infrared Astronomy
ASTRONOMY	4030	Optical Astronomy - 100-inch
GEOLOGY/GEOCHEMISTRY	4032	Geologic Mapping and Stratigraphy
	4033	Drilling and Subsurface Sampling
	4037	Petrographic Analysis
	4038	Mineralogic Identification
GEOLOGY/GEOCHEMISTRY	4039	Transient Activity Investigation
GEODESY/CARTOGRAPHY	4044	Geodetic Grid Construction
GEOPHYSICS	4045	Gravity Profiling
GEOPHYSICS	4046	Active Seismic Investigations
GEOPHYSICS	4047	Passive Seismic Investigations
GEOLOGY/GEOCHEMISTRY	4048	Deep Drilling and Sampling
PARTICLES & FIELDS	4050	Solar Wind and Energetic Particles
PARTICLES & FIELDS	4051	Magnetic and Electrical Field Variations
LUNAR ATMOSPHERE	4053	Total Pressure and Composition
LUNAR ATMOSPHERE	4055	Escape and Transport Rates
GEOLOGY/GEOCHEMISTRY	4057	Natural Radiation Spectrum
GEOPHYSICS	4058	Magnetic Profiling
GEOPHYSICS	4059	Hole Bore Logging
GEOLOGY/GEOCHEMISTRY	4060	Mineralogic Analysis
GEOLOGY/GEOCHEMISTRY	4061	Chemical Analysis in Lab
ENG., TECH., & OPNS.	4064	Biologic Monitor and Eco-System
	4066	Effects on Plants
	4071	Thin Film Bearings
	4074	Mining and Transport
	4078	Electromagnetic Propagation
	4079	Transmission Line Interactions
	4081	Heat Transfer in Liquids
	4082	Film and Drop Heat Transfer
	4084	Metals Joining
	4085	Differential Thermal Analysis
	4086	Self-Welding Characteristics
ENG., TECH., & OPNS.	4087	Lunar Dry Cement and Concrete
GEOPHYSICS	4088	Near Surface Temperature Gradient

DISCIPLINE: Bioscience

EXPERIMENT ID NO.: 4001

EXPERIMENT TITLE: Life Detection - Viable Life Forms and Dormant Spores

APPLICABLE SUB-OBJECTIVES:

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

Analysis of samples from full range of depths, protected areas, volcanic sites, and any other representative sample site. This experiment will provide a major portion of the information required to characterize life forms on the moon.

OBSERVATION REQUIREMENTS:

Characteristics to be identified include chemicals (amino acids, peptides, nucleosides, proteins, lipids, carbohydrates) and processes include turbidity, ph, metabolism, phosphatases. Functions can be performed on site (at the location of the sample taking) or at the Base depending upon the number of samples to be taken from a given site. Activities at the Base are of the more analytical variety. The sample (at the site) is to be separated into five parts (one for each instrument) thus allowing parallel examination at both the site and the Base. If a positive indication is observed on any one sample portion, that examination is required to be repeated at least three more times to establish confidence in that observation.

Identification of a life form through the above observation then establishes a candidate for incubation to determine if that form is dormant.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
14026	Mass Spectrometer (lab)
14018	Gas Chromatography (site)

Equipment No.	Equipment Name
14017	Multivator (site)
11103	J-Band Detector (UV Spectrophotometer) (lab)
11104	Electron Microscope (miniaturized) (lab)
11083	Photomicrographic Camera (lab)
90015	Incubator - with earth atmosphere (lab)
90014	Field Bioscience Kit (site)

Avg. Pwr. (watts) - 3.0 - 500
Weight (lbs) - 392
Volume (cu ft) - 81.0
Data Rate (BPS) - 280

MASTER TIMELINE

EXP. NO. 4001

FREQUENCY OF OPERATION MIN 75 MAX 250	OPERATION NO.	TIME (Hours) 0 2 4 6 8 10	CONSTRAINT	EQUIP. NO.
ON SITE				
Equipment Setup	1			
Sample Preparation	2			
Chemicals (On-Site)	3			14018 90014
Processes (On-Site)	4			14017
Equipment Dismantle		TIME (Hours) 0 2 4 6 8 10 12		
IN LAB				
Phys. Property and Biological Anal. (In Lab)	5	Continuous as required		14026 11103 11104 11083
Incubation	6			90015

MANPOWER REQUIREMENTS: 10 MAN-HOURS/REPETITION (EXCLUDING INCUBATION)

DISCIPLINE: Bioscience

EXPERIMENT ID NO.: 4003

EXPERIMENT TITLE: Terrestrial Contamination

APPLICABLE SUB-OBJECTIVES:

BI-2 Evaluate the lunar environment for survival of terrestrial micro-organisms and the amount of forward-back contamination. The present experiment will provide a major contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

Primary target is organic carbon of terrestrial living things. Frequently traveled or exhausting areas will be sampled to check for the number of terrestrial organisms. To-be-traveled areas will be examined to verify the absence of hydrocarbons. Samples will be analyzed in situ by the organic carbon analyzer or a mass spectrometer; a separate portion of a positive-indicating sample will be packaged for detailed characterization in the Base by use of an electron microscope. The in situ spectrography will be performed on 50 percent of the samples only.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
14018	Gas Chromatograph
14026	Mass Spectrograph (Lab)
14022	Organic Carbon Analyzer
11104	Electron Microscope

Avg. Pwr. (watts) - 3 - 15
Weight (lb) - 155
Volume (cu ft) - 3.25
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4003

FREQUENCY MIN	FREQUENCY MAX		OPERATION NO.	TIME-MINUTES (0 5 10 15 20)	CONSTRAINT	EQUIP. NO.
300	1200					
		SAMPLE EXAM.	1	10	COORDINATE WITH TUG LANDINGS, BASE/SUIT EFFLUENTS	14022 14026 14018
		DETAIL EXAM. (IN LAB)	2	15		11104

MANPOWER REQUIREMENTS: 25 MAN-MINUTES/REPETITION

DISCIPLINE: Bioscience

EXPERIMENT ID NO.: 4006

EXPERIMENT TITLE: Behavior and Rhythms of Plants

APPLICABLE SUB-OBJECTIVES:

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

This experiment provides a major contribution to the sub-objective. A derived objective is the development of plants which will grow in the lunar day/night cycle. The animal portion is performed in conjunction with Experiment 4064. Genetic effects will also be obervable through the mechanics of this experiment.

OBSERVATION REQUIREMENTS:

The seed planting will be scheduled to have the plants at various stages in the lunar day/night to select the most likely candidate for development. Artificial light will be required. Observations of growth, development, and reproduction to be recorded photographically. Sections of plant leaves will be analyzed for structure changes by use of an electron microscope. It is anticipated that the observations would be more frequent during the lunar night than during the day to determine the timing for light activation. Control samples on earth will provide relative data for the plant material. The evaluations will also include genetic effects on the plants; i.e., cytological changes.

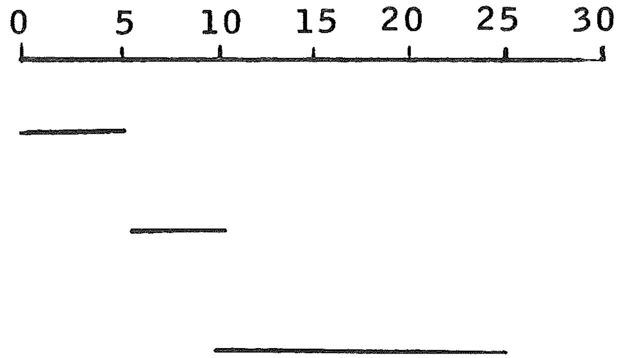
EQUIPMENT REQUIRED:

Equipment No.	Equipment Name	
90016	Time Lapse Camera	Avg. Pwr. (watts) - 10.0
90017	Microscope	Weight (lbs) - 6.4
		Volume (cu ft) - 0.70
		Data Rate (BPS) - N/A (film)

MASTER TIMELINE

EXP. NO. 4006

FREQUENCY OF OPERATIONS MIN. MAX.	OPERATION NO.	TIME (MINUTES)	CONSTRAINTS	EQUIP. NO.
PLANT SEED	1		EXP. 4064 MAY BE CONDUCTED SIMULTANEOUSLY - NOT REQUIRED	
OBSERVE	2			90016
CUT-EXAMINE	3			90017



NOTES (1) IT IS ASSUMED THAT ADDITIONAL SEEDS ARE PLANTED IN CONJUNCTION WITH EACH OBSERVATION PERIOD

(2) PERFORM THE FUNCTIONS EVERY THREE DAYS FOR THREE YEARS

MANPOWER REQUIREMENTS: 25 MAN-MINUTES/REPETITION

DISCIPLINE: Aerospace Medicine

EXPERIMENT ID NO.: 4008

EXPERIMENT TITLE: Flicker Vision

APPLICABLE SUB-OBJECTIVES:

AM-1 Determine the effect of the reduced magnetism (of the moon) on the body rhythms.

An examination of the Flicker Vision Effect in this experiment will constitute a minor contribution toward meeting the sub-objective.

OBSERVATION REQUIREMENTS:

The observation requirement is the onset of flicker fusion response of each crew member of the Base to a known flashing light source. The threshold is identified by an increase in the pulse and heartbeat of the individual and is recorded in intensity and frequency of the light.

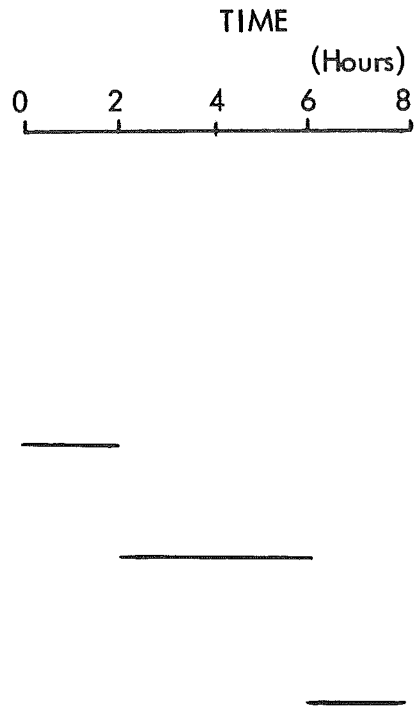
The experiment requires the establishment of the threshold for each individual, of the flicker vision fusion before the Base tour and after the Base tour. The measurements should be duplicated for an individual at the beginning and end of the same day to identify fatigue effects. The experiment should be continued upon the return of the individual to earth to determine the long term effects of the changes.

The test itself requires the observation of the normal response to the disturbance and return to the normal. Correlate with Experiment 4051.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90007	Flashing Light (variable frequency and intensity)
90002	IMBLMS (biomedical measurement console)

MASTER TIMELINE EXP. NO. 4008



FREQUENCY OF OPERATIONS MIN.	MAX.	OPERATION NO.	CONSTRAINTS	EQUIP. NO.
Three observations during ea. crew man's tour	2/man week			
Set up		1	Subject isolated. (Assumes IMBLMS equip. operational)	90002 90007
Observe (entire crew)		2		
Dismantle & evaluate		3		

MANPOWER REQUIREMENTS: 8 man-hours/repetition

DISCIPLINE: Aerospace Medicine

EXPERIMENT ID NO.: 4009

EXPERIMENT TITLE: Reduced Gravity and Behavior Effects

APPLICABLE SUB-OBJECTIVES:

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

The experiment will be a minor contribution to meeting this sub-objective, since a more intensive program will be carried out on earth orbiters.

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

The present experiment constitutes a minor contribution toward this sub-objective due to more extensive information being obtained previously elsewhere; i.e., on earth orbiters.

OBSERVATION REQUIREMENTS:

This experiment is a part of the continuing medical/behavioral program of men in the space environment. All of the crew members will participate as test subjects. Observations will be in cardiovascular, pulmonary, endocrionology, hematogical, neurophysiologic, nutrition, microbiological, and behavioral.

Observations are scheduled upon arrival of the crew member on site, at three-week intervals during the staytime, and prior to departure. The behavioral activities will be performed on a weekly basis to identify any changes in response of the crew to the planetary type environment.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90002	IMBLMS (Integrated Medical Behavior Laboratory Measurement Systems)

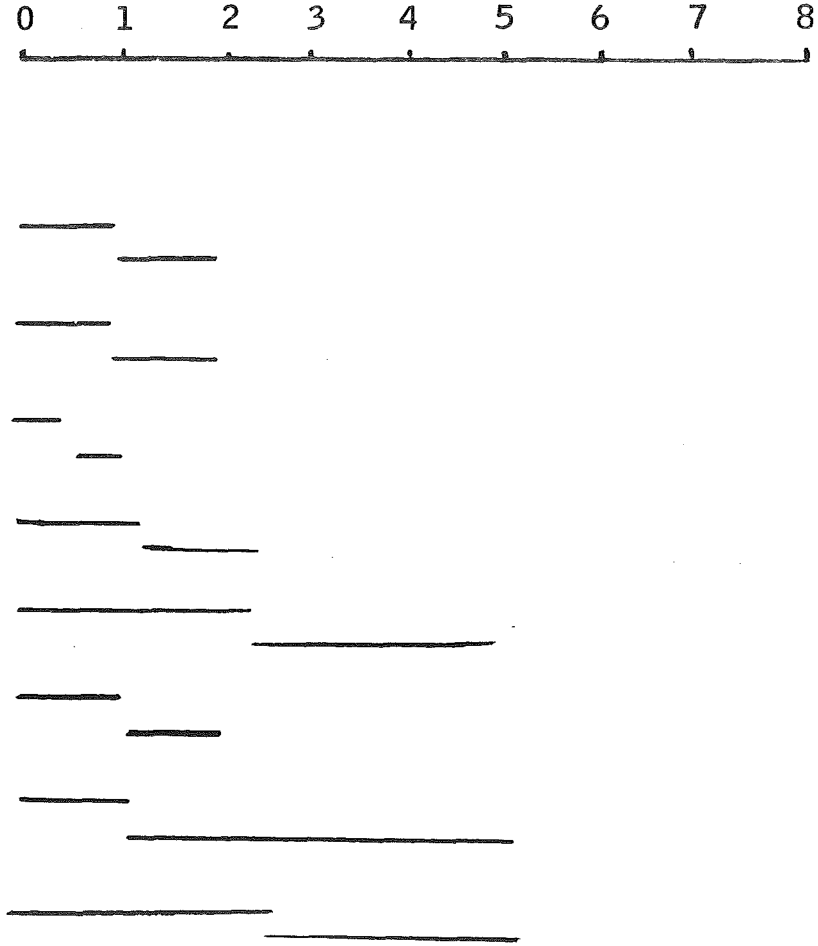
MASTER TIMELINE

EXP. NO. 4009

Time - Hours

FREQUENCY OF OPERATION*
MIN 6/Man
MAX 26/Man

OPN. NO.



FUNCTIONS (PER CREWMAN)

SET UP Cardiovascular

SET UP Pulmonary

SET UP Endocrine

SET UP Hematol

SET UP Neurophys.

SET UP Nutritional

SET UP Microbiolog.

SET UP Behavioral

CONSTRAINTS

1) Distribute uniformly over total crew stay time

2) Functions may be performed in parallel on up to 8 crewmen simultaneously

EQUIP. NO.

90002

*Frequency for a six-month duration.

NOTE: Durations shown for each function provide for testing entire crew

MANPOWER REQUIREMENT: 24 MAN-HOURS/REPETITION (ENTIRE CREW)

DISCIPLINE: Aerospace Medicine

EXPERIMENT ID NO.: 4011

EXPERIMENT TITLE: Vision Effects

APPLICABLE SUB-OBJECTIVES:

AM-4 Verify the effect of the lack of atmosphere on human vision.

This experiment will complete the vision verification program and be a minor contribution toward fulfilling this sub-objective.

OBSERVATION REQUIREMENTS:

This experiment is intended to investigate the influence of size, shape and patterns on objects in the lunar environment, both direct sunlight and shade. The appearance of typical hand-held operated tools and the variation of that appearance with the lunar day require investigation. The investigation will involve the evaluation of tool handling for each operation under light and shade conditions, and supplementary lighting. The evaluation of dark adaptation by various filters will be performed. These vision effects will be evaluated in conjunction with the operations outside the Base.

EQUIPMENT REQUIRED:

No equipment peculiar to this experiment is required.

MASTER TIMELINE

EXP. NO. 4011

FREQUENCY OF OPERATIONS MIN. MAX.	OPERATION NO.	TIME (Minutes) 0 5 10 15 20 25 30	CONSTRAINTS	EQUIP. NO.
250 800 Per six months				
Set up		Not Specific	Lunar day and night operation required.	None. Use standard operational equipment.
Tool Handling	1			
Vehicle/Equip Obs.	2			
Dark Adaptation	3			

MANPOWER REQUIREMENTS: 15 man minutes/repetition

DISCIPLINE: Astronomy

EXPERIMENT ID NO: 4012

EXPERIMENT TITLE: Intensity Distribution for X-Ray Sources

APPLICABLE SUBOBJECTIVES:

AY-1 Investigate celestial regions in X-ray domain. This experiment is a major contributor to these subobjectives.

AY-3 Perform radio observations of galactic and extragalactic sources.

OBSERVATION REQUIREMENTS:

The nature of this experiment is to obtain an X-ray map of the sky. The site should be located near the lunar equator and possibly inside a fairly large crater, $\sim$ 100 km in diameter, in order to obtain an occulting edge for the determination of position and angular size of weak discrete sources. The measurements include the intensity distribution for X-ray sources in the energy region from 1 to 10 Kev, as a function of angle (watts/steradian). A gas-filled proportional counter with an approximate area of 100 cm^2 aperture will fill the initial requirements. In order to perform the occultation experiment to a higher degree of accuracy, an X-ray telescope will be used to yield position accuracies of 1.0 to 0.5 arc second. The diameter of the telescope will be on the order of one meter.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11097	X-ray Telescope (wide angle)
11092	X-ray Telescope (grazing incidence)

Avg. Pwr. (watts) - 20-150 (RTG)
Weight (lb) - 4019
Volume (cu ft) - 3636
Data Rate (BPS) - 1 x 10^5 (film - 1.1 lb/day)

FREQUENCY OF OPERATION MIN. 12 cycles MAX. 36 cycles	OPERATION NO.	Time (Hours) 10 20 30 48	CONSTRAINTS	EQUIP. NO.
Site Preparation		Approx. 48 hours	See remarks	11097
Installation		8 hours		
Calibration		4 hours		
Operation		1 month per cycle	Operate continuously one month per cycle	11092

REMARKS:

1. Best Location - near lunar equator, inside large crater (~100Km diam.)
2. Surface grader required for site preparation.

MANPOWER REQUIREMENT: 60 MANHOURS/REPETITION

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4014

EXPERIMENT TITLE: Observations of flux densities from galactic and extra galactic sources in the frequency region of 300 kHz to 1000 kHz

APPLICABLE SUB-OBJECTIVES:

AY-3 Perform radio and optical observations of galactic and extra galactic sources. This experiment is a major contributor to this subobjective.

OBSERVATION REQUIREMENTS:

A two-element interferometer will be used to resolve radio sources in the frequency region from 300 to 1000 kHz. The resolving power is directly proportional to the separation of the two main elements. Each element will consist of an array of end-loaded, folded dipoles. Each array consists of 16 multiwire loaded, folded dipole elements, spaced a half-wavelength apart and with each element horizontal and at right angles to the line of the array. The arrays will be spaced 9 kilometers apart, center-to-center, to yield the main lobe's half-power beamwidth of 1.7 degrees at 1 mHz. The location will be on the lunar equator with the baseline on the east-west line. In order to overcome transmission losses, solid-state amplifying elements, like tunnel diodes or transistors will be used at appropriate points in the antenna or part of the transmission link. Non-resonant corporate feed transmission line system will be used for this broadband operation. Each element will consist of a multiwire folded dipole, support structure (with ground screen) and battery and control circuits.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11093	Two element radio interferometer (300 kHz to 1000 kHz)

Avg. Pwr. (watts) - 25
Weight (lbs) - 11,583
Volume (cu ft) - 1884
Data Rate (BPS) - 300 with 10^5 peaks

MASTER TIMELINE

EXP. NO. 4014

FREQUENCY MIN	FREQUENCY MAX	OPERATION NO.	TIME-HOURS (0 – 10 – 20 – 30)	CONSTRAINT	EQUIP. NO.
12 cycles	36 cycles				
		Site Preparation	48 hrs (approx)	Install 2 arrays separated 9 Km	
		Installation	20 hrs		
		Calibration	4 hrs		
		Operate	1 month	Operate continuously one month per cycle	11093

REMARKS:

1. Best Location - Near Lunar Equator
   Baseline Orientation - East/West

2. 10-Meter Drill required for Site Preparation

MANPOWER REQUIREMENT: 80 MANHOURS/CYCLE

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4015

EXPERIMENT TITLE: Observations of flux densities from galactic and extra-galactic sources in the frequency of 1 mHz to 15 mHz

APPLICABLE SUB-OBJECTIVES:

AY-3 Perform radio and optical observations of galactic and extra-galactic sources. This experiment is a major contributor to the subobjective.

OBSERVATION REQUIREMENTS:

A similar setup to Experiment No. 4014 but in the different frequency interval of 1 mHz to 15 mHz. The dimensions can be scaled by approximately a factor of 0.1.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11094	Two element radio interferometer (1 mHz - 15 mHz)

Avg. Pwr. (watts) - 25
Weight (lb) - 350
Volume (cu ft) - 18
Data Rate (BPS) - 300 with 10^5 peaks

MASTER TIMELINE

EXP. NO. 4015

FREQUENCY MIN.	FREQUENCY MAX.	OPERATION NO.	TIME (Hours): 0, 10, 20, 30, 40 … 1 mo.	CONSTRAINT	EQUIP. NO.
12 cycles	36 cycles				
Prepare site		1	24 hrs	Install two arrays 1 km apart. Locate near lunar equator. Orient baseline in east/west direction. Operate continuously at one month per cycle	11094
install, align		2	6 hrs		
calibrate		3	5 hrs		
Operate		4	1 month		

MANPOWER REQUIREMENT: 80 MANHOURS PER CYCLE

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4016

EXPERIMENT TITLE: Optical Astronomy

APPLICABLE SUB-OBJECTIVES:

AY-3 Perform radio and optical observations of galactic and extra galactic sources. This experiment makes a small contribution to this sub-objective in terms of the overall objectives of optical astronomy.

OBSERVATION REQUIREMENTS:

Determine sky brightness of the full sky. Optical telescopes approaching 50-inches in diameter will be housed in an appropriate shielded observatory dictated by the results of the exposure effect experiment. The accessories would include a photometer, camera and film. The location should be near the lunar equator in order to achieve near full coverage of the sky and 15 earth days of darkness. Location at the pole in a region of permanent shade will afford the longest period of darkness.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11095	Optical Telescope (50-in.)

Avg. Pwr. (watts) - 250 (RTG)
Weight (lbs) - 11,055
Volume (cu ft) - 3670
Data Rate (BPS) - Film (3 lb/day) (Processing - 1.5 lb/day)

MASTER TIMELINE

EXP. NO. 4016

FREQUENCY MIN	FREQUENCY MAX	OPERATION NO.	TIME-HOURS (0 10 20 30 40 50 60 70 80 1 Yr)	CONSTRAINT	EQUIP. NO.
1 cycle	5 cycles				
Prepare Site					
Install and align		1	40 hrs	Intermittent operation anticipated for one year. Share time with Exp. 4029	11095 (1.3m optical telescope)
Calibrate & actuate		2	8 hrs		
Observe and Photograph			1 year		

MANPOWER REQUIREMENT: 750 MANHOURS/YEAR

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4017

EXPERIMENT TITLE: Optical Effects from Environment

APPLICABLE SUB-OBJECTIVES:

AY-3 Perform radio and optical observations of galactic and extragalactic sources. This experiment makes a moderate contribution to this subobjective.

OBSERVATION REQUIREMENTS:

A variety of optical surfaces such as concave mirrors, convex mirrors and flat surfaces of diameters on the order of 0.3 meters will be emplaced on the surface of the moon for environmental effects (exposure). The actual emplacements of these surfaces would include locations near the lab and also a few kilometers away. The measurements to be conducted on these surfaces would include dust accumulation, micrometeoroid bombardment, fogging of the surfaces, and warping of the surfaces due to gravitational and thermal effects. The supporting instruments would be microscopes to view the surface irregularities and telescope mounts or stands to view light through or reflected from the surface. Also, thermistors should monitor the thermal environment of the surfaces.

The stay times should approach several months to a year.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90004	Convex Mirror (12" dia.)
90005	Flat Surface Mirror (12" dia.)
90006	Concave Mirror (12" dia.)

Avg. Pwr. (watts) - N/A
Weight (lb) - 15
Volume (cu ft) - 1.5
Data Rate (BPS) - N/A

MASTER TIMELINE EXP. NO. 4017

FREQUENCY MIN.	MAX.	OPERATION NO.	TIME	CONSTRAINT	EQUIP. NO.
Once	Ten		Hours: 0 2 … 170 194		
Set up, align, calibrate		1	2 hrs		90004 90005 90006
Operate		2	1 week 1 week etc. for one year		
Test		3	1 day 1 day		
Deactivate					

Repeat testing at intervals up to 10 yrs

MANPOWER REQUIREMENT: 42 MANHOURS PER YEAR

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4021

EXPERIMENT TITLE: Noise Survey

APPLICABLE SUB-OBJECTIVES:

AY-4 Determine surface and subsurface electrical properties. This experiment makes a moderate contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

Measurement of naturally occurring electromagnetic signals in the frequency range 10 Hz to 300 kHz in the region of the lunar surface will be made by an antenna system coupled to a set of broad and narrowband receivers. The antenna system will consist of a 15-meter crossed vertical loop system, a 15-meter vertical whip, and a 2 km horizontal wire, each of which operates over individual receiver channels. Stepping receivers (similar to those employed aboard the POGO satellite) will be employed to measure amplitudes of signals that are in an 80-db range above the threshold sensitivity. The measurements performed by these receivers are: (1) a recurrent amplitude spectrum analysis of signals in five bands - 10 to 80 Hz, 80 to 600 Hz, 0.6 to 4.7 kHz, 4.7 to 37.5 kHz, and 37.5 to 300 kHz; (2) amplitude of signals at any desired single frequency; (3) relative amplitude of signals sensed by each loop with respect to the whip; and (4) relative phase of signals sensed by each loop with respect to the whip. This information is used to determine noise wave impedance, polarization and direction of arrival of signals. The broadband receiver is used to investigate signals in the range of 50 Hz to 200 kHz. Phase and amplitude are measured in the two bands, 50 Hz to 2 kHz and 5 to 200 kHz. The crossed loop antenna is 15 meters square. The whip is 15 meters long.

The 2 km horizontal antenna will sample the horizontal electric field component of the noise. In calibrating the loops and whips, a precalibrated simple transmitter of low power feeding a short vertical whip situated about a kilometer away should be used. The experiment should be performed during special events (lunar day and night, passage through the tail of the earth's magnetosphere, during solar flares and quiet solar activity). Another type of measurement would be to apply a dc potential (both positive and negative) varied from 0 to 150 volts between the loops and ground, the object being to note the effects of the applied potential against charged dust particles and plasma environment. Also an insulating plastic balloon radome could be used to cover the antennas in order to isolate dust particles and their associated noise.

EQUIPMENT REQUIREMENTS:

Equipment No.	Equipment Name
15013	R. F. Noise Survey System (surface)

Avg. Pwr. (watts) - 35
Weight (lbs) - 800
Volume (cu ft) - 150
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4021

FREQUENCY MIN.	FREQUENCY MAX.	OPERATION NO.	TIME (Hours: 0, 8, 16, 1 mo.)	CONSTRAINT	EQUIP. NO.
Once	Twice				
Install, align calibrate and actuate		1	16 hrs		15013
		2	4 hrs		
Observe and record		3	1 month continuous		
Analysis		4	2 weeks		
Observe on intermittent basis 1 hr/day for one year		5	1 hr		

MANPOWER REQUIREMENT: 400 MANHOURS PER YEAR
(AT LSB)

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4022

EXPERIMENT TITLE: Radio Propagation

APPLICABLE SUB-OBJECTIVE:

AY-4 Determine surface and subsurface electrical properties. This experiment makes a moderate contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

Evaluation of the ground wave propagation and propagation upon the lunar surface is the final output of this experiment. Radio transmission, from a transmitter and an antenna, will be measured by a calibrated field strength receiver deployed upon the lunar surface at a distance of about 10 kilometers. The radio transmitter will be an AM 10-watt nominal-output-frequency and amplitude-stabilized master oscillator and power amplifier capable of providing an output of 40 watts over the frequency range of 1 kHz to 30 mHz. A long-wire Beverage wave antenna (1 km) plus a vertical whip antenna will be matched to the transmitter. A portable field strength indicator which measures CW or AF AGC voltage in the frequency range of 1 kHz to 30 mHz in several bands will be located about 10 km away with ultimate distances of hundred of kilometers. A VHF data link with a wire mesh ground mat may be used to transmit the field strength measurements to the home base.

The parameters to be measured are the transmitter antenna current and field strength. The range and accuracy of the parameters are as follows: log antenna current of 1 to 10^3 ma (two significant figures) and log field intensity of 10 to 10^4 mv/m (two significant figures).

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
15014	Transmitter and Antenna
15019	Field Strength Meter

Avg. Pwr. (watts) - 5-40
Weight (lbs) - 33
Volume (cu ft) - .91
Data Rate (BPS) - 30-50

MASTER TIMELINE

EXP. NO. 4022

FREQUENCY OF OPERATIONS MIN. 4 MAX. 32	OPERATION NO.	TIME (0 20 40 60 168)	CONSTRAINT	EQUIP NO.
Install	1	20 hrs		15014 15019
Align & Calibrate	2	6 hr.		
Observe & Record	3	4 hr.		
Inactive	4	141 hr.		

MANPOWER REQUIREMENTS : 25 MAN-HOURS PER CYCLE

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4023

EXPERIMENT TITLE: Impedance Measurements of Antennas

APPLICABLE SUBOBJECTIVES:

AY-4 Determine surface and subsurface electrical properties. The experiment is a minor contributor to this subobjective.

OBSERVATION REQUIREMENTS:

Through accurate antenna impedance measurements, useful information concerning the subsurface properties such as conductivity, permittivity and depth of penetration, and the surface properties such as lunar surface density, permittivity and maybe surface magnetic fields will be determined. The magnitude and phase angle of the unknown impedance are measured directly from each antenna configuration over the frequency range of 1 kHz to 30 mHz in present incremental frequency steps. The impedance magnitude will have a range of 1 to 10^7 ohms and an accuracy to three significant figures. The phase angle will have a range of 0 to $\pm$ 180 degrees to be known to three significant figures. The equipment will consist of (1) a vector impedance meter and (2) a data recorder and antenna switching box. It is desirable to test as many antenna types as possible; therefore, a configuration of a long dipole antenna stretched on top of the surface and one strung 3 to 5 meters above the surface. The dipoles will be 2 km long and separated into different lengths to make shorter dipoles (e.g., 1 km, 20 meters, 10 meters, etc.). Also, a ship antenna 5 to 10 meters will be used and a short dipole of 20 meters oriented at right angles to the longer antenna. Two configurations should be run, grounded and not grounded for each antenna. Also, ground screens could be used on the whip to reduce ground losses. After the measurements have been made and analyzed, then the antenna showing the best response to the lunar plasma will be set up for control from earth.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
15015	Dipole Antenna (2 km)
15016	Dipole Antenna (20 m)
15017	Whip Antenna (10 m)
30005	Tape Recorder
11091	Vector Impedance Meter

Avg. Pwr.(watts) - 6-15
Weight (lb) - 454.1
Volume (cu ft) - 113.78
Data Rate (BPS) - 7

MASTER TIMELINE

EXP. NO. 4023

FREQUENCY OF OPERATIONS MIN. MAX.	OPERATION NO.	TIME Hours 0 4 8 10 14 18 33 57	CONSTRAINTS	EQUIP. NO.
Three Five				
Install	1	10 hr		15015
Calibrate	2	2 hr		15016 15017
Measure & Record	3	3 hr		30005 11091
Inactive	4	21 hr		
Repeat 3 & 4	5			

MANPOWER REQUIREMENTS: 10 MAN HOURS PER CYCLE

DISCIPLINE: Astronomy

EXPERIMENT ID NO: 4024

EXPERIMENT TITLE: Lunar Plasma Effects

APPLICABLE SUBOBJECTIVES:

AY-4 Determine surface and subsurface electrical properties. The experiment makes a moderate contribution to this subobjective.

OBSERVATION REQUIREMENTS:

The objectives of this experiment are to detect any plasma or ionosphere near the lunar surface, to measure the electrical potential and vertical electric field gradient. The instrumentation will consist of three metallic spheres of 5-10 cm in diameter supported by a pole of electrical insulation (teflon or fiberglass pole) at several heights above the surface. One sphere will be located on the surface, another two meters from the surface, and one 10 meters from the surface, each connected with switches to electrometers which are grounded. A fourth spherical probe in a lunar orbiter would also be desirable. The electrometers will measure the instantaneous probe potential. From the probe potential versus time curves, the plasma potential at the various elevations above the lunar surface can be inferred. The vertical electric field strength could be crudely measured by using the determinations of the electrical potential versus time at the several elevations. These measurements would be correlated with the precise electric field strength meter. Another form of experiment would be to apply different potentials to the probes and use them as simple Langmuir plasma probes. Two separate setups could be used.

EQUIPMENT REQUIRED:

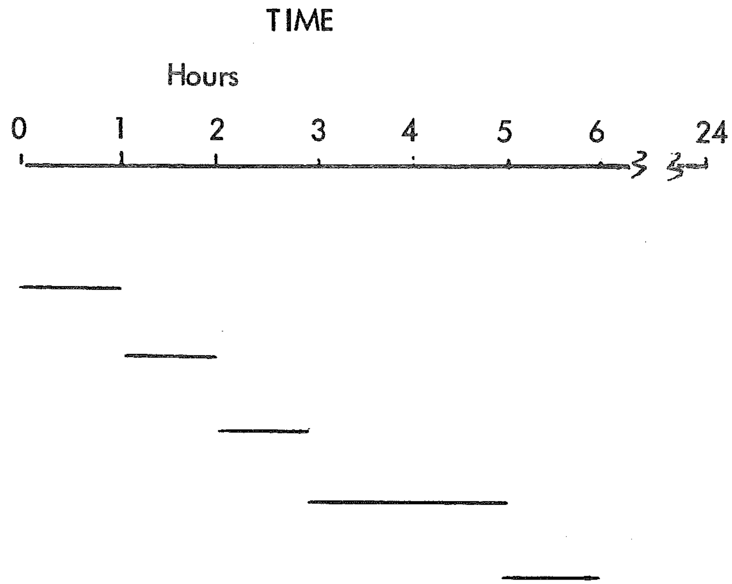
Equipment No.	Equipment Name
15018	Plasma Probe Assembly
15020	Electrometer Assembly

Avg. Pwr. (watts) - 3.0
Weight (lb) - 62
Volume (cu ft) - 7
Data Rate (BPS) - 300

MASTER TIMELINE

EXP. NO. 4024

FREQUENCY OF OPERATIONS MIN.	MAX.	OPERATION NO.	TIME Hours	CONSTRAINTS	EQUIP. NO.
30	90				
Installation		1		Twice daily; continuous during special events such as solar flares, 6 hrs. before and after nightfall.	15018
Calibration		2			15020
Measurement		3			
Deactivated		4			
Repeat Op. No. 3					



MANPOWER REQUIREMENTS: 3 Man Hours per Cycle

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4025

EXPERIMENT TITLE: Antenna Dust Accumulation

APPLICABLE SUB-OBJECTIVES:

AY-4 Determine surface and subsurface electrical properties. The experiment makes a minor contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

The general nature of the experiment is to measure the amount of dust particles (charged or neutral) that accumulate on and/or near the surface of the antenna. A 30-meter horizontal wire antenna about 1 mm in diameter will be stretched parallel to the ground at a 3 meter height. An electrometer is hooked up to the highly insulated antenna on one side and a sensing circuit would measure the potential in millivolts of the antenna as a function of time. Large fluctuations of amplitude will appear when charge dust particles are passing overhead. Actual contact of the antenna by charge particles and micrometeorite showers could cause problems. In this case, a trolley type device could be run over the wire to remove the particles. The setup must be removed from the vicinity of the base to obtain measurements that are unaffected by disturbances that are man-made. The parameter to be measured is the antenna potential in millivolts at 1 mHz.

EQUIPMENT REQUIRED:

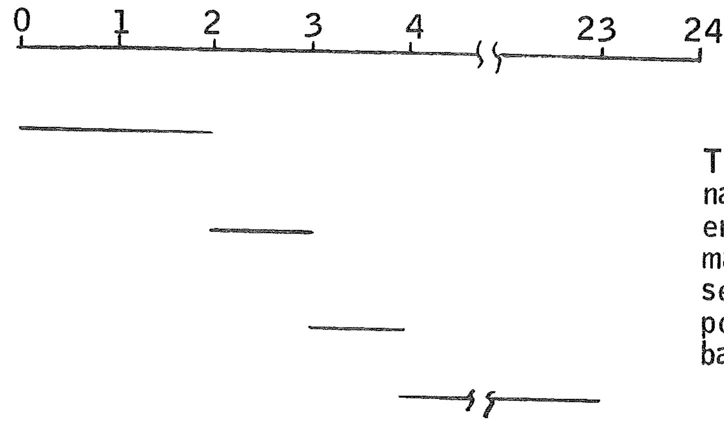
Equipment No.	Equipment Name
11064	Antenna
15020	Electrometer Assembly

Avg. Pwr. (watts) - 3.0
Weight (lbs) - 41.1
Volume (cu ft) - 7.0
Data Rate (BPS) - 300

MASTER TIMELINE EXP. NO. 4025

FREQUENCY MIN.	FREQUENCY MAX.	OPERATION NO.	CONSTRAINT	EQUIP. NO.
10	20			
Installation		1	To distinguish natural dust environments from man-made ones, set up at remote position from other base activity	11064 15020
Calibration		2		
Measurement		3		
Inactive		4		
Repeat Ops. 3 & 4 on an irregular basis; e.g., during meteoroid showers		5		

TIME
Hours



MANPOWER REQUIREMENTS: 8 man hours

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4026

EXPERIMENT TITLE: Cislunar Wave Propagation

APPLICABLE SUB-OBJECTIVES:

AY-5 Investigate cislunar medium. The experiment makes a major contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

The techniques involve the measurement of electron densities in the magnetospheric and extra-magnetospheric regions and the radar range to the moon and the accompanying range-rate. A doppler radar technique is used for the range rate, a cislunar wave ranging technique for absolute range, a cislunar wave dispersion technique for total cislunar integrated electron density, and a Faraday rotation technique to determine the magnetospheric electron density. A set of three transponders for each of the three RF carrier frequencies (VHF, L-band and S-band) is used to coherently translate the earth-to-moon signal to the moon-to-earth signal. The VHF transponder receives the up-link signal at 47 mHz and transmits the down-link signal at 51 mHz; the carrier is phase modulated with 470 Hz, 4.7 kHz and 470 kHz sinusoidal signals. The L-band transponder receives at 423 mHz and transmits at 459 kHz with 4.7 kHz and 470 kHz modulation signals. The S-band transponder receives and transmits at 2115 mHz and 2295 mHz, respectively. Phase modulation is employed at 470 kHz and 4.7 mHz signals on this carrier. A single antenna is utilized at each band for continuous wave reception and transmission. At VHF, a crossed Yagi will be used. Paraboloid antennas will be utilized at L-band and at S-band. A diplexer separates the receiver from the transmitter. Phase-locked loops are utilized to track the carrier and modulation sidebands. The locations of the transponder sites should be separated by several hundred to a thousand kilometers apart. At least two sites would be located in the equatorial region with a possible third site located toward the polar region.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
30008	Transponder - 3 frequency (with antennas)

Avg. Pwr. (watts) - 75
Weight (lb) - 384
Volume (cu ft) - 36
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4026

FREQUENCY OF OPS. MIN.	FREQUENCY OF OPS. MAX.		OPERATION NO.	TIME Hours	CONSTRAINT	EQUIP. NO.
1	2			0 18 19 20 8760 (1 yr)		
		Installation	1	18 hrs	Locate on side of moon facing earth	30008
		Calibration		2 hrs		
		Measurement (0.5 hr/day)				

MANPOWER REQUIREMENTS: 200 MANHOURS PER YEAR

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4027

EXPERIMENT TITLE: Radio Astronomical Observation of Discrete Sources Exhibiting Temporal Variations in the Frequency Range 0.6 mHz to 1.2 mHz

APPLICABLE SUB-OBJECTIVE:

AY-6 Perform radio and optical observations of solar system sources. The experiment makes a significant contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

The time variable signals that will be studied will come from sources lying within the solar system such as the Sun, Jupiter, and the Earth's atmosphere and possibly other solar systems sources. The instrument will be a phase-switching interferometer to discriminate the source against the background and to greatly reduce the receiver stability problem. The basic system consists of two sets of mutually orthogonal loops spaced 3 km apart with an angular resolution of ~7 degrees. The loops will be 3-meter crossed loops at a height of 5 meters. The receiver will cover the frequency range 0.6 to 1.2 mHz and have an IF bandwidth of 25 kHz. The number of lobes in the antenna pattern will vary from 13 at 0.6 mHz and 25 lobes at 1.2 mHz. The sweep rate is 6 mHz per second and the phase switch rate is 800 Hz.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11108	Antenna Set
30011	Interferometer (radio frequency)

Avg. Pwr. (watts) - 12
Weight (lb) - 495
Volume (cu ft) - 17.5
Data Rate (BPS) - 1560

MASTER TIMELINE

FREQUENCY OF OPERATIONS		OPERATION NO.	TIME (Hours) 10 20 40 720 (1 mo.)	CONSTRAINTS	EQUIP. NO.
MIN.	MAX.				
12	36				
Installation		1	16 hr	Strong sources must be sufficiently different in direction to be resolved.	11108 30011
Calibration		2	24 hr		
Measurement		3	680 hr		
Repeat Ops. 2 & 3		4			

MANPOWER REQUIREMENTS: 108 Manhours first month
50 Manhours per month subsequently

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4028

EXPERIMENT TITLE: Observations for Correlation with Earth Observations 5 mHz to 500 mHz

APPLICABLE SUB-OBJECTIVES:

AY-6 Perform radio and optical observations of solar systems sources. This experiment makes a significant contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

These observations will be closely correlated with earth observations. The lunar based operations will study the temporal variations in the received signals. The earth based operations will provide the directional or angular resolution needed.

Wideband or sweep-frequency radiometric receivers will be sensitive from 5 mHz to 500 mHz with a variety of antennas. Two log periodic antennas will be used, one from 5 to 50 MHz and one from 50 to 500 MHz.

The location of the antennas will preferably be the far side of the moon or secondarily the limb.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11109	Log Periodic Antenna System
11110	Sweep Frequency Radiometer

Avg. Pwr. (watts) - 3
Weight (lbs) - 115
Volume (cu ft) - 7.8
Data Rate (BPS) - 300

MASTER TIMELINE

EXP. NO. 4028

FREQUENCY OF OPERATIONS MIN	MAX	OPERATION NO.	TIME Hours (0 – 16 – 32 – 48)	CONSTRAINT	EQUIP. NO.
15	45				
INSTALLATION		1	16	Perform from bases on earth side of moon	11109 11110
CALIBRATION		2	4		
MEASUREMENT		3	28		
REPEAT OP. 3		4			

MANPOWER REQUIREMENTS: 32 Manhours per Month (One Cycle performed per Month)

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4029

EXPERIMENT TITLE: Infrared Astronomy

APPLICABLE SUB-OBJECTIVES:

AY-6 Perform radio and optical observations of solar system sources. This experiment makes a major contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

The nature of the experiment will be to closely observe the infrared phenomena related to the planets, stars, and galaxies. The reasons for the lunar operations are the long observation time afforded by the lunar night on the equator, and near full coverage of the planets. Also, the lunar horizon occults the sun and this permits near-solar access for measurements of the inner planets.

Observation will be made through the 1.3 meter telescope with appropriate camera accessories and IR detectors.

EQUUIPMENT REQUIRED:

Equipment No.	Equipment Name
11095	Telescope (50-in.)

Avg. Pwr. (watts) - 250 (RTG)
Weight (lbs) - 11,055
Volume (cu ft) - 3,670
Data Rate (BPS) - Film (3 lbs/day) (processing 1.5 lbs/day)

DISCIPLINE: Astronomy

EXPERIMENT ID NO.: 4030

EXPERIMENT TITLE: Optical Astronomy

APPLICABLE SUB-OBJECTIVES:

AY-6 Perform radio and optical observations of galactic and extra-galactic sources. This experiment makes a major contribution to this sub-objective in terms of the overall objectives of optical astronomy.

OBSERVATION REQUIREMENTS:

Observe discrete and extended stellar objects such as star clusters, diffuse nebulae, planetary nebulae, galaxies, quasars, and peculiar objects in the 900 - 10,000 Å spectral region using imaging, spectrographic, and photometric techniques. These observations will be accomplished through multiple experiments covering the entire celestial sphere. The planned experiments are:

1. Field image videographic recording
2. Concave grating spectroscopy
3. 70 mm and 250 mm photometry

Infrared experiments will not be performed on this telescope.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11099	Optical Telescope (100-inch)

Avg. Pwr. (watts) - 4000
Weight (lb) - 33,000
Volume (cu ft) - 746 (launch configuration)
Data Rate (BPS) - 3×10^6

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4032

EXPERIMENT TITLE: Geologic Mapping, Analysis and Stratigraphy

APPLICABLE SUB-OBJECTIVES: GG - All

This experiment encompasses nearly all geologic field studies including mapping, analysis, and stratigraphic investigations. It is a major contributor to the geology/geochemistry program, especially to sub-objectives GG-2, 3, 4, 5, and 6.

GP-2 It will also be a significant contributor to determining the state and composition of the moon by study of ejecta of deep seated origin and other surface features indicative of lunar geologic history.

ET-4 Because this experiment involves close observation and sampling of large areas where water-rich rocks may occur, it is a major contributor to ET-4, supporting the extraction of water or oxygen from lunar materials.

OBSERVATION REQUIREMENTS:

(1) In situ observations, analysis and notation of areal geologic features, specifically geologic contacts, distribution of lithology, structure, and landforms. The end product is a geologic map.

(2) Instrumental measurements of lithologic types for reflected and emitted IR radiation, 1-14μ, and fluorescence excited by UV at 2500 Å and 3500 Å.

(3) Point studies of the stratigraphic succession at specific localities, delineation and measurement of rock units according to lithology and genetic features representing significant events in the evolution of the lunar surface.

Geologic Mapping

This is a two-man, EVA mission. The basic equipment will be camera, recorder, base map, tools, and sampling kit. The observer is required to travel around his area making visual observations and collecting samples for analysis. He will, at times, stop for extended periods (1/2 - 1 hour) and make description of observed structure. The remaining time will be taken up in traveling and short (1 - 2 minute) stops to make records.

Instrumental Measurements

During mapping or stratigraphic investigations, some physical and chemical characteristics of exposed lunar materials will be determined *in situ*, using various portable "black box" devices, such as an IR radiometer, Auger spectrometer, and UV "blacklight".

Stratigraphic investigations call for EVA sorties at specific localities by a two-man team. Useful exposures are generally found in steep crater and rille walls. Sorties may vary from 100-meter traverses across narrow rilles, to several km in length. Geologic data will be recorded by cameras and vocally. Location and recording of operations may be assisted by geologic mapping process (a concurrent operation) or by use of Lunar Surveying System. Only quantitative measurements always required are stratigraphic thickness, by measuring tape, clinometer and azimuthal device. Occasional sorties will involve use of UV fluorescence detector, IR radiometer, and/or "black box" such as Auger spectrometer.

Another form of this investigation (same end result) is the construction of a drill hole, with concurrent geologic and geophysical logging. This activity is described in experiments 4033 and 4059.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11111	IR Radiometer (portable, such as the Barnes PRT-10 model)
90018	Mapping Kit
90019	Geological Tool Kit
90020	UV Light
14025	Portable Auger Spectrometer

Avg. Pwr. (watts) - 2

Weight (lbs) - 126.5

Volume (cu ft) - 8.8

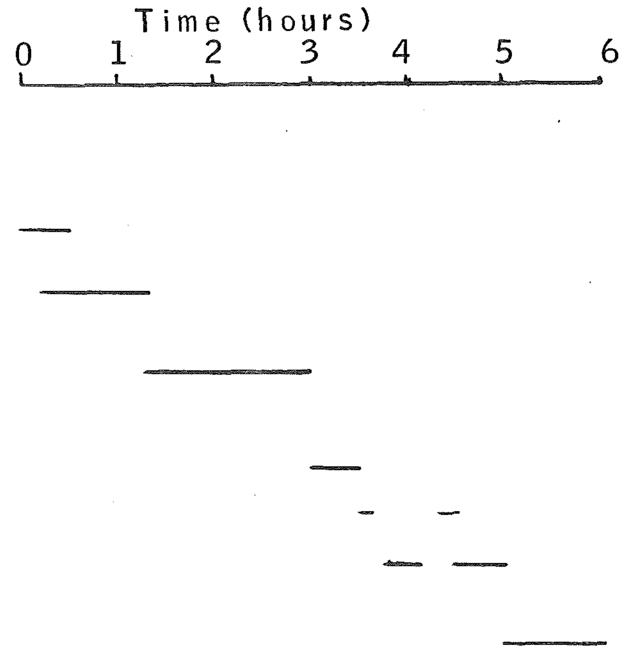
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4032

FREQUENCY OF OPERATIONS

MIN.	MAX.
1	300



Operation	OPERATION NO.	CONSTRAINT	EQUIP. NO.
Foot travel to exposures	1		
Reconnaissance of area	2	Daylight operation	
Detailed observation and note taking of stratigraphic section	3	Complexity of stratigraphic section may require one or more complete EVAs thus postponing geologic mapping to a later EVA. Conversely, some EVA's may be occupied totally by mapping and analysis & instrumental measurements.	11111 90018 90019 90020 14025
Instrumental measurements	4		
Foot travel	5		
Stops for notes, mapping, analysis & observations	6		
Return to Rover	7		

Note: All times noted above are variable and the operations, except for 1 and 7, are not necessarily sequential.

MANPOWER REQUIREMENTS: 2-MAN CREW. MIN. 13 HRS PER EVA. TWO OR MORE 2-MAN CREWS MAY WORK CONCURRENTLY

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4033

EXPERIMENT TITLE: Drilling and Subsurface Sampling (30-meter drill on Mobile Lab)

APPLICABLE SUB-OBJECTIVES: GG-ALL, ET-4

Drilling and subsurface sampling, with associated geophysical experiments utilizing the drill hole, will be one of the most productive operations in the LSB scientific program, and will contribute significantly to all geoscience sub-objectives.

Those most directly advanced will be GG-2, study of lunar materials; GG-5, geologic history or geochronology; and GG-4, study of ancient processes, such as deposition of hydrocarbons or action of water on the moon. This experiment is a major contributor to ET-4, the extraction of water or oxygen from lunar materials.

OBSERVATION REQUIREMENTS:

Visual and Physical

Lithologic logging concurrent with drilling operation; identification of lithology (rock types), gaseous emanations, textural nature, degree and manner of bedding, as a function of depth. Same features sought in the field, Experiment 4032. Stratigraphic investigations.

Methods

Largely visual and simple physical inspection of cuttings and cores from hole.

Instrumental

1. Examined as they are obtained from hole, according to Experiment 4038, mineralogic and chemical analysis in situ.

2. Water and other volatile materials emanating from hole will be detected by gas chromatography/mass spectrometer.
3. Samples examined and analyzed further in LSB lab according to Experiments 4037 - Petrographic Analysis, 4060 - Mineralogic Analysis, 4061 - Instrumental Chemical Analysis. Preferred specimens will be returned to earth for detailed study.

<u>Procedure</u>

Holes will be drilled at places of greatest estimated value for shallow depth exploration.

The drill will be either a rotary type with diamond bit (as currently under development by Westinghouse) or a percussive type with a down-hole anchoring and vibrator driving a tungsten carbide coring bit (currently under development by Bendix-Martin Marietta). When time permits, the holes will be cored continuously. When time or energy for drilling is limited, or if a hole is being drilled for a specific purpose (e.g., for seismic "shooting" or a heat flow probe), cores may be taken only at intervals.

As drilling proceeds, the cuttings and cores produced will be logged (plotted versus depth) according to their lithology and other physical characteristics. The rate of drilling is also recorded to give an idea of rock tenacity and hardness. Samples are labeled and taken to LSB laboratory for analysis.

<u>Further Uses of Drilling</u>

1. Following drilling, lower geophysical probes (Experiment 4059) to measure: resistivity, density (gamma-ray scattering), water content (neutron bombardment), magnetic susceptibility, and permittivity.

2. Test hole for expelled gas with cold cathode gage and mass spectrometer for determination of volcanic, organic, or other emanations.

3. For seismic experiments, insert geophone to bottom of hole, thump surface to obtain direct measurement of velocity in the upper level of crust, or regolith.

4. For (heat flow) measurements, temperature sensors will be buried in the leave hole. Temperatures will be modified for a year to insure equilibrium conditions will be identified.

5. Detonate explosive charges in bottom of hole for effective active seismic sounding of subsurface layering or structures (This destroys the hole, do it last).

EQUIPMENT REQUIRED:

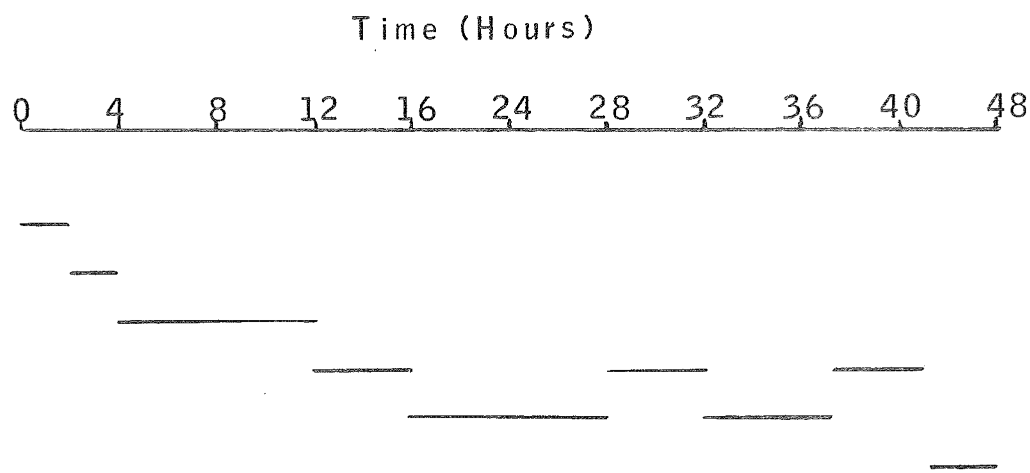
Equipment No.	Equipment Name
50009	30-meter mobile drilling rig (mounted on mobile laboratory)
90019	Geologic tool kit
14025	Auger Spectrometer
14027	Portable Mass Spectrometer
14028	Portable Gas Chromatograph

Avg. Pwr. (watts) - 3000
Weight (lb) - 333.8
Volume (cu ft) - 39.8
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4033

FREQUENCY OF OPERATIONS MIN.	MAX.		OPN. NO.
5	50		
		Set up	1
		Core Surf. Mat'l	2
		Drill	3
		Core Removal	4
		Drill	3
		Tear down (pack up)	5



CONSTRAINT	EQUIP. NO.
High power requirements. Very hard rock; e.g., dense basalt. May be impractical to drill deeply.	50009 90019 14025 14027 14028

MANPOWER REQUIREMENTS: 2 MEN INTERMITTENTLY; SEMI-AUTOMATIC OPERATION

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4037

EXPERIMENT TITLE: Petrographic Analysis of Rocks (in lab)

APPLICABLE SUB-OBJECTIVES:

GG-2 Determine the physical, mineralogical, and chemical properties of lunar materials.

Petrographic analysis will identify rock type, give gross fabric and semi-quantitative mineralogic composition and is, therefore, a major contributor to this sub-objective. It will also indicate the degree of alteration due to shock processes or mineralization.

OBSERVATION REQUIREMENTS:

A thin section of each specimen to be analyzed will be required. These must be mounted on glass slides and ground to .003 inches. The petrographer will examine the sample using the petrographic microscope. The main areas of interest are fabric, texture, composition, and internal structure. Standard petrographic techniques will be employed. A written description of each sample will be required.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90008	Petrographic Microscope
50006	Sample Preparation Device (for cutting and preparing thin sections on glass slides)

Avg. Pwr. (watts) - 100 - 500
Weight (lbs) - 57.6
Volume (cu ft) - 23.35
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4037

FREQUENCY OF OPERATIONS MIN 1 MAX 2 per rock sample	OPERATION NO.	TIME Hours 0 1 2 3 4 5 6 7	CONSTRAINT	EQUIP. NO.
Preparation of section	2			
Initial observation (fabric & gross mineral composition study)	2			50006
Detailed examination (mineralogic identification and conclusions)	3			90008
Write report	4			

MANPOWER REQUIREMENTS: 7 MANHOURS PER ROCK SAMPLE

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4038

EXPERIMENT TITLE: Mineralogic Identification and Chemical Analysis In Situ

APPLICABLE SUB-OBJECTIVES:

GG-2 Determine the physical, mineralogical and chemical properties of lunar materials.

The in situ identification of the properties of lunar materials is a moderate contributor to the sub-objective. The in situ analyses will assist operational planning of LSB missions and serve to screen specimens for more detailed analyses to be performed in the LSB laboratory and on earth with returned samples.

OBSERVATION REQUIREMENTS:

In situ analysis will be short duration scanning examinations of lithologic materials and natural lunar gases from volcanic or other sources. These analyses will use the Auger spectrometer, the Neutron Activation Analyzer, and a Mass Spectrometer.

Detailed analyses (X-ray, IR-UV) (5) and (6) of chips of select materials will be performed in the Base. Additional analyses will be performed on earth. It is expected that one in five in situ samples will be removed for further examination inside the Base.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11086	Neutron Activation Analysis Equipment
14025	Auger Spectrometer
14026	Mass Spectrometer

Avg. Pwr. (watts) - 3 - 25
Weight (lbs) - 125
Volume (cu ft) - 2.0
Data Rate (BPS) - 280

MASTER TIMELINE — EXP. NO. 4038

FREQUENCY OF OPS. MIN.	FREQUENCY OF OPS. MAX.		OPERATION NO.	TIME (Minutes) 0 5 10 15 60	CONSTRAINT	EQUIP. NO.
2500	5000					
		In Situ				
		Visual selection of materials and sites	1	3	Daylight	
		Examination - surface	2	3		14025
		Examination - depth	3	15		11086
		Examination - gas.	4	60		14026

MANPOWER REQUIREMENTS: 1 MANHOUR PER SAMPLE

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4039

EXPERIMENT TITLE: Investigation of Lunar Transient Activity (LTA)

APPLICABLE SUB-OBJECTIVES: GG-3, GG-8, GG-1

This experiment yields increased knowledge of active lunar processes, such as outgassing, moonquakes or other unknown processes; hence, it is a moderate contributor to sub-objectives GG-3, study of dynamic processes; GG-8, locating LSB sites with exploitable resources; and GG-1, study of lunar surface features (such as active volcanic landforms).

OBSERVATION REQUIREMENTS:

Glowing or wispy features as seen from earth (hundreds of documented occurrences), dust clouds, or flames are candidates for observation. Ionization pressure sensor will detect outgassing. Mass spectrometer will detect outgassing and identify composition and seismometers will detect strong ground movement. Maintain constant atmospheric monitoring on all long rover trips or traverses (experiments 4053 and 4054) using boom-mounted cold cathode and gas mass spectrometers. Sites of outgassing found by above or by earth-based telescopy will be investigated by field crew for clues to the cause of the LTA. Both day and night observations are useful. At sites at which activity appears active, but intermittent, a LTA experiment package will be deployed for remote monitoring.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
14005	Mass Spectrometer
12001	Ionization Pressure Sensor
11088	Seismometer (4 Component Lamont)

EQUIPMENT REQUIRED: (Continued)

Avg. Pwr. (watts) - 1 - 12
Weight (lbs) - 39.4
Volume (cu ft) - 1.462
Data Rate (BPS) - 10 - 1000

MASTER TIMELINE

EXP. NO. 4039

FREQUENCY OF OPERATIONS

MIN.	MAX.
1	1 on Op. #1 & 2
3	10 on Op. # 3
2	6 on Op. # 4

	OPERATION NO.	Time (Hours) 0 1 2 3 4 8	CONSTRAINT	EQUIP. NO.
Calibration	1	2 hrs		
Atmos. Monitoring All long Rover trips	2	6 hrs minimum	Time depends on Rover traverse	14005 12001
Examination of sites of outgasing	3	1 1/2 1 1/2 1 1/2	Operations concurrent with Exps. 4032, 4035, 4041. Day or night	
Emplace remote monitor at active site	4	1 1/2 hr		11088

MANPOWER REQUIREMENTS: 25 MANHOURS

DISCIPLINE: Geodesy/Cartography

EXPERIMENT ID NO.: 4044

EXPERIMENT TITLE: Geodetic Grid Construction

APPLICABLE SUB-OBJECTIVES:

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.

The present experiment will be a major contributor toward this sub-objective.

OBSERVATION REQUIREMENTS:

Basic ground observation requirements include construction of permanent geodetic monuments, visible from orbital altitudes, ground based stellar photography and absolute gravimeter measurements. These will be used in conjunction with laser/radar altimetry data and metric photography taken from orbit. The basic unit of measurement on the surface will be one degree ($\approx$30 km). Accuracy of $\pm$ 100 meter will be required. This means absolute gravity measurements accurate to $\pm$ 10 milligals. A vertical accuracy of $\pm$ 10 meters is also required. It is desirable to set up a network of regularly spaced measurement stations; however, this is probably not feasible on the moon. Instead it is anticipated that at each experiment location an absolute gravity reading will be taken. Surface triangulation of measurements stations should be accurate to $\pm$ 1 inch.

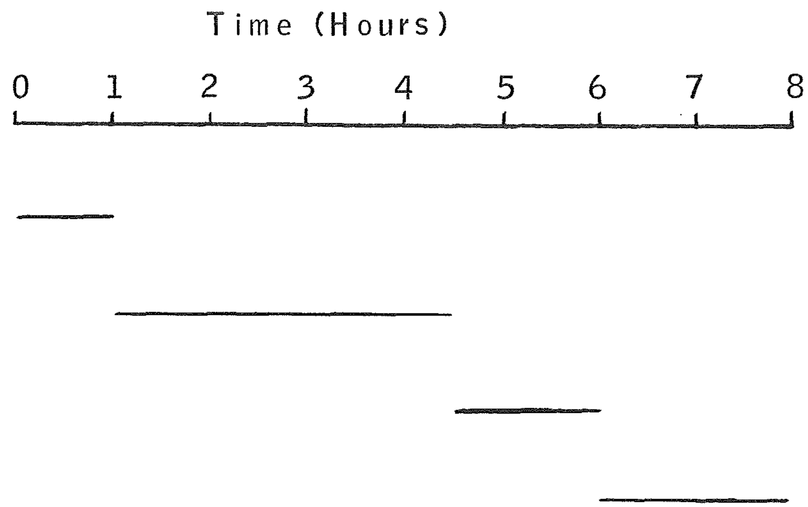
EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11112	Absolute Gravimeter
11082	Photographic Astronomical Transit
11081	Gravimeter (LaCoste Romberg)

EQUIPMENT REQUIRED: (continued)

Avg. Pwr. (watts) - 1-25
Weight (lbs) - 175
Volume (cu ft) - 5.0
Data Rate (BPS) - 0.2 - 0.7

FREQUENCY OF OPERATIONS MIN. 1 per expmt. location MAX. 2	OPERATION NO.	Time (Hours)	CONSTRAINT	EQUIP. NO.
Set Up	1			
Calibration	2			11112
Reading	3			11082
Dismantle	4			11081



The actual time required to construct the net will be several years. It is a matter of obtaining the data, making the ground measurements and building the grid.

MANPOWER REQUIREMENTS: 8 MANHOURS PER LOCATION

DISCIPLINE: Geophysics

EXPERIMENT ID NO.: 4045

EXPERIMENT TITLE: Gravity Profiling

APPLICABLE SUB-OBJECTIVES:

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

GP-4 Determine earth-moon mechanical interactions.

This experiment will be a moderately important contribution toward meeting the above two sub-objectives.

OBSERVATION REQUIREMENTS:

The general nature of this experiment is to obtain absolute gravity measurements and gravity anomalies at all the bases and along all traverses. It is desirable for absolute measurements to achieve an accuracy of 0.1 milligal or less. Also obtained with absolute gravity measurements are vertical gradient measurements. The accuracies required for gravity anomalies are dependent on relative elevation accuracies. If a precision of 1 meter in elevation is available, then a gravity measurement of 0.1 milligal accuracy is usable; a 10-meter precision would permit reductions to 1.0 mgal. Portable gravimeters would be used on the traverses with spacing of each measurement to every 100 meters for features on the order of 200-300 meter extent if elevation control is known to 1.0 meter. The range of the gravimeters should be several thousand milligals. The range of the gravimeters should be several thousand milligals. Gravity anomalies are the differences between measured gravity and a normal value; it reflects the difference between subsurface distribution of density and some density model. Such instrumentation should be free of drift or have at worst a linear drift. Gravity measurements will be restricted to the LSB and on traverses. The LSB operations will be limited to the emplacement

EXPERIMENT ID NO.: 4045

OBSERVATION REQUIREMENTS (con't)

of a gravimeter near the site within walking distance. The traverse operations will entail measurements taken every 100 meters for the smallest features to every kilometer for longer traverses. The vehicle must stop to make the measurements.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11112	Absolute Gravimeter

Avg. Pwr. (watts) - 1.0
Weight (lbs) - 22
Volume (cu ft) - 1.8
Data Rate (BPS) - 0.2

EXP. NO. 4045

MASTER TIMELINE

FREQUENCY OF OPERATIONS	OPERATION NO.	Time (Hours) 0 1 2 3 4 12 24	CONSTRAINT	EQUIP. NO.
EACH SORTIE				
Calibration	1	2 hrs	Emplace instrument within walking distance of LSB	11112
Site measurements	2	10 min. 10 min.		
Traverse measurements (Per Sortie)	3	5 min. per stop, 30 stops		
Travel between stops (Assumed)	4	10 min. intervals, 29 intervals		

MANPOWER REQUIREMENTS: 36 MANHOURS PER SORTIE

DISCIPLINE: Geophysics

EXPERIMENT ID NO.: 4046

EXPERIMENT TITLE: Active Seismic Investigations

APPLICABLE SUB-OBJECTIVES:

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

Active seismic soundings will given information to a depth of approximately 2000 feet; will be a minor contributor to this sub-objective.

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

Active seismic measurements will give information on velocity of basement rocks and thickness of debris layer, and will be a minor contributor to this objective.

ET-7 Support the utilization of lunar materials.

Measured seismic velocities will indicate the type of lunar materials (e.g., unconsolidated vs. rigid materials) existing near surface which may be utilized.

OBSERVATION REQUIREMENTS:

Seismic data will be taken along geophysical traverses and at locally selected areas around the LSB site. There is an initial set-up time of several hours to emplace geophones along a path several hundred meters long. An explosive charge is buried approximately two feet below the surface. The charge will be detonated and travel times of the reflected and refracted waves measured. Recording equipment may be contained within a rover. Approximately 10-15 pounds of explosive will be required at each site. Alternate seismic energy sources may be preferable to explosives.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
40005	Time Base Generator
11087	Seismic Amplifier
50010	Seismic Energy Source
50012	Geophones

Avg. Pwr. (watts) - 5.0
Weight (lbs) - 555.5
Volume (cu ft) - 14.708
Data Rate (BPS) - 4000

MASTER TIMELINE

EXP. NO. 4046

FREQUENCY OF OPERATIONS MIN.	MAX.	OPERATION NO.		Time (Hours)	CONSTRAINT	EQUIP. NO.
			Installation	4 hours		40005 11087 50010 50012
			Actuate energy source and measure	1 hr		
			Dismantle	10 min.		
			Analysis	3 hours		

MANPOWER REQUIREMENTS: 16 MANHOURS PER DAY

DISCIPLINE: Geophysics

EXPERIMENT ID NO.: 4047

EXPERIMENT TITLE: Passive Seismic Measurements

APPLICABLE SUB-OBJECTIVES:

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.

GG-3 Deduce the nature and relative importance of dynamic natural processes on the lunar surface.

GG-6 Construct geologic maps of the lunar surface, delineating lithologic contacts, tectonic structures, physiographic and petrographic provinces.

GG-8 Locate geologically favorable sites for advanced lunar exploration/exploitation scientific facilities.

This experiment will be a major contribution toward meeting the above sub-objectives.

OBSERVATION REQUIREMENTS:

The acquisition of seismic data is the highest priority in determining the structure and composition of the interior of the moon. This experiment will determine the seismically active areas and will establish the travel times of body waves and the dispersion of surface waves to infer the seismic velocity distribution and an elasticity of the moon. The measurements will be of short period waves, 0.2-25 Hz, and of long period waves, 0.005-3.3 Hz. The dynamic range should be 1.0 millimicron to 10 micron. The instrumentation will be a 4-component (one short period and three long period components) station

OBSERVATION REQUIREMENTS: (continued)

at each site with two other stations located at the vertices of a 10 kilometer triangle (minimum). Triangle scale should expand to 1000 km using "arrays of arrays".

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11088	Seismometer (4 Comp. Lamont)

Avg. Pwr. (watts) - 1.0
Weight (lbs) - 22.2
Volume (cu ft) - 0.56
Data Rate (BPS) - 230

MASTER TIMELINE

EXP. NO. 4047

FREQUENCY OF OPERATIONS MIN.	MAX.		OPERATION NO.	TIME (Hours) 0 1 2 8	CONSTRAINT	EQUIPMENT NO.
3	60					
		Installation	1	1.5 hr.	Each of three sites located at a corner of 10 km triangle	11088
		Calibration	2	0.5 hr		
		Measurements	3	Continuous Unmanned		
		Analysis	4			

(Travel time over 10 km sides of triangle not included)

MANPOWER REQUIREMENTS: 30 MAN HOURS PER SITE

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4048

EXPERIMENT TITLE: Deep Drilling and Sampling

APPLICABLE SUB-OBJECTIVES: GG-2, 4, 5, 6

This experiment will give core samples to a depth of 300 meters and make it a major contributor to these objectives.

OBSERVATION REQUIREMENTS:

The drill, because of the long term nature of the drilling operation, will be located at semi-permanent sites. The geologist in charge will make preliminary examination of core samples and choose samples to be returned for detailed examination. A log of drilling rate should be kept. Chips raised from hole should also be logged. At completion of the drilling the hole may be used for geochemical/geophysical experiments using down hole probes.

EQUIPMENT REQUIRED:

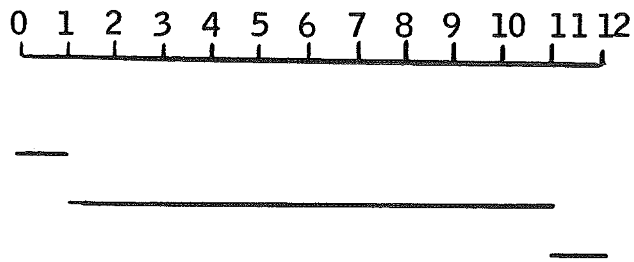
Equipment No.	Equipment Name
50008	Stationary Drill

Avg. Pwr. (watts) - Self contained power supply
Weight (lbs) - 30,200
Volume (cu ft) - 2,100
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4048

FREQUENCY OF OPERATION MIN.	MAX.	OP. NO.		CONSTRAINT	EQUIPMENT NO.
1 300 m hole at each LSB site	Others where practical				
Setup				High power requirements of drill. Extremely hard rocks encountered may make drilling very slow.	50008
Core 30'/day					
Dismantle					



DISCIPLINE: Particles and Fields

EXPERIMENT ID NO.: 4050

EXPERIMENT TITLE: Solar Wind and Energetic Particles

APPLICABLE SUB-OBJECTIVES:

PF-1 Solar Wind-Moon Interaction

The measurement of solar wind at the lunar surface is a major contribution toward meeting this objective.

PF-2 Fundamental Physics of Plasma Interactions

Measurement of solar wind distributions at the lunar surface provides a major contribution to the accomplishment of this objective.

PF-4 Lunar Particle Environment

The measurement at the lunar surface of incident, reflected and secondary nuclei, electrons and radiations is a major contribution to this sub-objective.

OBSERVATION REQUIREMENTS:

The nature of the first part of this experiment is to better understand the interaction between the solar wind and the lunar surface. The measurement requirements for the proton distribution are: (1) proton flux 10^7 - 10^{10} particles/cm^2/sec, (2) proton energy 10^2 - 2×10^4 ev, (3) angular extent. The instrument will be a solar plasma spectrometer. Two instruments, at least, are necessary for measurements toward the sun and in a fixed direction away from the sun (in the horizontal direction away from the ecliptic).

The nature of the second part of this experiment is to observe and record incident charged particles in the solar and anti-solar direction with discrimination techniques from galactic particles and solar particles. The measurement requirements for the galactic particles are: (1) flux 1-20 particles per cm^2, (2) energy - 5×10^8 to 1×10^{10} ev, (3) energy accuracies $\pm$ 20%. The measurement requirements for solar particles are: (1) primary particle flux up to 10^{10} particles/cm^2/sec and secondary fluxes up to 10^4 particles/cm^2/sec, (2) proton energy 3×10^5 - 5×10^8 ev, (3) electron energy 5×10^4 - 5×10^7 ev, and (4) resolution in energy and flux $\pm$ 10%.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
14001	Particle Counter (Low Energy)
14002	Particle Counter (High Energy)
14020	Particle Spectrometer
11098	Cosmic Ray Spectrometer Telescope

Avg. Pwr. (watts) - 0.5 - 5.0
Weight (lbs) - 37.3
Volume (cu ft) - 0.94
Data Rate (BPS) - 200 - 2000

MASTER TIMELINE

EXP. NO. 4050

FREQUENCY OF OPERATIONS (MIN. 60, MAX. 120)	OPERATION NO.	TIME (Hours) 0 – 1 – 2 – 3 – 4 – 24	CONSTRAINT	EQUIP. NO.
Installation	1	3 hr		14001 14002 14020 11098
Calibration	2	1 hr		
Measurement	3	1 hr 1 hr	2 one-hour measurement periods per day, except during special events when measurements are continuous.	
Deactivate	4	0.5 hr		

MANPOWER REQUIREMENTS: 5 MAN HOURS PER CYCLE

DISCIPLINE: Particles and Fields

EXPERIMENT ID NO.: 4051

EXPERIMENT TITLE: Magnetic Field and Electric Field Temporal Variations

APPLICABLE SUB-OBJECTIVES:

PF-3 Magnetic and Electric Fields Around, On and Within the Moon.

Direct measurement of the magnetic and electric fields at the lunar surface will fulfill a major part of this sub-objective.

AY-4 Plasma Properties (surface and subsurface)

This experiment gives major support to the sub-objective with respect to measuring the magnetic fields at low frequencies in the plasma at the lunar surface.

OBSERVATION REQUIREMENTS:

A metastable helium magnetometer will be utilized to measure the magnitude (gammas) and direction (degrees) of the ambient magnetic field vector. These measurements will be conducted at a sample rate of once per second, (duration 5 minutes) and the experiment will be carried out twice each 24-hour period during the lunar day and lunar night. The experiment duration will be extended as required during periods of solar wind activity and special events. The sensor should be placed at a location where unwanted stray magnetic fields are less than 0.25 gamma. The range of the magnitude of the magnetic field will be 0.25-100 gammas with an accuracy of two significant figures.

Low frequency plasma waves in the range of 0.01 to 10 Hz will be monitored with respect to magnetic field magnitude and intensity by two additional types of magnetometers: a search coil system and a flux gate instrument. Magnetic field range will be from 0.01 to 100 gammas. The emplacement of the experiment must be near the noise survey experiment and far enough away from the base to obtain measurements free of man-made fields.

The intensity and direction of the electric field will be measured at the surface and 5 to 10 meters above the surface. Two electric field meters will be used -- one at the foot of a mast and the other at a variable height on the mast. The experiment would be automated after the initial setup and calibration. The interval of electric field values to be measured is from 0.01 to 100 volt/meter with a sensitivity of 0.01 volt/meter.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
15011	Search Coil Magnetometer
15008	Flux Gate Magnetometer
15010	Helium Magnetometer
15012	Electric Field Detector (Emplaced)

Avg. Pwr. (watts) - 0.4 - 10
Weight (lbs) - 43.4
Volume (cu ft) - 0.83
Data Rate (BPS) - 2 - 320

MASTER TIMELINE

EXP. NO. 4051

FREQUENCY OF OPERATIONS MIN. 30 MAX. 90	OPERATION NO.	Time (Hours) 0 2 4 6 8 24	CONSTRAINT	EQUIP. NO.
Install magnetometer	1	1 hr		
Install electric field meter	2	4 hrs		
Calibrate both	3	1 hr		
Measurements magnetic & electric	4	10 min. 10 min.	Measurements twice daily, except continuously during special events; e.g., passing thru earth's magnetospheric tail or during solar flares	15011 15008 15010 15012

MANPOWER REQUIREMENTS: 10 MANHOURS PER DAY

DISCIPLINE: Lunar Atmosphere

EXPERIMENT ID NO.: 4053

EXPERIMENT TITLE: Total Pressure and Composition

APPLICABLE SUB-OBJECTIVES:

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

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

This experiment will provide a minor unique contribution in defining the lunar atmosphere but will provide a major portion of the contamination aspect.

OBSERVATION REQUIREMENTS:

Establish influence of Base on the lunar atmosphere by the concurrent measurement--in four places-- of the absolute pressure and atmospheric constituents for a total period of 2 months. Beyond that range of influence, the four concurrent readings (pressure and composition) shall be recorded over the period of one earth year.

Pressure/composition recording time per se is not considered since remote recording/display is required. One sample per 5 minutes is required for both pressure and each constituent.

Within the established range of base influence four pairs of instruments are required to continue the monitoring of the effect of the Tug landings and the Base itself on the lunar atmosphere.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
12001	Ionization Pressure Sensor
14005	Mass Spectrometer
14019	Mass Spectrograph (Quadrupole)

EQUIPMENT REQUIRED: (Continued)

Avg. Pwr. (watts) - 12 -48
Weight (lbs) - 244.8
Volume (cu ft) - 5.728
Data Rate (BPS) - 40 - 1000

MASTER TIMELINE

EXP. NO. 4053

FREQUENCE OF OPERATIONS MIN. MAX.	OPERATION NO.	Time (Hours)	CONSTRAINT	EQUIP. NO.
Continuous Operation at selected locations		0 2 4 1442		
Base Influence				
Set Up		2 hr	Tug landings required during this period.	12001 14005 14019
Operate		2 months		
Dismantle		1 hr	Coordinated surface/orbit observations required.	
General Atmosphere (Beyond Base Inf.) Set Up		2 hr		
Operate		Continuous	Coordinated surface/orbit observations required.	"

MANPOWER REQUIREMENTS: 4 MANHOURS PER SETUP

DISCIPLINE: Lunar Atmospheres

EXPERIMENT ID NO.: 4055

EXPERIMENT TITLE: Escape and Transport Rates

APPLICABLE SUB-OBJECTIVES:

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

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

This experiment will be a major contribution to these sub-objectives requirements which also include the observations from an orbiting vehicle.

OBSERVATION REQUIREMENTS:

Known times of additions to the lunar atmosphere; e.g., Tug/Lander descent or controlled releases will dictate many of the times of occurrence of this experiment. Observation of the transport mechanism of the natural lunar atmosphere will be keyed to natural events (fumaroles). Observing the natural occurring atmosphere will not be so time critical but will be more demanding because of scarcity and moon perturbations. The samples release should be performed remotely to avoid interaction of excess gases in the vicinity of the sample. The observations require long duration recording (remotely) to accurately record the full escape history, especially of the natural occurring lunar events.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
14029	Mass Spectrometer (Directional)
14030	Supra Thermal Ion Detector

MASTER TIMELINE

EXP. NO. 4055

FREQUENCY OF OPERATION: MIN. 10, MAX. 100

Operation	Operation No.	Time (Hours)	Constraints	Equip. No.
Instrument Setup	1	4 hrs ea. time		
Sample Release	2	2 hrs		
Observation	3	8 hrs	Simultaneous ground/orbit meas. req'd.	14029 14030
Reconfigure for Continuous Operation	4		Continuous Operation for 2 - 4 weeks	

MANPOWER REQUIREMENTS: 12 HOURS PER SETUP

DISCIPLINE: Geology and Geochemistry

EXPERIMENT ID NO.: 4057

EXPERIMENT TITLE: In-Situ Measurement of the Natural Radiation Spectrum

APPLICABLE SUB-OBJECTIVES: GG-2, GG-4

This experiment will be a minor contribution to determining the chemical nature of lunar material (GG-2) and the nature of chemical differentiation of the lunar crust and related long term geologic processes (GG-4).

OBSERVATION REQUIREMENTS:

Natural and induced gamma radiation from surface materials at different lunar locations and on rover traverses. The locations of all areas from which readings have been taken will be recorded.

Procedure/Equipment Requirements

Gamma Spectroscopy on Traverses: During all rover traverses, the scintillation detector and pulse height analyzer (gamma ray spectrometer) will monitor the distribution in the lunar crust of gamma ray emitting radionuclides--primarily uranium, thorium and potassium and their decay products. Pulse height analysis will be used to determine the gamma ray flux vs. energy spectrum of specific materials to be analyzed. The energy spectra are then compared to the known spectra of the nuclides to identify constituents.

This experiment will be performed continuously (300 to 800 times) during rover traverses. At locations of anomously high radioactivity, stops will be made for detailed analysis of the gamma ray spectra of the local soil or rock. This must be done before or concurrently with any experiment making use of radioactive sources.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11005	Gamma Ray Spectrometer

Avg. Pwr. (watts) - 10
Weight (lbs) - 85
Volume (cu ft) - 2
Data Rate (BPS) - 3000

MASTER TIMELINE

EXP. NO. 4057

FREQUENCY OF OPERATIONS MIN. 25 MAX. 50	OPERATION NO.	TIME (Minutes) 0 1 2 3 4 120	CONSTRAINTS	EQUIP. NO.
Procedure 1:				
Set up	1	1.5 min		
Measure continuously on traverse.	2	2 hr.	Limited to total length of traverse	11005
Measure detailed spectrum at a specific site, 15 sec to 2 min.	3	1.5 min		
Procedure 2:				
Set up	4	1 min		
Measure detailed spectrum at one site or down drill hole up to 2 hrs.	5	2 hr		

MANPOWER REQUIREMENTS: 2 Man Hours per Procedure

DISCIPLINE: Geophysics

EXPERIMENT ID NO.: 4058

EXPERIMENT TITLE: Magnetic Profiling

APPLICABLE SUB-OBJECTIVES: GP-2, GG-1, GG-2, GG-4

This experiment will contribute to the accomplishment of all geology and several geophysics sub-objectives. It will especially contribute toward the interpretation of lunar surface features (GG-1), physical state and composition of the interior (GP-2), and the physical properties of lunar materials (GG-2).

OBSERVATION REQUIREMENTS:

Local and regional magnetic anomalies measured as horizontal variations in intensity and polarity on the lunar surface. This experiment is designed to obtain magnetic profiles across specific geologic features, and during other rover traverses to obtain information on hidden magnetized bodies. It is to be performed concurrently with gravity profiling; and in areas of special interest, seismic sounding experiments may also be performed to aid in interpretation of the magnetic and gravity data.

Procedure

The experiment will be performed on rover traverses with a boom-mounted 3 component fluxgate magnetometer and a proton precession magnetometer. Readings will be taken under shirtsleeve conditions at intervals ranging from 1 km for regional structures to 20 meters for location of smaller structures. More detailed traverses may be performed on foot.

A total field magnetometer will be operated at the LSB to provide secular data for correction during data analysis.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
15021	Fluxgate Magnetometer (on traverse)
15022	Proton Precession Magnetometer

Avg. Pwr. (Watts)	- 5.0
Weight (lb)	17.2
Volume (cu ft)	0.95
Data Rate (BPS)	3 - 20

MASTER TIMELINE

EXP. NO. 4058

FREQUENCY OF OPERATIONS: MIN. 25, MAX. 100

	OPERATION NO.	TIME (Minutes) 0 — 1 — 2 — 120	CONSTRAINT	EQUIP. NO.
Setup for boom operation	1	1.5 min.	Perform this experiment concurrent with operation of total field magnetometer at LSB	15021 15022
Continuous operation during Rover traverse	2	120		
Detailed measurements during Rover stops	3	5 min.		

MANPOWER REQUIREMENTS: 2 MANHOURS PER CYCLE

DISCIPLINE: Geophysics

EXPERIMENT ID NO.: 4059

EXPERIMENT TITLE: Geophysical Bore Logging

APPLICABLE SUB-OBJECTIVES: GG-2, GG-6, GP-2

This experiment will contribute moderately to determining the nature of lunar surface materials (GG-2) and will be a significant aid in geologic mapping and correlation of buried near surface geologic units (GG-6). It will be a minor contributor to GP-2, determining the physical state and composition of the lunar interior.

OBSERVATION REQUIREMENTS:

Electric resistivity by dry hole resistivity sonde using multiple electrodes, wetted with liquid electrolyte. Density by gamma ray bombardment in which back scattered gammas are proportional to rock density. Water, ice, or other hydrogenous matters by neutron bombardment, in which fast neutrons (energies $\geqslant$ 0.025 ev) are absorbed in porous zones filled with hydrogenous matter. Magnetic susceptibility by ac induction probe. Permittivity by induction.

Procedure: These sensors and energy sources can be assembled in one or two sondes for lowering down boreholes. Automatic readout will be recorded or transmitted as the probe is raised slowly from the botton. Data will be plotted and analyzed as a function of depth.

EQUIPMENT REQUIRED:

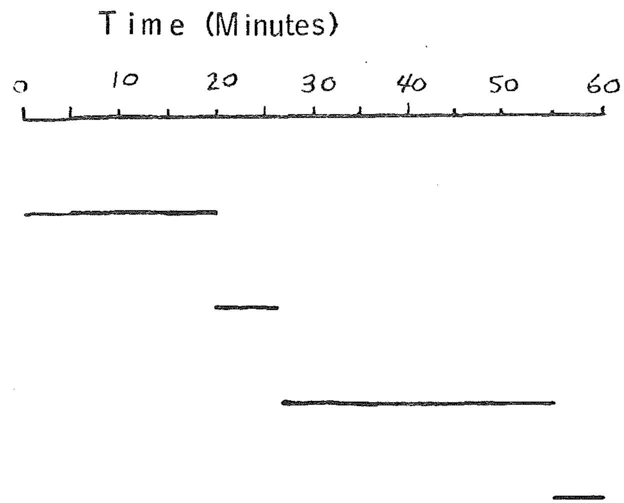
Equipment No.	Equipment Name
11079	Down-hole Geophysical Probe

Avg. Pwr. (watts) - 34
Weight (lbs) - 57
Volume (cu ft) - 4
Data Rate (BPS) - 1.1 x 10^4

MASTER TIMELINE

EXP. NO. 4059

FREQUENCY OF OPERATION MIN.	MAX.	OPERATION NO.	CONSTRAINTS	EQUIP. NO.
1 logging on completion of each bore-hole	Same - plus 1 or 2 additional logs while bore uncompleted			
For typical hole, 30 m deep:				
Setup; pulley, cable reels & sonde over borehole		1	EVA Req'd.	11079
Lower probe to bottom		2		
Raise sonde, record data on way up		3		
Dismantle		4		



MANPOWER REQUIREMENTS: 1 MANHOUR PER HOLE

DISCIPLINE: Geology/Geophysics

EXPERIMENT ID NO.: 4060

EXPERIMENT TITLE: Mineralogic Analysis in Lab

APPLICABLE SUB-OBJECTIVES: GG-2, 4, 6, 7, and 8

Identification of the minerals and the determination of their association with other minerals will make major contributions toward these sub-objectives.

OBSERVATION REQUIREMENTS:

The astronauts will be working with samples collected in the field. They will be required to prepare samples for analysis by making thin sections and powder mounts of each sample. Standard petrographic analysis techniques will be employed in the microscopic analysis. The X-ray analysis is a matter of making the exposure and reading the film. Where deemed necessary, samples can be returned to earth for detailed analysis.

EQUIPMENT REQUIRED:

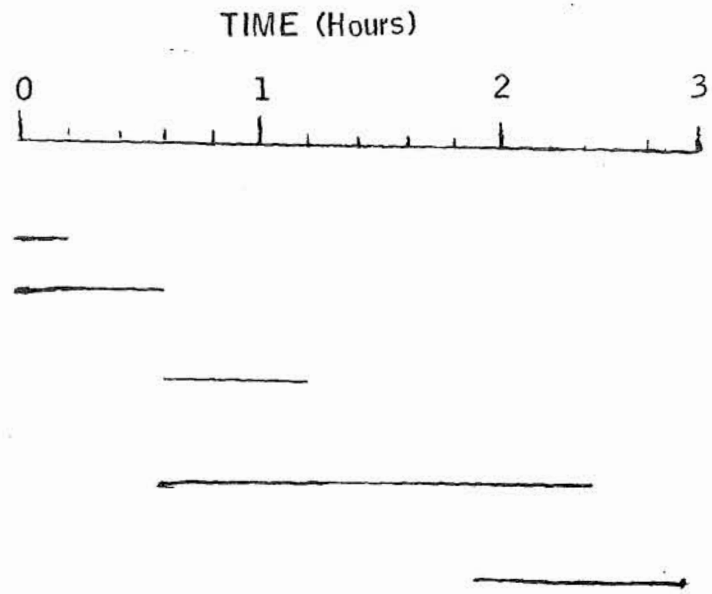
Equipment No.	Equipment Name
50006	Sample Preparation Equipment
11096	X-Ray Diffractometer
90008	Petrographic Microscope

Avg. Pwr. (watts) - 10 - 500
Weight (lbs) - 77.6
Volume (cu ft) - 24.05
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4060

FREQUENCY OF OPERATIONS MIN. 200 MAX. 400	OPERATION NO.	TIME (Hours)	CONSTRAINT	EQUIP. NO.
Sample Preparation for X-Ray				
Thin Section Preparation				50006
X-Ray - Exposure				11096
Microscopic Analysis and Notes				90008
X-Ray Film Reading				



MANPOWER REQUIREMENTS: 50 MANHOURS FOR 200 SAMPLES

DISCIPLINE: Geology/Geochemistry

EXPERIMENT ID NO.: 4061

EXPERIMENT TITLE: Instrumental Chemical Analysis in Lab

APPLICABLE SUB-OBJECTIVES:

GG-2 Determine the physical mineralogical and chemical properties of lunar materials.

The nondestructive chemical laboratory analysis of lunar materials is a major contributor to this sub-objective, although the laboratory analyses may be performed in greater detail on earth, as required, with returned samples.

GG-4 Study the effects of ancient or long-term geologic processes.

This experiment will allow investigation of chemical differentiation of lunar crust as related to long-term processes and, therefore, will be a major contributor to this sub-objective.

GG-6 Construct geologic maps of the lunar surface, delineating lithologic contacts, tectonic structures, physiographic and petrographic provinces.

The identification of chemical elements from different lunar regions will establish the degree of chemical differentiation and aid in the delineation of regional differences and thus be a major contributor to this sub-objective.

GG-7 Determine the nature of morphologic differences between the near and far side of the moon.

This experiment will support this sub-objective only in a minor way since samples from opposite sides of the moon will be collected only on OLS-Tug sorties and probably be analyzed on earth or at best very infrequently at the LSB.

GG-8 Locate geologically favorable sites for advanced lunar exploration/exploitation scientific facilities.

Samples brought from other lunar surface locations to the LSB lab may, upon chemical analysis, be of unusual interest and grossly different from local samples and, thereby, provide some motivation for establishing a new exploration site. Therefore, this experiment will provide a major contribution toward meeting this sub-objective.

OBSERVATION REQUIREMENTS:

The chemical analysis of lunar samples in the LSB laboratory involves measurements using neutron activation, gas chromatography, mass spectroscopy, X-ray spectroscopy, IR spectroscopy, and UV spectroscopy.

Activation analysis with a neutron activation analyzer consists of the irradiation of a sample of lunar material with fast neutrons from a fast neutron generator, which typically might be a positive ion Cockcroft-Walton accelerator with either a tritium target producing 14 Mev neutrons or a deuterium target producing 3 Mev. The fast neutron flux through (n, p) reactions produces gamma rays of energies characteristic of the elemental composition of each lunar sample. The gamma rays are detected typically with a NaI(Tl) scintillation crystal and their energies determined in a pulse height analyzer. A layer of paraffin between the neutron source and the sample will provide neutron moderation resulting in thermal neutrons, which when absorbed by the lunar sample will release capture gamma spectra of distinctive characteristics and allow additional means of element identification.

A gas chromatograph will be used for analyzing solid lunar samples which have first been volatilized in an oven. The sample vapors are carried through the absorbing-desorbing column by a carrier gas (typically He). After a sufficient length of flow the components are separated spacially and each component may be identified by a glow discharge detector whose measured differences in breakdown voltage were a function of the identify of the isolated component of the lunar sample.

A mass spectrometer will be used for the compositional analysis of soild surfaces and layers below, but near the surface. A sputter-ion source allows monolayers to be removed from the sample for analysis and thus establish change of composition with depth. A magnetic mass analyzer for the LSB laboratory will be used with a resolution intermediate between those of earth-based laboratories and those of flight hardware (e.g., intermediate values might be a resolution of 1000 and a sensitivity of parts per million). An electron multiplier type of ion detector will give adequate sensitivity.

An X-ray spectrometer, including an X-ray source, will be used to identify elements and measure compositions in lunar samples brought inside the LSB laboratory. An X-ray Coolidge tube type source irradiates the test sample which fluoresces X-rays in all directions. A multiple fixed dispersive channel system is used to separate the X-rays according to wavelength. Each channel consists of a collimator, reflecting crystal and detector oriented at the appropriate Bragg angle to detect the particular intended wavelength interval of X-rays.

An infrared spectrometer system will be used to analyze lunar samples by both absorption and reflection. The source of infrared radiation is typically a Globar (bonded silicon carbide rod) or a Nernst glower (bonded mixture of rare earth in rod form) heated to 1000° to 1200° K with an electric current. Dispersion is accomplished in prisms. The sample-transmitted and sample-reflected radiations are sensed by infrared detectors (thermistor or photocell) followed by signal amplification as required. To provide sensing across the dispersed wavelengths in both transmission and reflection, a scanning and beam-splitting system is required. Samples for absorption spectral measurements may be powdered and pressed into KBr pellets. Samples for reflection spectral measurements are prepared with polished surfaces from lunar mineral powders formed into briquets bound by Lucite.

The IR wavelength-integrated results from this experiment will be compared with the measurements of the IR emissivity and reflectivity in situ in Experiment No. 4063. Optics for IR experiments will be NaCl from 2 to 15 microns and interchanged with KBr to extend wavelength interval to 2.5 microns. Replacement of gratings with prisms will extend operation to 400 microns.

Ultraviolet absorption measurements of lunar samples will also be made in the LSB laboratory. A continuous spectrum UV light source will be provided. A high resolution monochromator with good light gathering power without excessive transmission loss is required. Quartz optics are to be used.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11086	Neutron Activation Analyzer
14018	Gas Chromatograph
14026	Mass Spectrometer
11114	X-Ray Spectrometer (with source)
11115	IR Spectrometer (with source)
11113	UV Spectrometer (with source)

EQUIPMENT REQUIRED: (continued)

Avg. Pwr. (watts) - 0.3 - 25
Weight (lbs) - 228
Volume (cu ft) - 5.8
Data Rate (BPS) - 1 - 280

MASTER TIMELINE

EXP. NO. 4061

FREQUENCY OF OPERATIONS MIN. 2 MAX. 40	OPN. NO.	0	15	30	45	60	75	90	CONSTRAINTS	EQUIP. NO.
		Time - Days								
Set up, actuate, warm up, calibrate	1	1	1	1	1	1	1		Provide biological shielding against neutrons & X-rays.	
Operate and make observations:										
neutron activation	2	14								11086
gas chromatography	3		14						These operations (2 through 7) not necessarily sequential or performed in this order.	14018
mass spectroscopy	4			14						14026
X-ray spectroscopy	5				14					11114
IR spectroscopy	6					14				11115
UV spectroscopy	7						14			11113
Deactivate								1		

MANPOWER REQUIREMENTS: 520 MANHOURS PER ONE COMPLETE CYCLE

DISCIPLINE: Engineering, Technology and Operations

EXPERIMENT ID NO.: 4064

EXPERIMENT TITLE: Biological Monitor and Eco-System Prototype

APPLICABLE SUB-OBJECTIVES:

ET-2 Verify performance of a long-duration life support system.

This experiment is a major activity of this sub-objective since it will enable evaluation of a working, closed ecology model.

OBSERVATION REQUIREMENTS:

This experiment is to be conducted within a greenhouse. An atmosphere is required and all elements of the experiment require exposure to the same atmosphere. Five experiments (4064, 4065, 4066, 4067 and 4068) will be included within the environment; all are required to enable the closed system evaluation. Atmospheric pressure, temperature, moisture and constituent monitoring are required. The animal portion of the experiment requires control of the food and water the animals eat, their waste products, the measurement of their physiological characteristics (body temperature, respiration analysis), and animal autopsies. The measurements are to be performed daily. The duration is expected to be at least one year. An identical closed Ecological System on earth is required for comparative purposes. The above will enable evaluation of their growth, development, reproduction, and survivability.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90021	Biological Monitor and Ecological Experiment Equipment

Avg. Pwr. (watts) - 50
Weight (lbs) - 22
Volume (cu ft) - 1.7
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4064

FREQUENCY OF OPERATION MIN. MAX. (* SEE NOTE)	OPERATION NO.	TIME (Minutes) 0 5 10 15 20 25 30 35 40	CONSTRAINT	EQUIP NO.
INPUT/Output Measurements	1	10 min (0–10)		90021
Physiological Measurements	2	30 min. (10–40)		90021
Behavioral Measurements	3	Full Time Monitoring (0–40)		90021

*NOTE: MINIMUM PERIOD OF OBSERVATION, 1 YEAR

MANPOWER REQUIREMENTS: 3000 MAN-HOURS PER YEAR

DISCIPLINE: Engineering, Technology and Operations

EXPERIMENT ID NO.: 4066

EXPERIMENT TITLE: Effects of Lunar Conditions on Plants

APPLICABLE SUB-OBJECTIVES:

ET-2 Verify a long-duration life support system.

This experiment will verify the plant growth characteristics on the moon for acquisition of plant data and projection of that data to the closed ecological system and provides a moderate contribution toward meeting this sub-objective.

OBSERVATION REQUIREMENTS:

The effect of the lunar gravity and ionizing radiation on barley, beans, corn, tomatoes will be observed and photographed. Both lunar soil and hydroponic farming methods will be evaluated. This experiment will continue that which is being evaluated in an earth environment. A concurrent control experiment will be in progress.

The plants will be physically evaluated photographically with a grid for dimensions and liminal angles and micrographically for minute structure comparisons (histological).

A chemical analyzer will utilize gas chromatography and a parafine oven for amino acids, carbohydrates, sugars, acids. The growth, development, reproduction, and survivability of the plants will be determined.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90022	Plant Life Experiment Equipment

Avg. Pwr. (watts) - 10
Weight (lbs) - 1034
Volume (cu ft) - 4
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4066

FREQUENCY OF OPERATIONS MIN.	MAX.	OPERATION NO.	TIME (Minutes) 0 4 8 12 16 20 24 28	CONSTRAINT	EQUIP NO.
200	800				
Physical Measurements		1	20 min		90022
Chem. Analysis		2	10 min		90022

NOTE:

SET UP TIME - 1 MAN WEEK

MANPOWER REQUIREMENTS (OPERATION): 3 MAN-HOURS PER WEEK
DURATION - ONE YEAR (MINIMUM)
ABOVE ACTIVITY REQUIRED ON ALTERNATE DAYS

DISCIPLINE: Engineering, Technology and Operations

EXPERIMENT ID NO.: 4071

EXPERIMENT TITLE: Tests of Thin Film Bearings

APPLICABLE SUB-OBJECTIVES:

ET-3 Effects of long duration exposure of equipment materials to the lunar environment.

This will provide a major contribution to the sub-objective since it will be a test of equipment in the lunar environment to understand lunar unique problems of machinery.

OBSERVATION REQUIREMENTS:

Bearing wear will be measured (photographically and physically) to evaluate the performance of candidate thin film bearings. An electrically driven shaft will hold five bearing samples and the response of the different samples to one load will be observed. Setup requires installation of the bearings on the shaft and loading the shaft. The "test" involves the running time of the shaft while the evaluation requires visual inspection and measurement-wear spots, characteristics of wear-prior to resuming the test or dismantling.

Some samples may fail requiring interruption at times other than scheduled.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90023	Thin Film Bearing Experiment Equipment

Avg. Pwr. (watts) - 200
Weight (lbs) - 22
Volume (cu ft) - .35
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4071

FREQUENCY OF OPERATION MIN.	MAX.		OPERATION NO.	TIME (HOURS) 0 2 4 6 // 238 240 242 244	CONSTRAINT	EQUIP. NO.
10	25					
		Set up	1	1 hr		90023
		Bearing test	2	240 Hours		90023
		Evaluation	3	2 hours		90023
		Resume test or dismantle	4	1 hr		90023

MANPOWER REQUIREMENTS: 24 MAN-HOURS PER CYCLE

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO.: 4074

EXPERIMENT TITLE: Mining/Transport of Lunar Materials

APPLICABLE SUB-OBJECTIVES:

ET-4 Support the extraction of water from lunar materials. The present experiment will be a major contribution toward meeting this sub-objective.

OBSERVATION REQUIREMENT:

The exact nature of this experiment is dependent upon the discovery of water on the Moon and the state of that water. If the water occurs in a natural state, i.e. a mixture, then transporting it will have to include an enclosed leak proof volume for holding the material during transport and storage. (It is assumed that surface material will not contain water which can be easily extracted, thus mining is directed toward sub-surface material). The lunar material will be tested for solubility in a liquid for application of a Frasch-type mining technique.(1) Several samples of each water-bearing material will be prepared to be analyzed for solubility according to liquid, temperature of liquid, mixture of liquid.

The transportation of the material is dependent upon the type of mining and whether a continuous or batch method is required. The continuous method requires storage for quantities of lunar materials as well as protection. The experiment involves evaluation of protective alternates for the mined materials; i.e., open, covered, sealed, pressurized.

(1) NASA CR77720, "A Study of Lunar Resources," 22 May 1965, R. Q. Shotts, University of Alabama

MASTER TIMELINE

EXP. NO. 4074

FREQUENCY OF OPERATION	OPERATION NO.	Time - Hours (0 2 4 6 8)	CONSTRAINT	EQUIP. NO.
Sample taking and testing: once per deep drill hole (100 m)				
SAMPLE TAKING	1	4 hours	AT SITES OF DEEP DRILLING	
TEST (SOLUBILITY)	2	4 hours	EXP. 4038, 4060, 4061	
OPERATE	3	Continuous		TBD

MANPOWER REQUIREMENTS: 12 MAN-HOURS FOR SAMPLE TAKING AND TESTING

NOTE: Equipment parameters and manpower requirements for operational phase of this activity cannot be estimated at this time. However, it is anticipated that (if implemented) this activity would create a very large requirement on base resources -- comparable to Experiment No. 4075

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO.: 4078

EXPERIMENT TITLE: Lunar Strata Electromagnetic Propagation Parameters

APPLICABLE SUB-OBJECTIVES:

ET-3 Support the construction of a lunar astronomical observatory.

The experiment will be a minor contributor to the sub-objective since isolation methods can be applied.

OBSERVATION REQUIREMENTS:

Existing core hole - geologic surveys - will be utilized to define the composition of the subsurface. Additional holes will be drilled in conjunction with soil composition changes to investigate the effect of the lunar strata on communication between two points for the significant levels (Task 1). The procedure is to sweep a power and frequency range to establish a satisfactory combination, if any (tasks 2 and 3). Once established, transmission quality may be observed. Three levels per drill holes are included.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90024	Lunar Strata E. M. Propagation Experiment Unit

Avg. Pwr. (watts) - 250
Weight (lbs) - 6.6
Volume (cu ft) - 0.5
Data Rate (BPS) - TBD

MASTER TIMELINE

EXP. NO. 4078

FREQUENCY OF OPERATIONS MIN. 15 MAX. 50	OPERATION NO.	TIME (Hours) 0 4 8 12 16 20 24	CONSTRAINTS	EQUIP. NO.
Select, level & prepare sites	1	4 hr, 4 hr } Two Sites	Strata identification & 4079	90024
Place antennas	2	1 hr		
X-Mit power freq.	3	1 hr 1 hr 1 hr 1 hr 1 hr 1 hr		
Dismantle	4	1 hr		

MANPOWER REQUIREMENTS: 2 Manhours/hour/14 hours

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO: 4079

EXPERIMENT TITLE: Lunar Surface Transmission Line Interactions

APPLICABLE SUBOBJECTIVES:

ET-6 Support the construction of a lunar astronomical observatory. This experiment should satisfy the requirements completely.

AY-4 Determine lunar surface and near-surface electrical properties. The experiment will make a moderate contribution to this subobjective.

OBSERVATION REQUIREMENTS:

The interaction between the lunar surface and electrical transmission line components (supports, insulators, lines and terminal equipment) will be investigated. The components' performance will be evaluated for shape, surface (lunar surface) finish, and material for best heat rejection. The experiment setup involves site selection and preparation, line and components' setup, stimulus and instrumentation hookup. Varying the components, type or arrangement will be a manual function; data recording for analysis is required at the Base. The experiment itself involves evaluation of power transmission data transmission and RF transmission. The experiment may be conducted in the three areas concurrently and will require a full lunar day (28 earth days) at each site.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90025	Lunar Surface Transmission Line Experiment Equipment

Avg. Pwr. (watts) - N/A
Weight (lb) - 4.4
Volume (cu ft) - 0.17
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4079

FREQUENCY OF OPERATION: MIN. 5, MAX. 15

	OPN. NO.	HOURS 0 4 8	DAYS 0 4 8 12 16 20 24 28	HOURS 0 4 8	CONSTRAINT	EQUIP. NO.
Set Up	1	8 hours				90025
Test - Power	2		4–24			
Data			4–24			
RF			4–24			
Dismantle	3			8 hours		

MANPOWER REQUIREMENT: 1.5 MANHOURS/DAY/24 DAYS

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO: 4081

EXPERIMENT TITLE: Heat Transfer in Liquids through Natural Convection

APPLICABLE SUBOBJECTIVES:

ET-4 Support the extraction of water and oxygen from lunar materials. The experiment will make a major contribution to this subobjective.

ET-5 Support the processing or storage of propellants. This experiment will provide a minor portion of the information required to satisfy the subobjective.

OBSERVATION REQUIREMENTS:

It is intended to derive heat transfer coefficients within liquids and between liquids and container walls. The experiment is an instrumented cylindrical container with electrical heater. Data requirements are in the form of thermocouple readout and motion picture photography of suspended particles. The experiment may be conducted inside the base laboratory.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90026	Liquid Heat Transfer Experiment Equipment

Avg. Pwr. (watts) - negligible
Weight (lb) - 15.4
Volume (cu ft) - 0.17
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4081

FREQUENCY OF OPERATION MIN.	MAX.	OPERATION NO.	0 8 16 24 32 40	CONSTRAINT	EQUIP. NO.
5	15				
Set Up		1	4 hrs		90026
Operate		2	24 hours		
Dismantle		3	2 hrs		

MANPOWER REQUIREMENTS: 1 MANHOUR/HOUR/DAY

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID. NO.: 4082

EXPERIMENT TITLE: Heat Transfer in Film and Drop Condensation Processes

APPLICABLE SUBOBJECTIVES:

ET-4 Support the extraction of water or oxygen from lunar materials

ET-5 Support the processing or storage of propellants.

This experiment provides a portion of the information required to satisfy these subobjectives.

OBSERVATION REQUIREMENTS:

Heat transfer and condensation characteristics will be observed. A small vessel, with a controlled electric heater, will be used to heat a metered quantity of vapor (from the test liquid) and fed into a condenser. The amount and rate of condensation will be monitored by nuclear trace techniques, while the temperatures will be monitored by thermocouples.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90027	Film and Drop Heat Transfer Experiment Equipment

Avg. Pwr. (watts) - negligible
Weight (lb) - 6.6
Volume (cu ft) - 0.70
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4082

FREQUENCY OF OPERATIONS MIN.	MAX		OPN. NO.	TIME (Hours) 0 2 4 6 8 10 12 14	CONSTRAINT	EQUIP. NO.
5	15					
		Set Up	1	2 hours	Base-Lab	
		Operate	2	10 hours		90027
		Dismantle	3	1 hr		

MANPOWER REQUIREMENTS: 1 MANHOUR/HOUR/13 HOURS

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO.: 4084

EXPERIMENT TITLE: Metals Joining Techniques

APPLICABLE SUBOBJECTIVES:

ET-6 Support the construction of a lunar astronomical observatory

ET-7 Support the utilization of lunar materials (resources). This experiment provides a moderate contribution of information to the subobjectives.

OBSERVATION REQUIREMENTS

This experiment utilizes an electron beam welding machine and will evaluate (1) loss of weld materials by vaporization, (2) pattern of vaporization, (3) quantities and pressures of inert gases required to direct metal flow.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90028	Metal Joining Experiment Equipment

Avg. Pwr. (watts) - 1800
Weight (lb) - 44.0
Volume (cu ft) - 1.7
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4084

FREQUENCY MIN.	FREQUENCY MAX.
10	40

	OPN. NO.	TIME - HOURS (0 1 2 3 4 5 6 7 8)	CONSTRAINT	EQUIP. NO.
Expmt. Setup	1	1 hr	EVA	
Weld/Inspect	2	5 hr		90028
Dismantle	3	1 hr		

MANPOWER REQUIREMENTS: 6 MANHOURS/CYCLE

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO.: 4085

EXPERIMENT TITLE: Differential Thermal Analysis of Potentially Castable Materials

APPLICABLE SUB-OBJECTIVES:

ET-7 Support the utilization of lunar materials (resources).

This experiment will provide a major contribution to the utilization of lunar materials.

OBSERVATION REQUIREMENTS:

The observation objective is melting temperature of lunar materials. This experiment is performed inside the Base. The procedure utilizes identification of the samples, experiment no. 4038. Samples are placed in differential thermal analyses cells and heated, cooled, cycled or maintained by a Thermal Analyzer. Thermomechanical properties variation with time and temperature are also observed. The volatiles from the materials are condensed for the analysis. This may lead to identification of lunar materials worthy of further evaluation of the construction qualities of the materials.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90029	Differential Thermal Analysis Experiment Equipment

Avg. Pwr. (watts) - 2.0
Weight (lbs) - 11.0
Volume (cu ft) - 3.5
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4085

FREQUENCY OF OPERATION MIN 100 MAX 300	OPERATION NO.	TIME (Hours) 0 1 2 3 4 5 6 7	CONSTRAINTS	EQUIP. NO.
SAMPLE PREP.	1	1 hr (0–1)	Expt. 4038 Base Lab	90029
INST. ACTIV/CALIB.	2	1 hr (1–2)		
OPERATE	3	4 hr (2–6)		

MANPOWER REQUIREMENTS: 1 MAN-HOUR/HOUR/6 HOUR

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO.: 4086

EXPERIMENT TITLE: Characteristics of Lunar Ores--Self Welding

APPLICABLE SUB-OBJECTIVES:

ET-7 Support the utilization of lunar materials (resources).

This experiment will contribute major information toward the utilization of a lunar material, since it will potentially use lunar material in a lunar structure.

OBSERVATION REQUIREMENTS:

The change in the cohesive characteristics of lunar materials will be evaluated after being freshly broken. The materials may be obtained from surface modification of seismic sites. The procedure requires the filling and compacting of cylindrical specimen molds with uniform size granules of material. Several molds - each with a different size granule - will be filled. The cylinders will be subjected to time sequenced load tests the day the samples are acquired. The tests are to be repeated once a day at one week and at two-week intervals to establish a change in cohesion with time. The test must be performed outside the Base.

Cohesion is of importance since reduction of it affects the performance of extraction, screening and crushing operations while increased cohesion is desirable for fill or handling operations.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90030	Ore Compaction Equipment

Avg. Pwr. (watts) - N/A
Weight (lbs) - 11.0
Volume (cu ft) - 0.1
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4086

FREQUENCY OF OPERATION MIN.	FREQUENCY OF OPERATION MAX.		OPERATION NO.	Time-Hours (0 1 2 3 4 5 6 7 8 9)	CONSTRAINT	EQUIP. NO.
25	75					
		Sample Prep.	1	1 hr		
		Load Test	2	7 hrs		90030
		Dismantle	3	0.5 hr		

MANPOWER REQUIREMENT: 1 MANHOUR/HOUR/9 HOURS

DISCIPLINE: Engineering, Technology, and Operations

EXPERIMENT ID NO.: 4087

EXPERIMENT TITLE: Lunar Dry Cement and Concrete Applications

APPLICABLE SUB-OBJECTIVES:

ET-7 Support the utilization of lunar materials (resources).

This experiment is a major contributor toward meeting the sub-objective.

OBSERVATION REQUIREMENTS:

Purpose is to develop and apply an approach to combining fillers and binders in physical-thermal-chemical processes to form a lunar concrete. A candidate process uses ash, pumice and clinkers as filler; sulphur as a binder; and exo-thermic reactant additives for setting. Once a lunar concrete is identified, applications to foundations, form casting, cementing of cast or natural block materials and sealing and calking will be assessed.

This experiment should be performed after site analyses for geologic purposes.

Evaluation of the applications requires analysis of the forms after exposure to lunar environment and structural loading.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
90031	Lunar Dry Cement and Concrete Experiment Equipment

Avg. Pwr. (watts) - 350
Weight (lbs) - 240
Volume (cu ft) - 35
Data Rate (BPS) - N/A

MASTER TIMELINE

EXP. NO. 4087

FREQUENCY OF OPERATIONS MIN 5 MAX 50	OPN. NO.	TIME (Hours) 0 2 4 6 8	CONSTRAINTS	EQUIP. NO.
PREPARE SAMPLE	1	3 hr	EVA	90031
MIX	2	1.5 hr		
APPLICATION Foundation, Form Cost, Cement, Seal	3	4.5 hr		

MANPOWER REQUIREMENTS: 1.1 MAN-HOURS/HOUR/9 HOURS

DISCIPLINE: Geophysics

EXPERIMENT ID NO.: 4088

EXPERIMENT TITLE: Determination of Near Surface Temperature Gradient for Heat Flow Studies

APPLICABLE SUB-OBJECTIVES:

Successful determination of lunar heat flow will be a major contribution to an understanding of internal dynamic processes in the moon (GP-3, GG-3) and, indirectly, will provide important clues to the moon's internal constitution (GP-2).

In planetary bodies such as the moon, internal heat is presumed due to (1) energy retained from initial formation, and (2) energy generated from internal processes such as radioactive decay. Because of the moon's smaller size, it is probable that it has lost a greater percentage of its original heat than has the earth. Consequently, surface heat flow probably results more from dynamic internal processes distributed throughout the moon's volume and, therefore, could yield more information about its internal constitution than terrestrial measurements yield about the earth.

OBSERVATION REQUIREMENTS:

The experiment determines near surface heat flow at a point on the moon's surface by measurement of the steady state temperature gradient (dT) along a vertical path (dz), and the thermal conductivity (K) of the material across which the gradient was measured. The heat flux per unit area $\vec{Q}$ is calculated by the conduction equation:

$$\vec{Q} = -K \frac{dT}{dz}$$

Procedure

In the Apollo Program, these measurements were made with slender probes 1 meter long placed at the bottom of two 3-meter boreholes. For advanced experiments, these same instruments will be employed in similar and deeper boreholes. The instrumentation consists of several components. A linear array of Chromel-constantan thermocouples emplaced near the top of the hole to measure temperature transients propagating downward from the lunar surface. In the lower part of the hole are more thermocouples for measuring the natural steady state thermal gradient and a heater mechanism for measuring the effective thermal conductivity.

The Apollo experiment was designed with a gradient interval (dz) of 1 meter for use in 3-meter (10 ft.) deep hole.

For advanced experiments, employing drill holes of 30 meters and more, the gradient interval should be increased to 10 meters, with provision for even greater expansion for exceptionally deep holes.

The probes will be buried in the drill holes (after other experiments; e.g., geophysical logging and geophone emplacement, utilizing them have been completed) and temperatures will be monitored for an experiment period of one year.

EQUIPMENT REQUIRED:

Equipment No.	Equipment Name
11116	Heat Flow Probes 4 thermocuples, Chromel-constantan 1 heat flow/conductivity probe (containing heater & sensors)
40009	Electronics Unit (developed by Gulton Industries, Albuquerque, New Mexico) gradient bridges and telemetering system

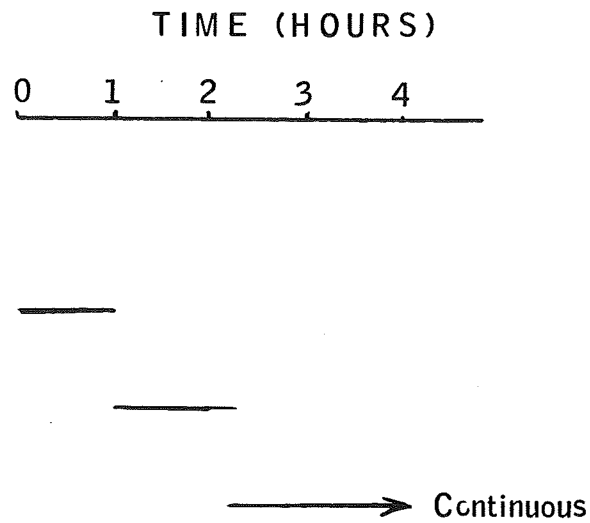
EQUIPMENT REQUIRED: (Continued)

Avg. Pwr. (watts) - 3.0
Weight (lb) - 9.1
Volume (cu ft) - 0.15
Data Rate (BPS) - 2000

MASTER TIMELINE

EXP. NO. 4088

FREQUENCY OF OPERATIONS MIN. 10 MAX. 20	OPERATION NO.	CONSTRAINT	EQUIP. NO.
		Drilled hole required.	
Emplace probe	1	Perform other non-destructive experiments in hole first	11116
Fill hole	2		40009
Calibrate temperature monitor and telemetry	3		



MANPOWER REQUIREMENTS: 4 MANHOURS PER PROBE EMPLACEMENT

APPENDIX C. REQUIREMENTS ANALYSIS SHEETS

This appendix contains the Requirements Analysis Sheets (RAS) developed for the lunar surface missions. The function number and functional requirement are taken from the functional flow diagrams. The performance requirements scope the functional tasks. For the more important functions, alternate methods are identified to form the initial basis for tradeoff studies. Because an excessive number of in-depth trades can be made, they were limited to just those which defined the top level mission concept. These trades are covered in Sections 6 and 7.

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LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.1	Perform shallow drilling operations.	Experiment No. 4033					
4.24.4.1.1	Load drill and equipment on roving vehicle. 1. Remove drill and equipment from shipment storage. 2. Assemble drill and check operations. 3. Load on vehicle.	one spacesuit manhour required.					

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.1.2	Transport drill equipment and crew to experiment site.	Mass and Volume: (lbs) (cu ft) Drill Equipment: 30 2.5 Power Source: 20 1.0 Sample Container: 10 1.0 Total: 60 4.5	1. Transport equipment on a man-propelled cart. 2. Transport equipment on a roving vehicle. 3. Transport equipment on a flying vehicle.				
		Distance from LSB to experiment site (site sensitive). Travel time required (site sensitive).					
4.24.4.1.3	Survey area for potential drill hole sites.	Time required	1. Use geophysical and/or geo-chemical properties of lunar surface materials. 2. Determine from preselected map site.				
4.24.4.1.4	Set-up drilling equipment. 1. Unload drill and equipment. 2. Insert drill rod. 3. Connect power source.	.25 spacesuit manhours required.					

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.1.5	Perform requird drilling operation. 1. Drill 3-10 feet hole. 2. Support drilling operation. 3. Analyze core material.	1.5 spacesuit manhour required per hole. 1a. Equipment time - .3 hrs. 1b. Power requirement - .8 kw 1c. Number of holes required - 1.d Penetration rate - 3 ft/20 min (Basalt) 10 ft/20 min (Tuft) 2. One astronaut full time. (1.5 hrs) 3. Analysis time					
4.24.4.1.6	Close out drilling operations. 1. Disconnect power source. 2. Load drill and equipment. 3. Load sampler container.						
4.24.4.1.7	Transport drill equipment and crew from experiment site to LSB.	Mass and Volume: Drill and equipment: 50 3.5 Sample material: 60 1 TOTAL: 110 4.5					
4.24.4.1.8	Store drill equipment. 1. Unload vehicle and store equipment. 2. Move samples to lab.	.5 spacesuit manhours required.					

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.2	Perform intermediate drilling operations.	Experiment No. 4033					
4.24.4.2.1	Load drill and equipment on vehicle. 1. Remove drilling equipment from shipment storage. 2. Rigidly attach moulting structure to body of transportation vehicle. 3. Activate and check drill for functional operations. 4. Unstow hand drill and check for functional operations. 5. Load equipment. a. Drill hole tubing. b. Drill bits (10) c. Circulating fluid. d. Motor and transmission e. Tools f. Hand drill and equipment (see 4.24.4.1.1) g. Sample container	1. .50 shirtsleeve manhours required. 2. .50 spacesuit manhours required. 3. .5 spacesuit manhours required. 4. .3 spacesuit manhours required. 5. .45 spacesuit manhours required.					
4.24.4.2.2 NOTE: Continued on next page.	Transport drill equipment and crew to experiment site.	Mass and Volume (lbs) (cu/ft) Mounting structure: 100 Drill hole tubing: 65 Drill bits: 50 Fluid and tanks: 200 Motor and transmission: 65 Tools and control equip. 120 Hand drill equipment: 60 3.5	1. Transport equipment on a roving vehicle. 2. Transport equipment on a drilling rig trailer towed by a roving vehicle.	1. Requires no additional equipment. 2. Eliminates the time required to load equipment for each experiment requiring drilling.	1. Requires no additional equipment. 2. Requires additional equipment (trailer) and payload.		

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LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.2.2(cont)		Mass and Volume: (lbs) cu/ft) Sample container: 10 1 Total: 670 Distance from LSB to Exp. site . Travel time required					
4.24.4.2.3	Survey area for potential drill hole sites.	Number of holes required.	1. Establish hole location by bench marks. 2. Identify hole locations on map.				
4.24.4.2.4	Prepare sites for drilling. 1. Remove loose debris and rock (less than 2 inches in diameter) on incline adjacent to site that are likely to fall into hole because of vibration. 2. Drill exploratory holes with hand drill. 3. Collect samples for analysis.	1 spacesuit manhour req. 1. Use hand tool (rake or shovel). 2a. Number of holes 2b. Sec. 2.24.4.1 for time line given to drill shallow holes. 3. Time required for analysis					
4.24.4.2.5	Move vehicle on drill site and set up for drilling. 1. Level align drilling rig. 2. Anchor drilling rig in position. 3. Activate drill and check for functional operation.	2 spacesuit manhours required. 1. Alignment not critical. 2. Degree of movement caused by vibration 3. Check Start Stop Lower Raise Rotation Gas Flow	1a. Use horizontal bubble levels. 1b. Use vertical plumbob. 1c. Visual align. 2a. Engage vehicle brakes. 2b. Use guide wires. 2c. Use lunar rock as weight. 2d. Tie down support rigs. 3a. Start and stop functions are site and remote operated. 3b. Gas flow rate for chip removal and bit purging.				

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.2.6	Perform required drilling operation. 1. Drill 100 feet. 2. Support drilling operation 3. Analyze core material.	1a. Performed in 5 ft. increments (1 core length) until completed. 1b. 20 manhours required to drill 100 feet. 1c. Power requirement 5 Kw peak. 1d. Drill operating time 16.5 hrs. Drilling 13.5 hrs. Raise & Lower Drill, 3.0 hrs. 2. Requires 6.5 spacesuit manhours for core and chip removal, control and servicing drill. 3. Core analysis time Shirtsleeve Spacesuit	1. EVA Drilling 2. IVA Drilling	A. No drill module required A. Eliminates spacesuit constraints in working	A. Spacesuit constraints and hazards A. Requires mobile module to house and seal drill		Trade study required to select drill module
4.24.4.2.7	Close-Out Drilling Operations 1. Disconnect power and close gas valves. 2. Remove anchor equipment. 3. Load sample container. 4. Load core samples. 5. Cover drill holes as required.	1 Spacesuit manhour required.					
4.24.4.2.8	Transport drilling equipment and crew from experiment site to base.	<u>Mass</u> <u>Volume</u> 100 ft. drill & equip.: 560 Hand drill & equip: 60 3.5 Core Material: 65 N/A Sample container: 150 1 TOTAL: 835 Time Required:					

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LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.2.9	Store drilling equipment. 1. Unload equipment from supporting vehicle and store. 2. Store equipment and vehicle. 3. Refueling of consumables.	1. 2 spacesuits and 1 shirtsleeve man hour required. 2. .5 spacesuit manhour required. 3. Requirements					

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.3	Perform deep drilling operation	Experiment No. 4048					
4.24.4.3.1	Survey area for potential drilling site.	5 manhours required. Spacesuit: 3 hrs. Shirtsleeve: 2 hrs.	1. Make use of visual sitings. 2. Use surveying equipment. 3. Use maps.				
4.24.4.3.2	Prepare area for drilling. 1. Excavate loose surface material and rock.	2 spacesuit manhours required.	1. Use hand rake and shovel. 2. Use scraper on roving vehicle.				
4.24.4.3.3	Load 10 and 100 ft. drilling equipment on vehicle. 1. Remove drilling equipment from storage. 2. Rigidly attach mounting structure to body of transportation vehicle. 3. Activate and check drill for functional operation. 4. Unstore handrill and check for functional operation. 5. Load equipment (see 4.24.4.2.1 for list).	2.25 manhours required. Shirtsleeve: .5 manhrs. Spacesuit: 1.75 manhrs.	1. Use hoist for heavy material.				
4.24.4.3.4	Transport 10 and 100 ft. drilling equipment to area.	Mass (lb.) 300 Volume (cu. ft.) 36	1. Transport equipment on a roving vehicle. 2. Transport equipment on a drilling rig trailer towed by a roving vehicle.	1. Requires no additional equipment. 2. Eliminates the time required to load equipment for each experiment requiring drilling.	1. Not as functional as 2. 2. Requires additional equipment (trailer) and payload.		
4.24.4.3.5	Set Up drilling equipment. 1. Align 100 ft. drilling rig. 2. Anchor 100 ft. drilling rig. 3. Unload hand drill and connect to power source.	2.25 spacesuit manhours required. 1.&2. See 4.24.2.5 for requirements.	1. & 2. See 4.24.2.5 for methods to accomplish requirements.				

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.3.6	Drill exploratory holes 3 to 10 ft. deep.	1.5 spacesuit manhours required per hole. 1. .3 hours of equipment time required per hole. 2. Astronaut participation is full time (1.5 hrs.) 3. Number of holes required 4. Power required .6 to .8 Kw. 5. *Penetration rates* 3 ft/20 min (Basalt) 10 ft/20 min (Tuft)					
4.24.4.3.7	Drill exploratory holes 100 ft. deep. 1. Drill 100 feet. 2. Support drilling.	20 hrs. required to drill one hole. 1a. Drill operating time 16.5 hours. Drilling: 13.5 hrs. Raise & lower drill: 3.0 hrs. 1b. Power requirements 12 Kw pk 1c. *Penetration rate*, 7.5 ft/hour 2. 6.5 spacesuit manhrs. required to remove core, control and service drill.					
4.24.4.3.8	Perform analysis of core samples and materials 1. Analyze core and sample material.	Core analysis time					
4.24.4.3.9	Secure drilling equipment.	1.15 spacesuit manhours required.					
4.24.4.3.10	Transport drill equipment to base.	Time required Mass (lbs) Volume (cu. ft) Equipment: 600					
4.24.4.3.11	Store 10 and 100 ft. drilling equipment.	2.5 spacesuit manhours required. 1.0 shirtsleeve manhours required.					

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.3.12	Load deep drilling equipment on vehicle.	3 spacesuit manhours required.					
4.24.4.3.13	Transport deep drilling equipment to site.	Mass (lb.) Volume (cu.ft.) Equipment: 6500 30 3 spacesuit manhours required.					
4.24.4.3.14	Set up deep drilling equipment. a. Assemble drilling rig and anchor. b. Connect gas lines and power cables. c. Check out instrumentation and monitoring displays. d. Check out manual and remote drill control.	40 manhours required. Spacesuit: 30 manhrs. Shirtsleeve: 10 manhrs.	1. A hoist may be required to erect assembled drilling rig. 2. See 4.24.4.2.5 methods for anchoring drill rig.				
4.24.4.3.15	Drill 1000 ft. hole. 1. Drill 1000 ft. hole.	485 manhours required. la. Drill operating time 420 hrs.: Drilling, 250 hrs. Raise and lower drill, 170 hrs. lb. Astronaut participation 150 hours: Core removal and servicing drill, 70 hrs. Monitoring and control (shirtsleeve) 80 hrs. lc. Power requirement: 12 Kw pk. 9 Kw. average Penetration rate: 4 ft/hour	1. EVA Drilling 2. IVA Drilling	A. No drill module required A. Eliminates spacesuit constraints in working	A. Spacesuit constraints and hazards A. Requires mobile module to house and seal drill		Trade study required to select drill module

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.4.3.16	Secure drill and equipment. a. Disconnect power source and cut off gas supply valves. b. Package non-return equipment for in place storage. c. Dismantle drill rig assembly.	15 manhours required. 15 manhours required to dismantle drill rig assembly.					
4.24.4.3.17	Transport earth return equipment to base. a. Power source b. Drill bits c. Core samples	46 spacesuit manhours required. Mass Volume a. 100 b. 30 c. 2000 20 Total: 2130					

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Sortie/Operation Remote Sorties

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.1	Perform remote sorties	The time required to complete all remote sorties to be performed at each LSB site ranged from 512 to 721 days.	1. Fly crew to site from LSB or OLS 2. Fly crew & deliver equipment by unmanned surface vehicle 3. Transport crew and equipment by surface vehicle	A. Minimizes enroute times A. Minimizes crew enroute times A. Minimizes enroute fuel	A. Excessive tug propellant consumption A. Fuel penalty for two vehicles A. Slow enroute travel		Trade study required to select transportation mode
4.24.1.1	Prepare crew, science equipment, mobility aids, and transportation vehicle for sortie. a. Prepare mission plan b. Select crew c. Check out experiments, support equipment and vehicles	Requires 40 manhours Integrate results of last sortie into mission plan c. Assumes that required maintenance has been performed	c.1. Provide pressurized hangar for vehicles 2. Vehicle maintenance - service - storage area outside pressurized shelter	1. Vehicle activity can be accomplished in shirt-sleeves 2. Requires no hangar for vehicles	1. Additional expense of providing and maintaining hangar 2.a. Requires vehicle activity to be performed in spacesuits b. Requires many airlock cyclings to load/unload vehicles	Pressurized hangar	Trade study required to support this recommendation
4.24.1.2	Load crew and equipment aboard transportation vehicle a. Assemble vehicle into sortie configuration except for main power supply b. Load consumables c. Ingress crew d. Final checkout of vehicle	80 manhours a.1. Payload weight - 1468 lb 2. Payload power - 1-3000 w 3. Payload volume - 123 ft^3 b.1. Science consumables - 335 lb 2. Data rate 0.7×10^4 bits/sec c. 4 crewmen required					

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FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.1.3	Egress shelter	Hangar will be deactivated during sortie duration					
	a. Stow checkout equipment and tools	2 manhours					
	b. Evacuate hangar for egress operations	4 hours					
	c. Open hangar hatch	0.25 hours					
	d. Close hangar hatch	0.25 hours					
	e. Maintain hangar in quiescent mode	78-day duration					
	f. Assemble main power supply onto vehicle	Assuming main power supply is an RTG, it will be stored in an area separate from the shelter					
4.24.1.4	Transport crew and equipment to experiment location.	The outbound leg is minimum distance and time to provide maximum consumables at site and a marked path for emergency return or rescue. Day and night driving will be required to minimize travel time to the site.					
4.24.1.5	Perform outbound experiments. a. While vehicle is in motion	a.1. No EVA operations to be necessary during these experiments 2. All experiments will be performed while vehicle is in motion 3. Data to be recorded continuously during driving 4. Data to be evaluated in real time					
	1. γ-ray Spectrometer Exp. No. 4057 2. IR Radiometer Exp. No. 4032 3. Mass Spectrometer Exp. No. 4039 4. Cold Cathode Gage Exp. No. 4039						

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4.24.1.5 Continued	b. While vehicle is stopped 1. Gravimeter Exp. No. 4045 2. Megnetometer Exp. No. 4058 3. Collect rock samples	b.1. NoEVA operations to be necessary during these experiments 2. Data to be analyzed in real time 3. Stops to be made for 5-10 minutes every 5 SM					
4.24.1.8	Transport crew and equipment to shelter	The inbound leg is designed to provide maximum additional traverse data, allow revisits to previous sites for revalidation of data and to investigate targets of opportunity. Day and night driving will be required to minimize travel time to shelter.					
4.24.1.9	Perform inbound experiments	Same as 4.24.1.5					
4.24.1.10	Ingress shelter a. Disassemble power supply from vehicle and install into Base power circuits b. Open hangar hatch c. Close hangar hatch d. Pressurize hangar	a. 1 hour Assuming main power supply is an RTG, it must be stored in an area separate from the shelter b. 0.25 hour c. 0.25 hour d. 4 hours Hangar will remain pressurized for 14 days					
4.24.1.11	Unload cabin a. Verify shirtsleeve environment b. Egress Crew c. Disassemble equipment	Requires 24 manhours					

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4.24.1.11 Continued	d. Perform mechanical tear-down e. Hook up servicing/electrical umbilicals f. Recover consumables and purge g. Perform leak check h. Deservice subsystems						
4.24.1.14	Complete crew debriefing	Requires 32 manhours					
4.24.1.15	Terminate mission plan a. Finalize crew reports b. Determine experiment results c. Report equipment anomalies	Requires 160 manhours					

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4.24.1.6	Perform traverse experiments and operations						
4.24.1.6.1	Establish and maintain traverse route	Day and night travel will be required throughout traverse					
4.24.1.6.2	Perform continuous enroute experiments while vehicle is in motion a. γ-ray Spectrometer Exp. No. 4057 b. IR Radiometer Exp. No. 4032 c. Mass Spectrometer Exp. No. 4039 d. Cold Cathode Gage Exp. No. 4039	1. No EVA operations to be necessary during these experiments 2. Data to be recorded continuously during driving 3. Data to be evaluated in real time					
4.24.1.6.3	Select site for discrete experiments and stop vehicle						
4.24.1.6.4	Recharge power system batteries	Requires 19 hours/day Repeat at 24-hour intervals					
4.24.1.6.5	Perform discrete enroute experiments at fixed intervals a. Magnetometer Exp. No. 4058 b. Gravitometer Exp. No. 4045	2 statute mile intervals Data to be analyzed in real time and rerun if necessary					
4.24.1.6.6	Perform active seismic profile at special sites a. Don suit b. Egress vehicle c. Drill hole 1 d. Insert charge e. Layout geophones f. Drill hole 2	4 hours/site Repeat at 24-hour intervals					

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4.24.1.6.6 Continued	g. Insert charge h. Initiate hole 1 i. Initiate hole 2 j. Record and analyze data k. Retrieve geophones						
4.24.1.6.7	Deploy remote geophysical monitor at selected points (Exp. No. 4033) a. Don suit b. Egress vehicle c. Drill hole d. Insert heat flow probe e. Connect to amplifier transmitter f. Check out and activate g. Select site for passive seismometer h. Connect to transmitter i. Check out and activate	4 hours/site Repeat at 24-hour intervals					
4.24.1.6.8	Perform post-EVA activities a. Ingress vehicle b. Stow equipment c. Doff suit d. Report results e. Bathe, eat, rest f. Analyse data and sample g. Sleep, eat h. Don suit i. Egress vehicle	17 hours/day Repeat at 24-hour intervals					
4.24.1.6.9	Complete traverse and terminate discrete experiments and start vehicle						
4.24.1.6.10	Configure vehicle and experiments for daytime operations						
4.24.1.6.11	Configure vehicle and experiments for nighttime operations						

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4.24.1.7	Perform experiment site operations						
4.24.1.7.1	Select control site for operations and stop vehicle a. Verify position b. Deploy shelter c. Unload and stow equipment and consumables in shelter d. Deploy power supply e. Inspect and repair equipment and vehicles f. Explore complete experiment site	24 manhours Travel to site is planned for arrival at sunset +1 day Repeat per mission plan					
4.24.1.7.2	Prepare vehicles and experiments for delivery to experiment site a. Revise and approve final experiment plan b. Assign experiments and locations c. Assign vehicles to teams d. Load vehicles with experiments, support equipment and consumables	16 manhours					
4.24.1.7.3	Transport crew and equipment to experiment sites	.68 hrs/day 1. Two 2-man crews utilizing surface site vehicles 2. Repeat at 24-hour intervals					
4.24.1.7.4	Perform sortie experiments a. Life detection Exp. No. 4001 b. Geologic mapping analysis and stratigraphy Exp. No. 4032 c. Drilling and subsurface sampling Exp. No. 4033	6.5 hrs/day 1. Repeat at 24-hour intervals 2. All experiments to be performed in day light					

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4.24.1.7.4 Continued	d. Mineralogic identification and chemical analysis in situ Exp. No. 4038 e. Investigation of lunar transient activity Exp. No. 4039 f. Geodetic grid construction Exp. No. 4044 g. Gravity profiling Exp. No. 4045 h. Active seismic investigations Exp. No. 4046 i. Passive seismic measurements Exp. No. 4047 j. Total pressure Exp. No. 4053 k. In situ measurment of the natural radiation spectrum Exp. No. 4057 l. Magnetic profiling Exp. No. 4058 m. Geophysical bore logging Exp. No. 4059 n. Determination of near surface temperature gradient Exp. No. 4088						
4.24.1.7.5	Return crew and equipment to main vehicle	.68 hrs/day Repeat at 24-hour intervals					
4.24.1.7.6	Perform post-EVA activities a. Secure site vehicle b. Ingress vehicle c. Stow equipment d. Doff suit e. Deliver samples to lab f. Report results	16 hrs/day Repeat at 24-hour intervals					

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4.24.1.7.6 Continued	g. Bathe, eat, rest h. Analyze data and samples i. Sleep, eat j. Don suit k. Egress vehicle	Selected data may be transmitted directly to earth					
4.24.1.7.7	Charge power system batteries on main vehicle	24 hours/day					
4.24.1.7.8	Transport antenna to highest local elevation	Utilize lunar flying vehicle 0.1 hour					
4.24.1.7.9	Erect and checkout antenna	1-6 hours					
4.24.1.7.10	Return flyer	0.1 hour					
4.24.1.7.11	Transport crew and equipment to local sites beyond drive mobility capability	Utilize lunar flying vehicle 0.1 hour					
4.24.1.7.12	Perform experiments	1-6 hours					
4.24.1.7.13	Return crew, equipment and samples	0.1 hour					
4.24.1.7.14	Transport medic, spares or empty seat for crew rescue or emergency equipment repair	0.1 hour					
4.24.1.7.15	Locate and pick up crew	1-6 hours					
4.24.1.7.16	Return crew	0.1 hour					
4.24.1.7.17	Inspect and repair or replace failed components	1-6 hours					
4.24.1.7.18	Return flyer	0.1 hour					
4.24.1.7.19	Configure experiments and equipment for night operations	Requires 8 manhours Sunset					

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4.24.1.7.20	Analyze data, photos and rock samples	0-336 hours					
4.24.1.7.21	Inspect, maintain, repair, service and check out experiments and vehicles	0-336 hours					
4.24.1.7.22	Perform night-scheduled experiments	0-336 hours					
4.24.1.7.23	Maintain quiescent operations	0-336 hours Utilize quiescent mode when 4.24.1.7.22 is completed and sunrise has not yet occurred					
4.24.1.7.24	Configure experiments and equipment for day operations	8 manhours					
4.24.1.7.25	Terminate experiments, load crew, equipment and samples aboard and start vehicle	8 manhours					

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4.24.2.1	Perform one-meter X-ray Imaging Telescope Experiment	Experiment No. 4012					
4.24.2.1.1	Prepare site.	Site Location: Lat-near equator - long - any Preferably in large crater (60 mi.) for occulation. Site preparation - 48 space-spacesuit manhours.					
	a. Survey						
	b. Provide stable mounting surface for telescope.	Maximum deflection in principal axis limited to: X - ± 1 cm/km Y - ± 1 cm/km Z - ± 1 cm/km	1. Utilize telescope structure for support. 2. Anchor to bedrock: A. Expose bedrock if within one ft. of surface. B. Drill to bedrock if surface soil depth one ft. 3. Provide concrete foundation in surface soil.	3. Use lunar soil for concrete.	3. Excessive weight (if concrete from Earth used).	1. Study extent of foundation anchoring required.	
4.24.2.1.2 NOTE: Continued on page 2.	Transport telescope components to site.	Subassembly Mass and Volume: (lbs) & (cu/ft): Telescope Tube Assy.: 1544 1553 Upper Bearing Support: 330 423 Polar Axis Tube Assy.: 220 282 Aspect Telescope Assy.: 660 282 Stowage Fixture: 110 282 Platform: 110 247	1. Transport telescope subassemblies as one payload. 2. Transport telescope subassemblies individually.				

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4.24.2.1.2 (Cont'd)	Transport telescope components to site.	Electronics, etc.: 507 17.6 RTG: 48 4.4 Total: 3529 3091.0 Distance from delivery site to installation site: miles.					
4.24.2.1.3	Assemble telescope.	110 manhours (spacesuit) required for assembly. Requires crane or handling hoist to lift components into place.					
4.24.2.1.4	Prepare telescope for operation. a. Activate assembly. b. Align telescope. c. Calibrate equipment d. Checkout facility.	40 manhours (spacesuit) required.					
4.24.2.1.5 NOTE: (Continued on Page 3.)	Perform telescope operations. a. Map sky automatically in in scheduled cycles. b. Support telescope operations.	a. Performed in one-month cycles. Experiment duration 12-36 cycles. b.1 Requires two spacesuit manhours/day for film and sensor charging. b.2 Emulsion coated plates expended at rate of one lb/day. b.3 Power requirements 20 watts during operation, 300-400 watts peak.					

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4.24.2.1.5 (Contd)	Perform telescope operations. c. Analyze data.	c. Scientific evaluation of data requires 60 shirt-sleeve manhours/cycle.					
4.24.2.1.6	Deactivate and stow telescope for reuse or disposal. a. Install protective shielding. b. Remove reusable equipment. c. Deactive power supply.	Requires eight (8) space-suit manhours.					

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4.24.2.2	Perform 50-inch optical telescope experiment.	Experiment No. 4016 and Experiment No. 4029. Site Location: Lat. - near equator; Long. - 5 S					
4.24.2.2.1	Prepare telescope module for operations. a. Provide stable mounting for telescope module. b. Assemble telescope dome. c. Unstow and install light tube and optics. d. Level telescope platform.	Requires 90 spacesuit manhours. a. Maximum deflection in principal axis limited to X - $\pm 5\ \mu$/sec Y - $\pm 5\ \mu$/sec Z - $\pm 5\ \mu$/sec b. & c. Requires crane or handling equipment. Mass and volume: 11055 pounds 3670 cubic feet.					
4.24.2.2.2	Prepare telescope systems for operation. a. Activate assembly. b. Align telescope. c. Calibrate equipment. d. Checkout facility.	Requires ten spacesuit and five shirtsleeve manhours.					

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4.24.2.2.3	Perform optical telescope operations. a. Determine sky brightness at full sky. b. Observe infrared phenomena related to planets, stars and galaxies. c. Support telescope operations. d. Analyze data.	Time-share experiments as viewing conditions permit. a. Requires 400 spacesuit and 1100 shirtsleeve manhours/year. b. Requires 200 spacesuit and 550 shirtsleeve manhours/year. Power requirements: 250 watts continuous, 400-500 watts peak powered by an RTG. c. Two spacesuit manhours/day to change film and sensors; one shirtsleeve manhour/day processing film and data. d. 4.5 shirtsleeve manhours/day analyzing data. Film expended at rate of 1 lb/day.					
4.24.2.2.4	Deactivate and stow optical telescope. a. Prepare mirrors and optics for long-term storage. b. Seal light tube. c. Configure subsystems for storage.	Requires ten spacesuit manhours.					

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4.24.2.3	Perform 100-inch optical telescope experiment.	Experiments No. 4016 and 4029.					
4.24.2.3.1	Prepare site. a. Survey site. b. Provide stable mounting surface for telescope.	Site location: Lat. - near equator; long. - 5 S Establish bench marks for telescope axis alignment. Maximum deflection in principal axis limited to: X - ± .5 μ/sec Y - ± .5 μ/sec Z - ± .5 μ/sec					
4.24.2.3.2	Transport telescope components to site.	Subassembly mass (lbs) non-expendables Dome & foundation: 6000 (Mass:lbs) Fixed telescope tube: 4592 Control Room: 4000 (ref) Instrument Room: 4000 (ref) Primary mirror housing and foundation: 900 200-inch mirror and back-up structure: 8000 200-inch mirror base and jacks: 4500 200-inch drive mech. and heaters: 500 100-inch mirror and back-up structure: 2000	1. Transport telescope subassemblies as delivery vehicle payload. 2. Transport telescope subassemblies individually.				

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4.24.2.3.2 (Cont'd)	Transport telescope components to site.	Mass (lbs) 100" mirror base and jacks: 1700 Secondary optics instrument: 705 Instruments, consoles, and supports: 2,006 Power: 110 Life support and environmental control: 5000 Total: 33,000 Expendables (six-month operation): Water: 1,082 Nitrogen: 855 Oxygen: 44 Hydrogen: 2.2 Film and Containers: 661 Film processing chemicals: 110 TOTAL: 2,754.2 Distance from delivery site to installation site miles.					
4.24.2.3.3	Assemble telescope: a. Install telescope components. b. Provide micrometeoroid thermal and radiation protection.	a. 325 spacesuit manhours required for assembly. b. Crane or handling hoist required to lift components into place.					

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4.24.2.3.4	Activate and checkout manned support systems.	Ten spacesuit and 100 shirtsleeve manhours.					
4.24.2.3.5	Prepare telescope for operations. a. Activate subassembly. b. Align telescope. c. Calibrate equipment. d. Checkout facility.	65 spacesuit and 240 shirtsleeve manhours					
4.24.2.3.6	Perform optical telescope operations. a. Determine sky brightness of full sky. b. Observe infrared phenomena related to planets, stars and galaxies. c. Support telescope operations. d. Analyze data.	a. Requires 1300 shirt sleeve and 200 spacesuit manhours/year. b. Requires 650 shirtsleeve and 100 spacesuit manhours/year. Power requirements: 4 kw supplied by nuclear powerplant delivered as a separate shelter. c. One spacesuit and one shirtsleeve manhour/day required for telescope maintenance. d. Six shirtsleeve manhours/day for data. Film and processing materials expended at rate of 4.3 pounds/day. Life support expendables (assume ten manhours/day) are used at rate of 9.6 pounds/day.					

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4.24.2.3.7	Deactivate and stow optical telescope. a. Prepare mirrors and optics for long-term storage. b. Seal light tube.						

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4.24.2.4	Perform radio telescope experiment (two-element interferometer) 300 KHz - 1000 KHz.	Experiment No. 4014. Site location: Lat. - near equator; long. - 180 W					
4.24.2.4.1	Prepare site. a. Level and clear as required. b. Survey site.	Requires 48 spacesuit manhours. a. Requires grading.					
4.24.2.4.2	Transport antenna components to site.	Mass and Volume (lbs) Dipoles: 10,988 Towers and ground screens: 355 Battery and control: 60 Transmission line: 250 Total: 11,533 Volume = 135 cu/ft Distance from delivery site to installation site = 8 miles.					
4.24.2.4.3	Assemble antenna. a. Erect and install antenna towers and intermediate poles. b. Deploy and install dipole elements. c. Deploy and install ground amplifiers. d. Install antenna tuner amplifiers. e. Deploy and install transmission lines. f. Install receiver and power supply.	Requires 236 spacesuit manhours. Requires two-man vehicle.					

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4.24.2.4.4	Correct receiver output to LSB data processing station via hardline. a. Erect and install intermediate poles. b. Deploy and install transmission lines.	Transmission line and poles can be deployed at rate of 0.6 mi./hr.					
4.24.2.4.5	Establish relay station operation. a. Deploy relay station and power supply. b. Connect receiver output to relay station. c. Activate relay station.	Requires five spacesuit manhours.					
4.24.2.4.6	Establish on-site data processing station operation.	Requires five spacesuit and five shirtsleeve manhours.					

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4.24.2.4.7	Prepare telescope systems for operation. a. Activate assembly. b. Align telescope. c. Calibrate equipment d. Checkout facility.	Four (4) shirtsleeve manhours required.					
4.24.2.4.8	Perform radio telescope operations. a. Observe flux densities in scheduled cycles. b. Monitor and analyze data. c. Transmit selected data to Earth. d. Return selected tapes to Earth.	a., b. Performed in one-month cycles. Experiment duration: 12-36 cycles. Requires 80 shirtsleeve manhours/cycle.					
4.24.2.4.9	Terminate operations and deactivate radio telescope.	Requires ten man-hours.					

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4.24.2.5	Perform radio telescope experiment (two-element interferometer (1 MHz - 15 MHz). Functions for 4.24.2.5 are the same as those for 4.24.2.4.	Experiment No. 4015 Site Location: lat. -near equator; long - 180 W					
4.24.2.5.1	Prepare site. a. Level and clear as required. b. Survey site.	Requires 24 spacesuit manhours. a. Requires grading.					
4.24.2.5.2	Transport antenna components to site.	Mass and Volume (lbs) Dipoles: 60 Towers and ground screens: 200 Battery and Control: 40 Transmission Line: 50 ——— 350 Volume = 18 cu/ft Distance from delivery site to installation site = TBD miles.					
4.24.2.5.3	Assemble antenna. a. Erect and install antenna towers. b. Deploy and install dipole elements. c. Deploy and install ground planes. d. Install antenna tuner amplifiers. e. Deploy and install transmission lines. f. Install receiver and power supply.	Requires 120 spacesuit manhours.					

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4.24.2.5.4	Connect receiver output to LSB data processing station via hardline. a. Erect and install intermediate poles. b. Deploy and install transmission lines.	Transmission line and poles can be deployed at rate of 0.6 mi./hr.					
4.24.2.5.5	Establish relay station operation. a. Deploy relay station and power supply. b. Connect receiver output to relay station. c. Activate relay station.	Requires five spacesuit manhours.					
4.24.2.5.6	Establish on-site data processing station operation.	Requires five spacesuit and five shirtsleeve manhours.					

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4.24.2.5.7	Prepare telescope systems for operation. a. Activate assembly. b. Align telescope. c. Calibrate equipment. d. Checkout facility.	Four (4) shirtsleeve man-hours required.					
4.24.2.5.8	Perform radio telescope operations. a. Observe flux densities in scheduled cycles. b. Monitor and analyze data. c. Transmit selected data to Earth. d. Return selected tapes to Earth.	a., b. Performed in one-month cycles. Experiment duration: 12-36 cycles. Requires 80 shirtsleeve manhours/cycle.					
4.24.2.5.9	Terminate operations and deactivate radio telescope.	Requires ten manhours.					

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4.24.2.6	Perform radio telescope experiment (phase-switching interferometer) 0.6 MHz - 1.2 MHz.	Experiment No. 4027. Site location: Lat. - near-equator Long.- near-side					
4.24.2.6.1	Prepare site. a. Survey site. b. Level and clear as required.	Requires eight (8) spacesuit manhours. Requires grading.					
4.24.2.6.2	Transport antenna components to site.	Mass and Volume (lbs) Antennas: 220 Cabling: 220 Receiver: 55 Total: 495 Volume: 17.5 cubic/feet Distance from delivery site to installation site = 2 miles.					
4.24.2.6.3	Assemble antenna. a. Erect and install antenna towers and intermediate poles. b. Deploy and install antenna loops. c. Deploy and connect ground planes. d. Deploy and install transmission lines. e. Install receiver and power supply.	Requires 16 spacesuit manhours. Requires two-man vehicle.					

TEMP-REAT 3114

Sortie/Operation ________

Analyst C. C. Turner

LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.2.6.4	Connect receiver output to LSB data processing station via hardline. a. Erect and install intermediate poles. b. Deploy and install transmission lines.	Transmission line and poles can be deployed at rate of 0.6 mi./hr.					
4.24.2.6.5	Establish relay station operation. a. Deploy relay station and power supply. b. Connect receiver output to relay station. c. Activate relay station.	Requires five spacesuit manhours.					
4.24.2.6.6	Establish on-site data processing station operation.	Requires five spacesuit and five shirtsleeve manhours.					
4.24.2.6.7	Prepare telescope systems for operation. a. Activate telescope. b. Align telescope. c. Calibrate telescope. d. Checkout facility.	Requires four (4) shirt-sleeve manhours.					

TEMP-RE&T 3114

Sortie/Operation ______

Analyst C. C. Turner

LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.2.6.8	Perform radio telescope operations. a. Observe temporal variation variations. b. Monitor and analyze data. c. Transmit selected data to Earth. d. Return selected tapes to Earth.	a., b Performed in one-month cycles. Experiment duration: 12-36 cycles. Requires 108 shirtsleeve manhours for first cycle and 50 shirtsleeve man-hours/cycle thereafter.					
4.24.2.6.9	Terminate operations and deactivate radio telescope.	Requires ten manhours.					

TEMP-REAT 3114

Sortie/Operation ____

Analyst C. C. Turner

LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.2.7	Perform radio telescope experiment (temporal variations from 5 MHz to 500 MHz	Experiment No. 4028 Site location: Lat. - near-equator Long. - far-side or limb					Trade study required to define optimum location for observatory
4.24.2.7.1	Prepare site. a. Survey site. b. Level and clear as required.	a. Requires four (4) spacesuit manhours. b. Requires grading.					
4.24.2.7.2	Transport antenna components to site.	Distance from delivery site to installation site = 1 miles.					
4.24.2.7.3	Assemble antenna. a. Erect and install antenna towers and poles. b. Deploy and install antennas. c. Deploy and install antennas. d. Install receivers and power supply.	Requires 16 spacesuit manhours. Requires two-man vehicle. Mass and Volume: Antenna set: 100 lbs 6.3 cu/ft Radiometer 9 lbs 1.5 cu/ft					
4.24.2.7.4	Connect receiver output to LSB data processing center via hardline. a. Erect and install intermediate poles. b. Deploy and install transmission lines.	Transmission lines and poles can be deployed at rate of 0.6 mi./hr.					

TEMP-REAT 3114

Sortie/Operation ______

Analyst C. C. Turner

LSB REQUIREMENTS ANALYSIS SHEET

FUNCTION NO.	FUNCTIONAL REQUIREMENT	PERFORMANCE REQUIREMENTS	ALTERNATE METHODS OF PERFORMING FUNCTION	ADVANTAGES OF METHOD	DISADVANTAGES OF METHOD	RECOMMENDATION	NOTES
4.24.2.7.5	Establish relay station operation. a. Deploy relay station and power supply. b. Correct receiver output to relay station. c. Activate relay station.	Requires five spacesuit manhours.					
4.24.2.7.6	Establish on-site data processing station operation.	Requires five spacesuit and five shirtsleeve manhours.					
4.24.2.7.7	Prepare telescope. a. Activate assembly. b. Align telescope. c. Calibrate equipment. d. Checkout facility.	Requires four (4) shirt-sleeve manhours.					
4.24.2.7.8	Perform radio telescope operations. a. Observe temporal variations in scheduled cycles. b. Monitor and analyze data. c. Transmit selected data to Earth. d. Return selected tapes to Earth.	a., b. Performed in cycles of 28 manhours. Experiment duration: 15-45 cycles Requires 32 shirtsleeve manhours/cycle.					
4.24.2.7.9	Terminate operations and deactivate radio telescope.	Requires two (2) man-hours.					

TEMP-REAT 3114

APPENDIX D. SURFACE NAVIGATION CONCEPTS

The objective of the navigation system is to supply information sufficient to enable the crew to maneuver the vehicle to some predetermined site or destination and return to the Lunar Surface Base.

Information to be provided in terms of operational requirements are:

1. Display vehicle present position during each sortie mission.

2. Display range and bearing to the destination of a previously visited site and to the LSB.

3. Display steering angle or heading data required to steer the vehicle to a predetermined site, a previously visited site or to the LSB.

4. Provide capability for position fix and heading reference update.

5. Provide capability for calibration and alignment of navigation equipment on lunar surface.

6. Provide a means for crew safe return to the LSB in event of on-board system failure.

The basic modes of navigation or guidance defined for the selection of component units were heading, velocity or distance, updating or position fixing and homing. Table D-1 is arranged to show weight, power and performance data for each alternate component concept listed under the above four modes. A wide range of weight and power is shown for some equipment. The more elaborate design configurations have less error but are heavier and require more power to operate.

Sun sensors and landmark correlation data are included, although these could be eliminated from consideration as a result of the assumptions given in the equipment survey.

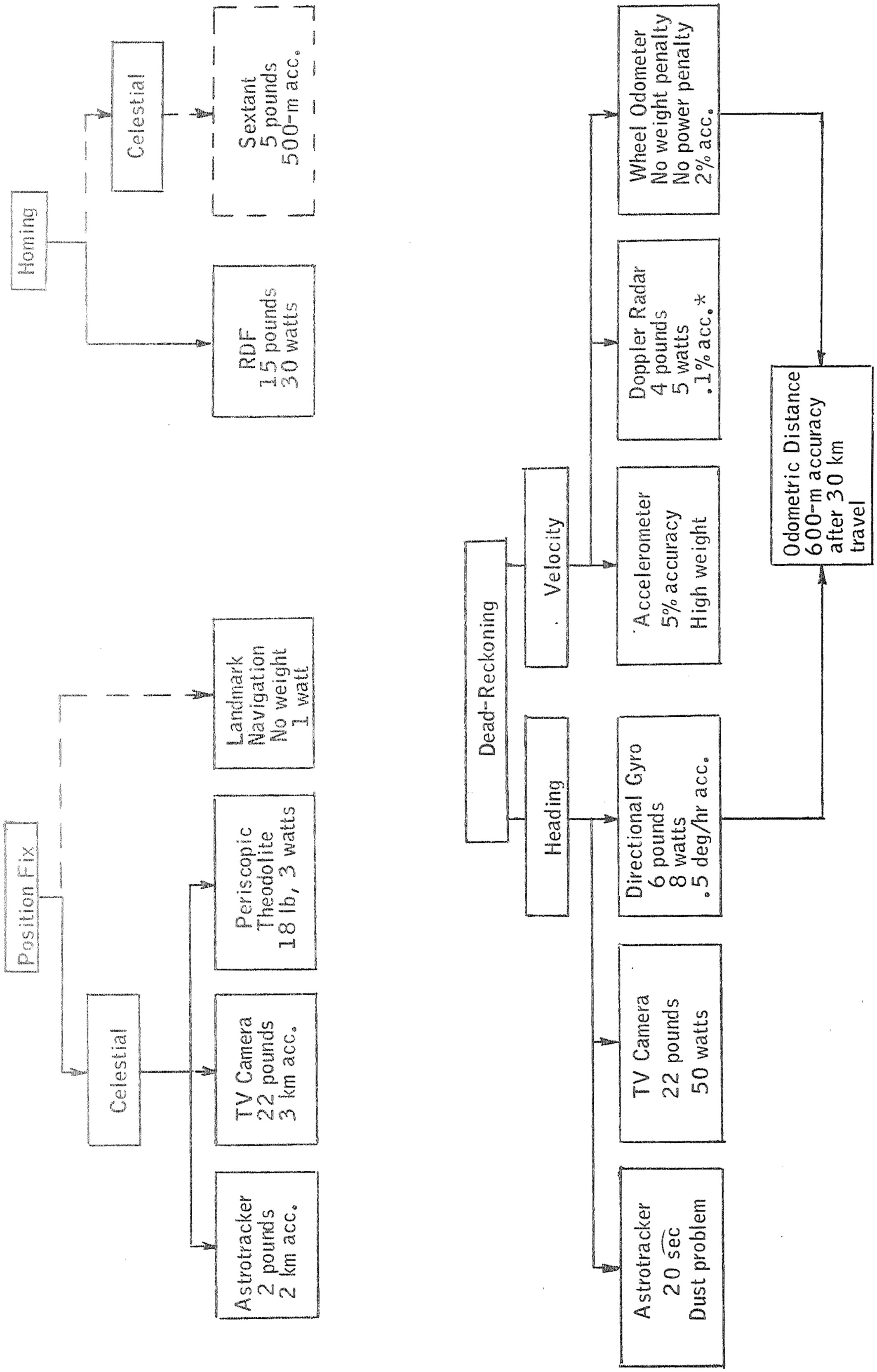
Figure D-1 is a block diagram of subsystem components used in the trade-off study under each navigation mode. Heading and distance are combined to define a dead-reckoning mode which provides continuous position and heading information. The position-fixing mode is used to update the dead-reckoning system when the accumulated error exceeds specified tolerances. The homing mode satisfies the abort requirement by providing an alternate method of navigating in the event of an onboard system failure.

Table D-1. Alternate Component Concepts

I. HEADING TECHNIQUES Component	Accuracy System	Accuracy Installation	Weight (lb)	Power (watts)	Requirements
Direction gyro	0.01 to 0.5 deg/hr	0.5 deg	4-7	5-12	Realignment/calibration
Continuous star tracker with vertical gyro	20 sec	0.5 deg	20 4-9	20 5-34	Stabilization Star acquisition
Strapdown IMU	0.01 deg/hr	0.5 deg	20	70	Realignment/calibration, digital computer complex
Platform IMU	0.01 deg/hr	0.5 deg	40	200	Realignment/calibration, digital computer
Star field correlator with vertical gyro			4-9	5-34	Digital computer (complex processing)
TV type	100 sec	0.5 deg	22	49	Preflight data
Optical/mechanical	50 sec	0.5 deg	14	20	Star field maps
Differential odometer	10 deg/hr	0.5 deg	1	1	Initial heading computer - secondary
Solar aspect sensors and electronics	±.5 deg		4	1	Sunlight operation only
II. VELOCITY TECHNIQUES Component	**Accuracy after 4 hr and 10 km (ft)**				
Odometer			1	1	Initial heading
with tilt sensor			1-5	2-10	Tilt sensor for corrections; computer
with DG	700				
without DG	1700				
Strapdown IMU	2800		20	70	Alignment/calibration Digital computer
Platform IMU	2800		40	200	Alignment/calibration Digital computer
Optical velocimeter	600		1	1	Terrain illumination Complex computer
Doppler velocity sensor	450		4	5	Sensitivity to low speeds. Very short range transmission
Groundwave (Loran)	1000		15	30	Established beacons Computer

Table D-1. Alternate Component Concepts (Cont'd)

III. UPDATE TECHNIQUES Component	Position Accuracy (ft)	Heading Accuracy	Weight (lb)	Power (watts)	Requirements
Handheld space sextant	1500	2 deg	9	1	Horizon or vertical ephemeris
Mounted sextant	700	30 sec	15	2	Horizon or vertical ephem.
Theodolite/inclinometer	700	30 sec	18	3	Computer or ephemeris
Navigation satellite	500		20	30	Surface slave station computer
Groundwaves (Loran)	1000		10	5	Established beacons Computer
Star tracker	5000	20 sec	29	54	Stabilization
Savet Gyrocompass		0.25 deg	15	30	Calibration procedure Computer
TV star field	10,000	.6 deg	2		
Landmark correlation (w/TV camera)	1500				
IV. HOMING TECHNIQUES Component					
Star tracker		50 sec	29	manual	Mechanical drive Vehicle mobility
Theodolite/inclinometer		50 sec	18	manual	Mechanical drive Vehicle mobility
Handheld space sextant	1500	2 deg	9	1	Horizon or vertical ephemeris
Handheld RDF	600	3 deg	15	5	LSB transmitter Line-of-sight range



*Needs development

Figure D-1. Navigation Subsystem Tradeoff Summary

The preferred navigation system concept contains a theodolite for position fixing, a directional gyro (DG) for providing instantaneous heading data, and wheel odometers with selection logic and calibrated electronics arranged to measure the distance traveled. The odometers are considered a part of the mobility system. A radio directional finding (RDF) unit is provided for homing on the LSB.

In addition to supplying star pointing data, the theodolite serves as a heading reference to update the DG. Manual drives on the theodolite could serve as a backup method for navigating the vehicle in the event of a system failure. Transformation of star azimuth and elevation angular data into coordinate system axes are corrected for vehicle roll and pitch throughout tilt sensor electronics. Figure D-2 shows the functional block diagram for the navigation subsystem. The subsystem weighs 64 pounds and requires 58 watts of electrical power.

The navigation computer processes the information obtained from sensory equipment aboard the vehicle and provides output functions necessary for the navigation of the vehicle., The two major navigation functions provided by the computer are position fixing and dead-reckoning.

The position-fix mode of operation is performed while the vehicle is stopped at a surface location chosen by the astronaut or at a site location. Position-fix calculations performed by the computer are reviewed by the astronaut before being used to make the new position update, or before defining a new DG heading reference.

Biasing of the DG is not required each time a position fix is made; however, the heading reference is redefined and an update of vehicle heading is accomplished. During dead-reckoning operation while the vehicle is in motion, odometer information obtained from at least two pairs of wheels is processed by the computer to determine distance traveled. Attitude (pitch and roll) information from the tilt sensor and heading information from the DG are processed to compute a change in position which is added to the original position to yield an updated position in terms of latitude, longitude, and elevation or position in terms of some chosen coordinate system.

This unit consists of alignment optics used to obtain an accurate line-of-sight to a celestial body and a reading optics portion which provides the operator with elevation data in the vertical plane and azimuth data in the horizontal plane. The astronaut inputs ephemeris and time reference data into the computer to obtain a position fix on the lunar surface.

The tilt sensor unit is the attitude system that establishes the local vertical reference by sensing components of the lunar gravity vector along two orthogonal axes when the vehicle is tilted. During dead-reckoning, navigation roll angle information is used to compute a correction for the heading angle obtained from the directional gyro. Pitch angle information is used to resolve the distance traveled into horizontal and vertical components. During position fixing, pitch and roll angle information is used to transfer the sensed celestial angles to the local vertical.

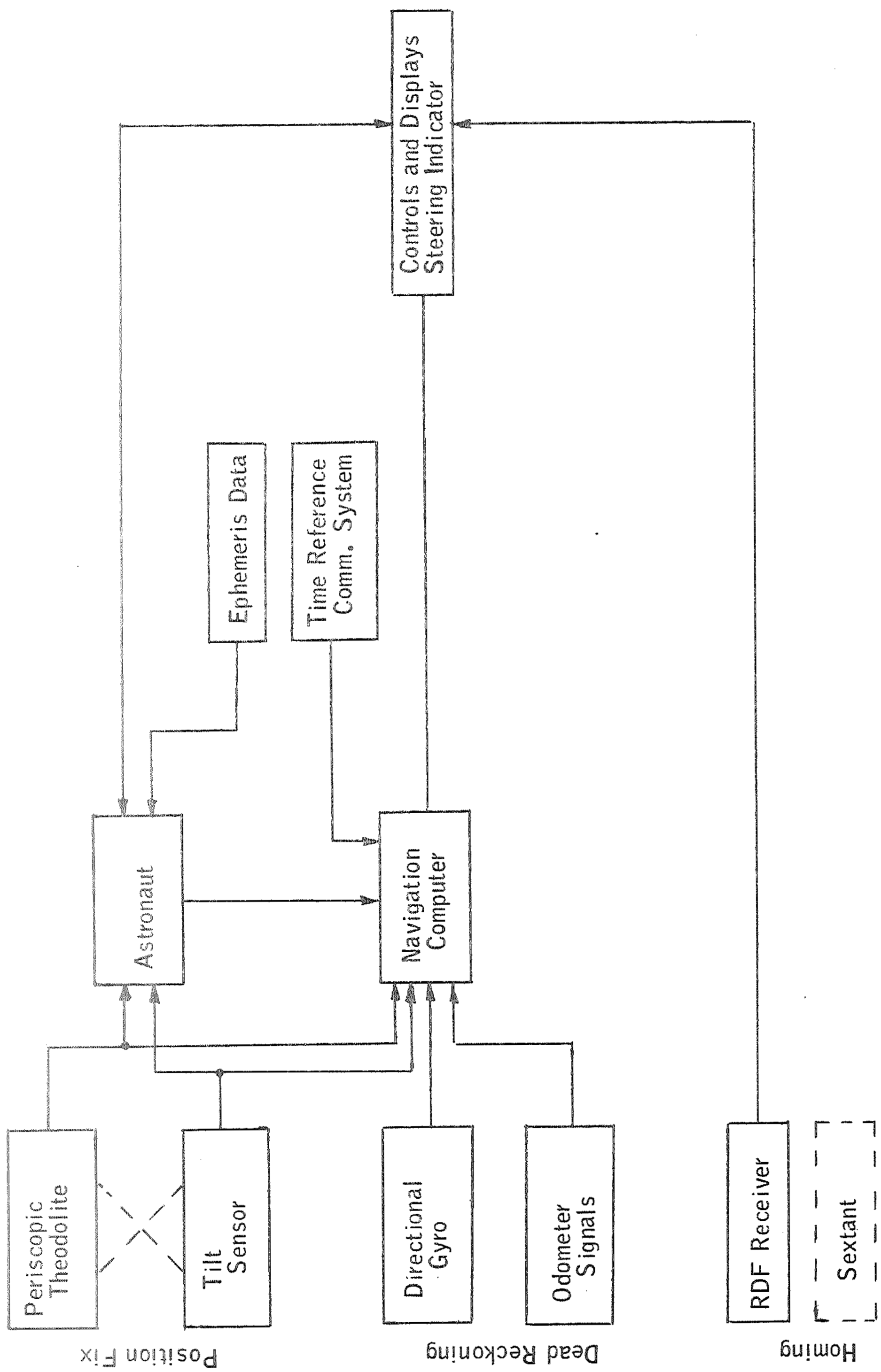


Figure D-2. Navigation Subsystem Block Diagram

The directional gyro provides the heading reference during dead-reckoning navigation. The unit incorporates a two-degree-of-freedom gyro with its spin axis kept horizontal by tilt sensor outputs. The gyro spin axis maintains a fixed azimuth angle in inertial space. This initial angle may be any value between ±180 degrees relative to the vehicle fore-aft axis. Initial gyro calibration to determine the gyro azimuth reference location relative to lunar north is accomplished using the theodolite.

The odometer system consists of four tachometers, each mounted on wheels, and selective circuit logic to determine which tachometer output should be used in the dead-reckoning computation. Selection is made on the basis that the tachometer with the slowest pulse rate is on the wheel with the least slip and, therefore, the most accurate measure of distance traveled. The pulse rate from the selected tachometer is proportional to vehicle velocity.

The RF homing system consists of a CW transmitter, operating at a constant frequency from an antenna of the LSB. A receiver unit and sensing antenna is located on the vehicle. Heading angle information to the LSB is the only data provided for navigation.

The sextant provides a backup mode for making a position fix. The unit provides a method for measuring the angle between a celestial body and the natural horizon.

Navigation Subsystem Performance

Accuracy of the system in the position update and dead-reckoning navigation modes are of interest. To relate vehicle position information, a north-east set of axes is chosen at the LSB. Position errors will accumulate as a function of time as the vehicle navigates on the lunar surface to a predetermined site. The position error accumulated during the dead-reckoning mode is maintained within limits by performing a position-fix at selected time intervals. As seen in Figure D-1, a position fix may be accomplished by the use of the periscope theodolite or by landmark navigation.

Lunar landmarks must be recognized and correlated with their positions shown on maps in order to establish vehicle position. Actual landmark navigation studies conducted on earth using TV cameras give a mean position error of 760 meters, with a variance of 1765 meters. When the worst cases were eliminated, the mean position error reduced to 268 meters with a variance of 216 meters. It is estimated in Reference D-1 that the position error utilizing this method would be 500 meters. Also, there are many influencing factors affecting this technique such as optimum distance of landmarks, landmark density and the need for establishing range to distant landmarks. Landmarks in close proximity of the vehicle (.5 to 2 miles) and those beyond 20 miles give erroneous results. Too many features in sight are confusing, so landmarks should be isolated for best results. It was found that large distance travel such as four miles was unwise until a series of successful location determinations could be obtained.

Craters and hills on a scale approximating camera resolution may hamper to an intolerable degree a clear view of the horizon and significant landmarks unless fixes are taken by moving to nearby elevated locations such as crater rims. This method of position-fixing is most likely to be employed during sunlight hours for sorties within a 30 kilometer radius of the LSB. As time progresses, maps with detailed lunar landmarks could be prepared for use during daytime operations. Position updates, on long navigation missions (400 to 800 statute miles) and during night time operations will be accomplished with the theodolite. Nominal position fix error with the theodolite is 2 to 6 statute miles (Reference D-2).

The dominant error sources during the dead-reckoning mode for a continuous measuring system are: (1) initial gyro heading misalignment, (2) DG drift, and (3) wheel slip velocity errors. The initial gyro misalignment error is a combination of theodolite azimuth misalignment, DG pickoff misalignment, and tilt sensor axes misalignment (attitude system misalignment). Wheel slippage or slip is a function of terrain pitch, and is expressed as:

$$S = K_1 + K_2 \tan P$$

where

S = fractional slip

K_1 = .01

K_2 = proportionality constant

P = terrain pitch

For pitch equal zero, slip is about one percent of the distance traveled. Another possible error is vehicle tilt caused by terrain tilt or slope and by chassis tilt due to loading. This error is random and difficult to estimate other than by terrain simulation using a computer. The magnitude of error has been less than one percent of the distance for results reviewed to date. The solution to eliminate errors due to tilt is to use a tilt sensor unit and measure chassis tilt continuously. This unit replaces the static inclinometer used to establish the local vertical during a position fix.

Position Accuracy

The 3σ component errors used to determine the maximum position error during the dead-reckoning mode are summarized as follows:

1. Odometer: 3% of distance traveled
2. Directional Gyro Drift: 0.5°/hr
3. Direction Gyro Pickoff: 0.5°
4. Tilt Sensor Axes Misalignment: 0.5°
5. Theodolite Azimuth Misalignment: .05°

Heading misalignment errors (3, 4, and 5) were combined in RSS fashion and used with the DG drift error in the following position error equations:

$$\Delta P_E = Vt - V/D \left[\sin(K + Dt) - \sin K\right]$$

$$\Delta P_N = V/D \left[\cos(K + Dt) - \cos K\right]$$

$$\Delta P = (\Delta P_E^2 + \Delta P_N^2)^{1/2}$$

where

ΔP_E is the error due East in a North, East and Vertical coordinate system

ΔP_N is the error due North in a North, East, and Vertical coordinate system

ΔP is the radial error in the horizontal plane.

These equations are plotted in Figure D-3 for a vehicle velocity of 4 Km/hr and 10 Km/hr, traveling in an eastward direction at the lunar equator.

For sortie distances less than 30 Km, a position fix by theodolite will not likely improve the position accuracy provided by dead-reckoning. For a high speed vehicle (10 Km/hr) a position fix every two to three hours would be adequate.

REFERENCES

D-1. Dual Mode Lunar Roving Vehicle Preliminary Design Study, Volume III, 1970 Grummon Aerospace Corporation

D-2. Lunar Landmark Study Document 760-45, 1970, Jet Propulsion Laboratory

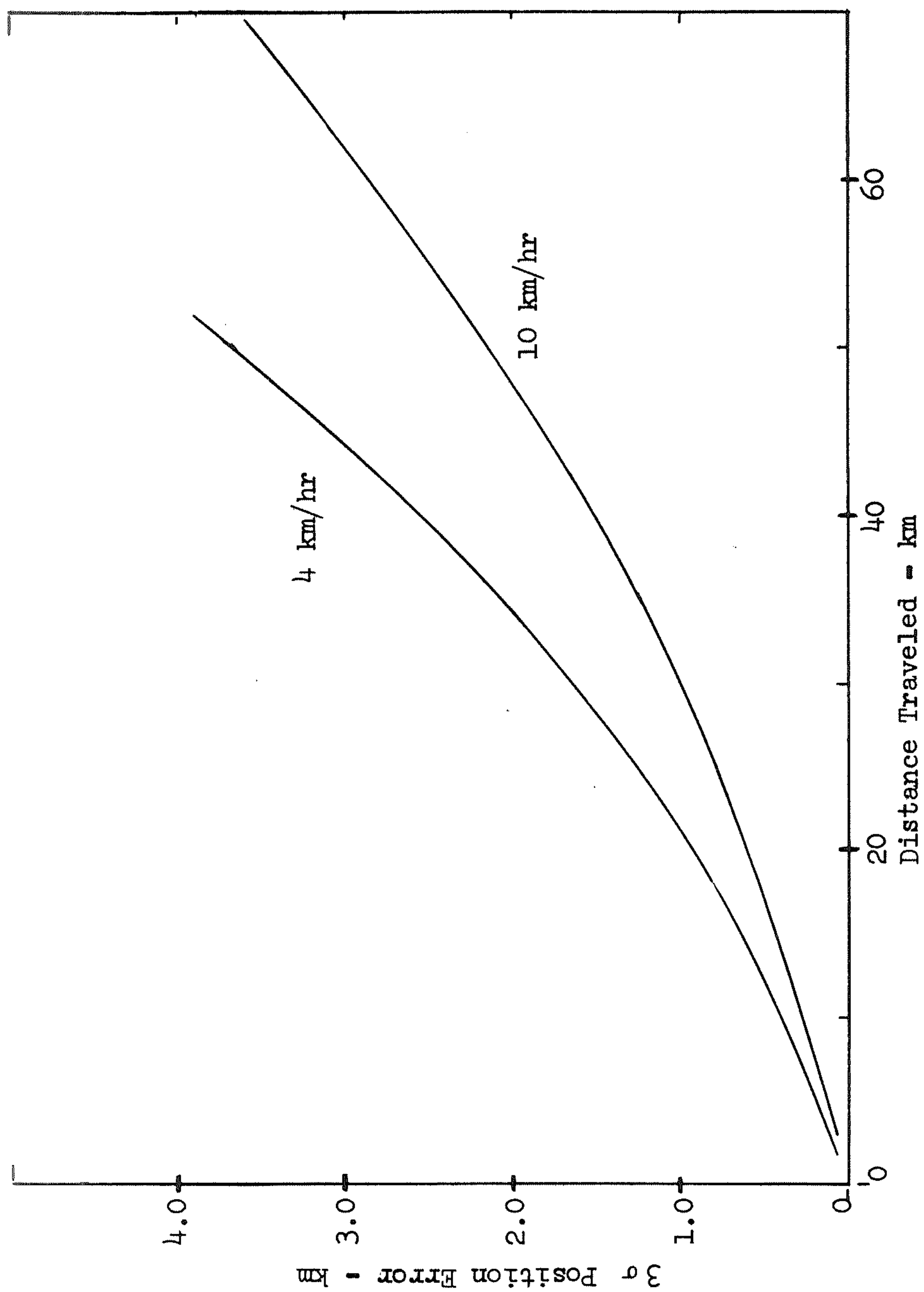


Figure D-3. Dead Reckoning System Errors

APPENDIX E. LSB SITE MATHEMATIC MODEL

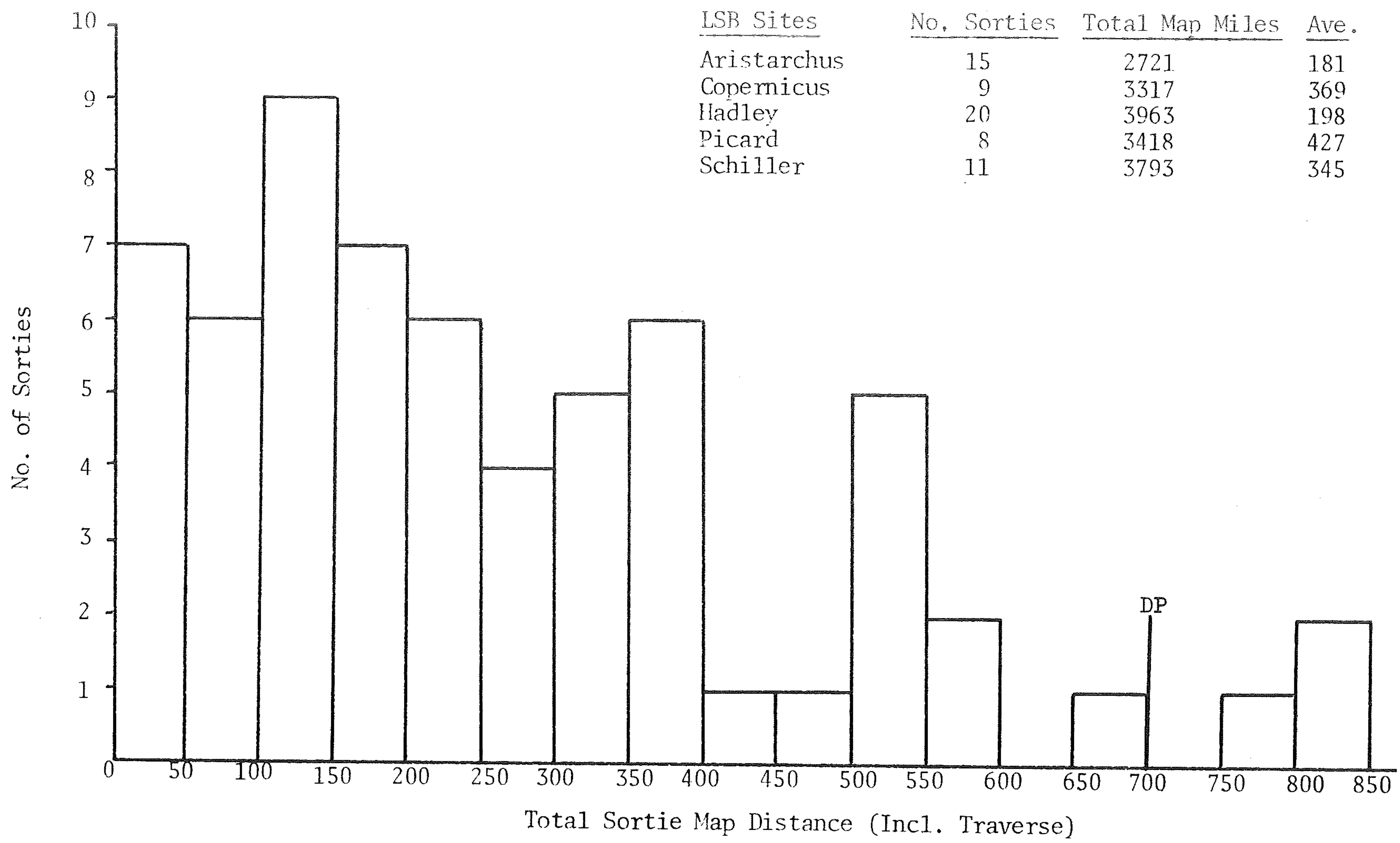
A mathematic model of a typical LSB site was formulated to summarize the results of the remote exploration sortie analyses and to provide the basis for subsequent studies of additional sites.

The model was developed in the form of histograms as shown in Figures E-1 through E-13. These figures show the frequency with which the various sortie variables occur on the missions planned at the various sites. The data are plotted independently of site location on the histograms. Table E-1 presents the equations which resulted from a least squares curve fit through smoothed data and also limited to a maximum of 4th degree in order to emphasize this study. Data from the three payload histograms are not included in the module because the variations were too small to be generalized. Also shown on the histograms are the design points selected for the mission variables (marked DP).

A generalized form of this model was developed for studying sites significant different in scope from those of this study. This model is presented in Table E-2. It is a normalized form of E-1 and the normalizing values are given in Table E-3. These are the peak values taken from the individual histograms. Because of the relatively large number of samples of sorties and experiment locations (sites) available, these equations could be converted to probability density functions by normalizing the total number of sorties or locations as given on each figure. However, this was not done as a more general form could be achieved by normalizing both the frequency of sortie or location and the random variables such as mission duration, payload weight, and so on.

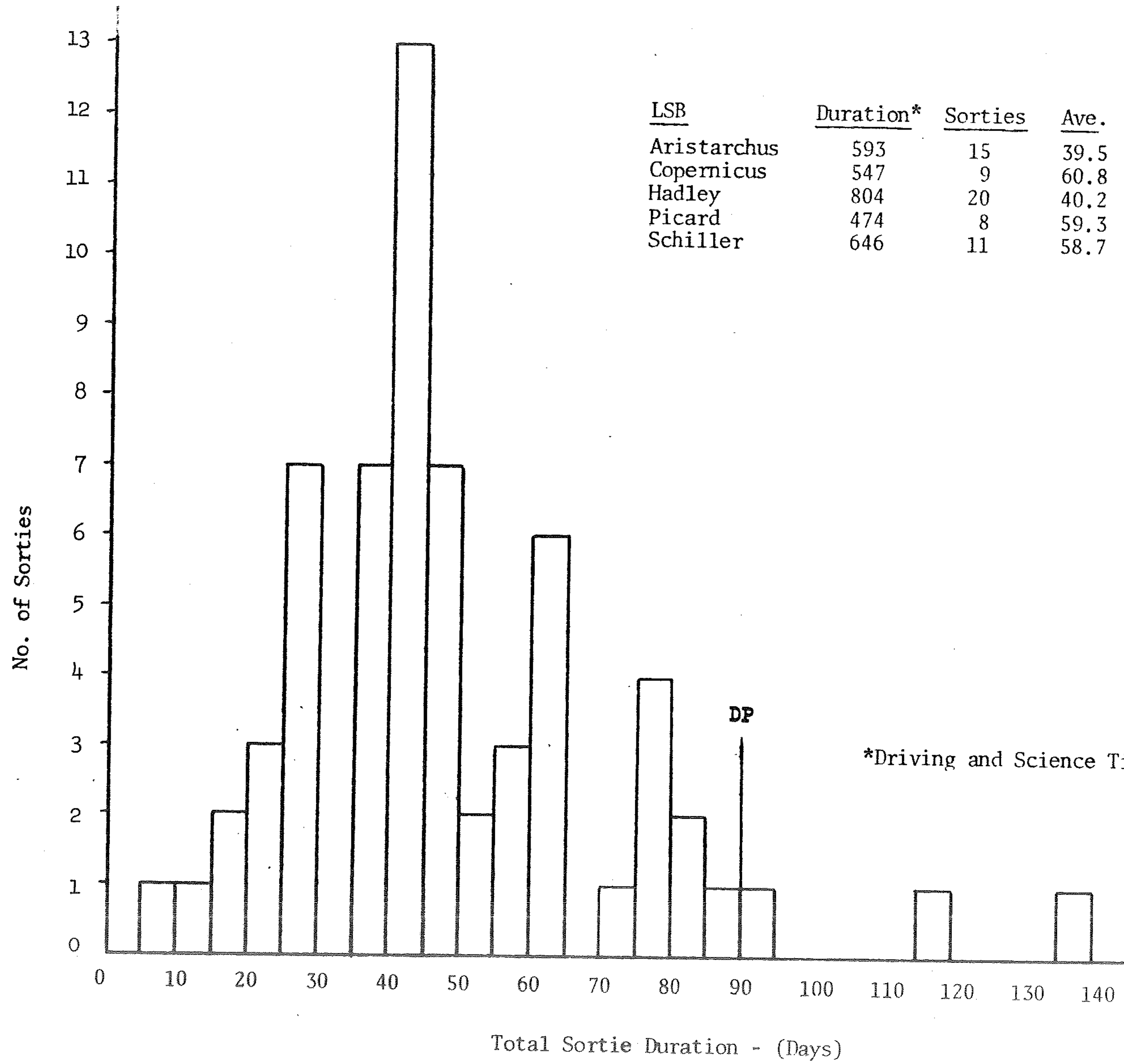
To use the model, the maximum values for the sortie or experiment location frequency and the random variable should be known. These, along with chosen intermediate values for the random variable will yield the frequency of sorties or experiment locations from the particular equation. Thus a site layout on a scaled map must be available with the location of the shelter and routes to all preselected experiment locations specified by computing, estimating, or choosing the maximum value of each random variable and knowing the number of sorties and experiment sites from the planned routes.

An inspection of the site dependent histograms shows a tendency towards a Gaussian distribution of the variables, generally centered on the shelter location. This is to be expected from the spatial nature of this problem and the addition of more sorties to more experiment locations would result in a smoother distribution more closely approximating the ideal Gaussian form.



LSB Sites	No. Sorties	Total Map Miles	Ave.
Aristarchus	15	2721	181
Copernicus	9	3317	369
Hadley	20	3963	198
Picard	8	3418	427
Schiller	11	3793	345

Figure E-1. Total Sortie Map Distance (Incl. Traverse) Histogram



LSB	Duration*	Sorties	Ave.
Aristarchus	593	15	39.5
Copernicus	547	9	60.8
Hadley	804	20	40.2
Picard	474	8	59.3
Schiller	646	11	58.7

*Driving and Science Time only

Figure E-2. Total Sortie Duration - (Days) Histogram

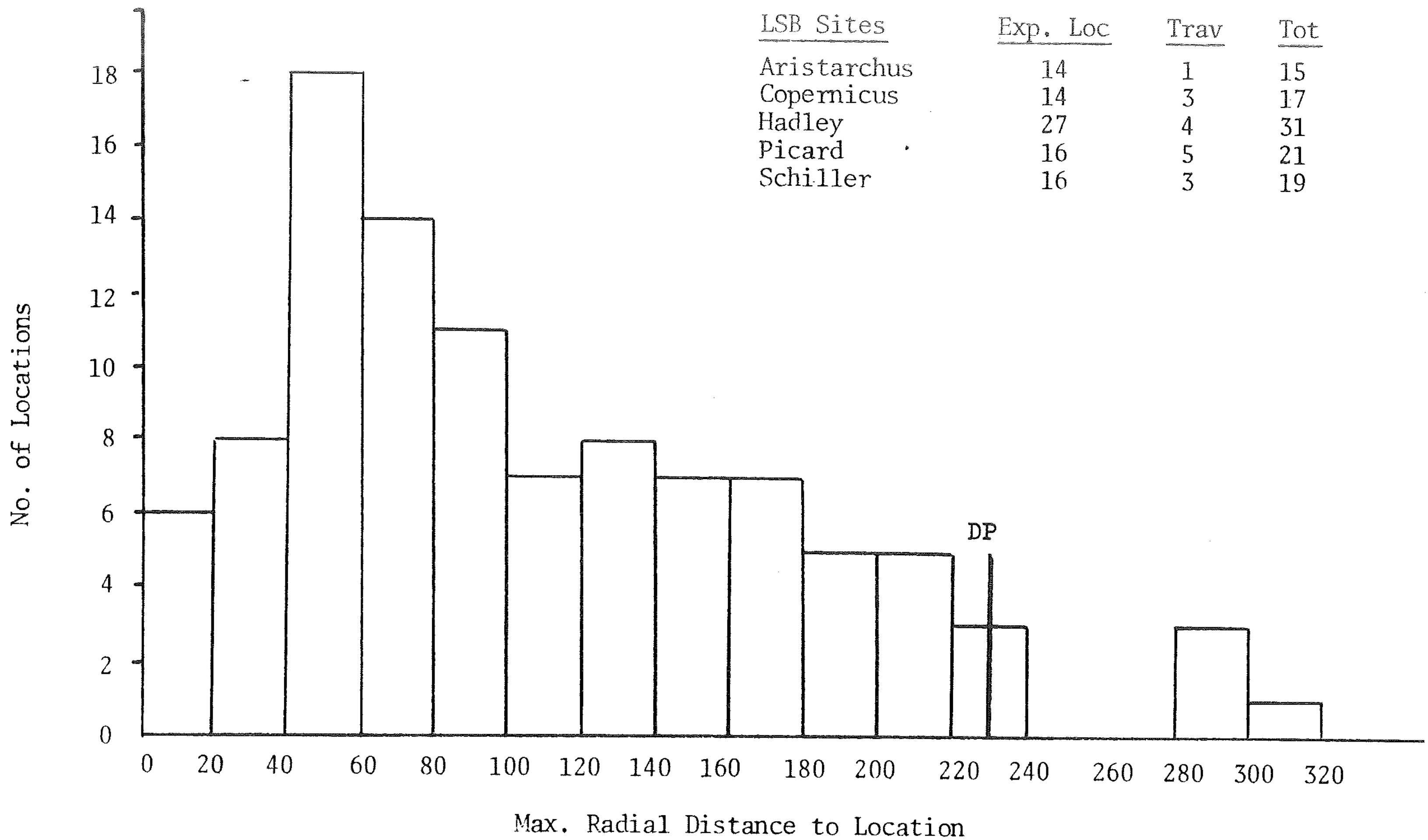


Figure E-3. Max. Radial Distance to Location Histogram

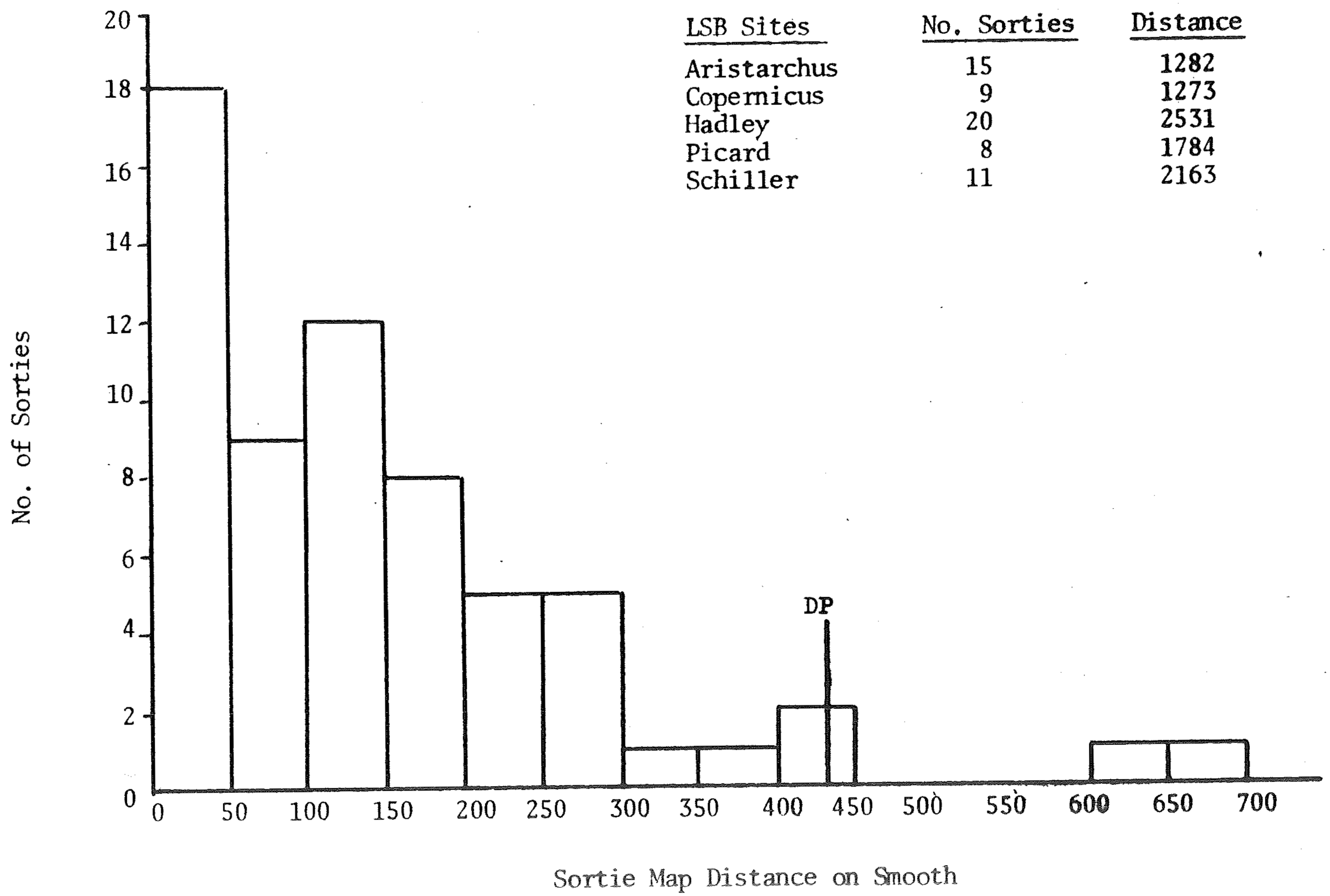


Figure E-4. Sortie Map Distance on Smooth Histogram

LSB Site	No. Sort.	Distance
Aristarchus	15	1439
Copernicus	9	2053
Hadley	20	1382
Picard	8	1634
Schiller	11	1621

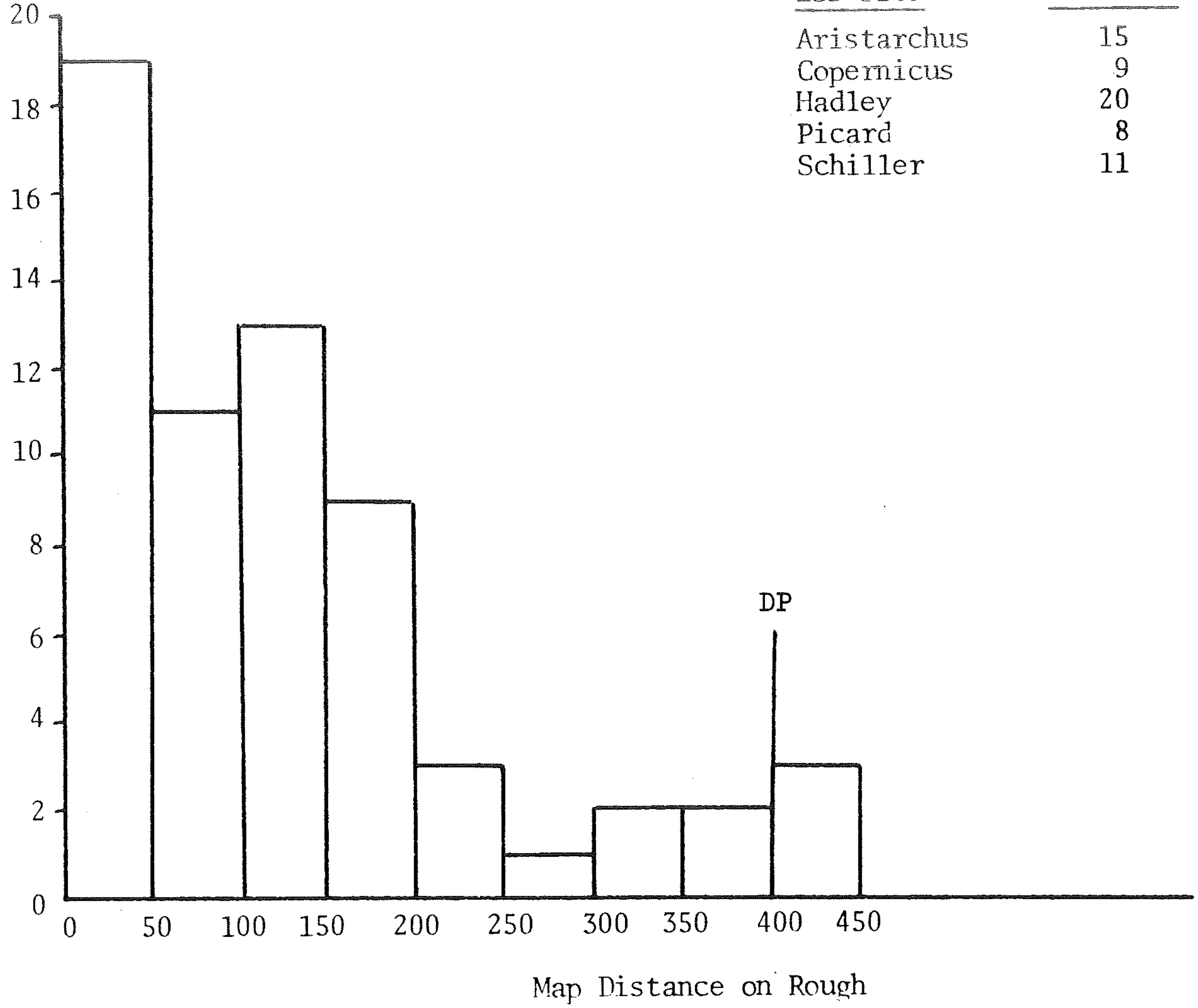


Figure E-5. Map Distance on Rough Histogram

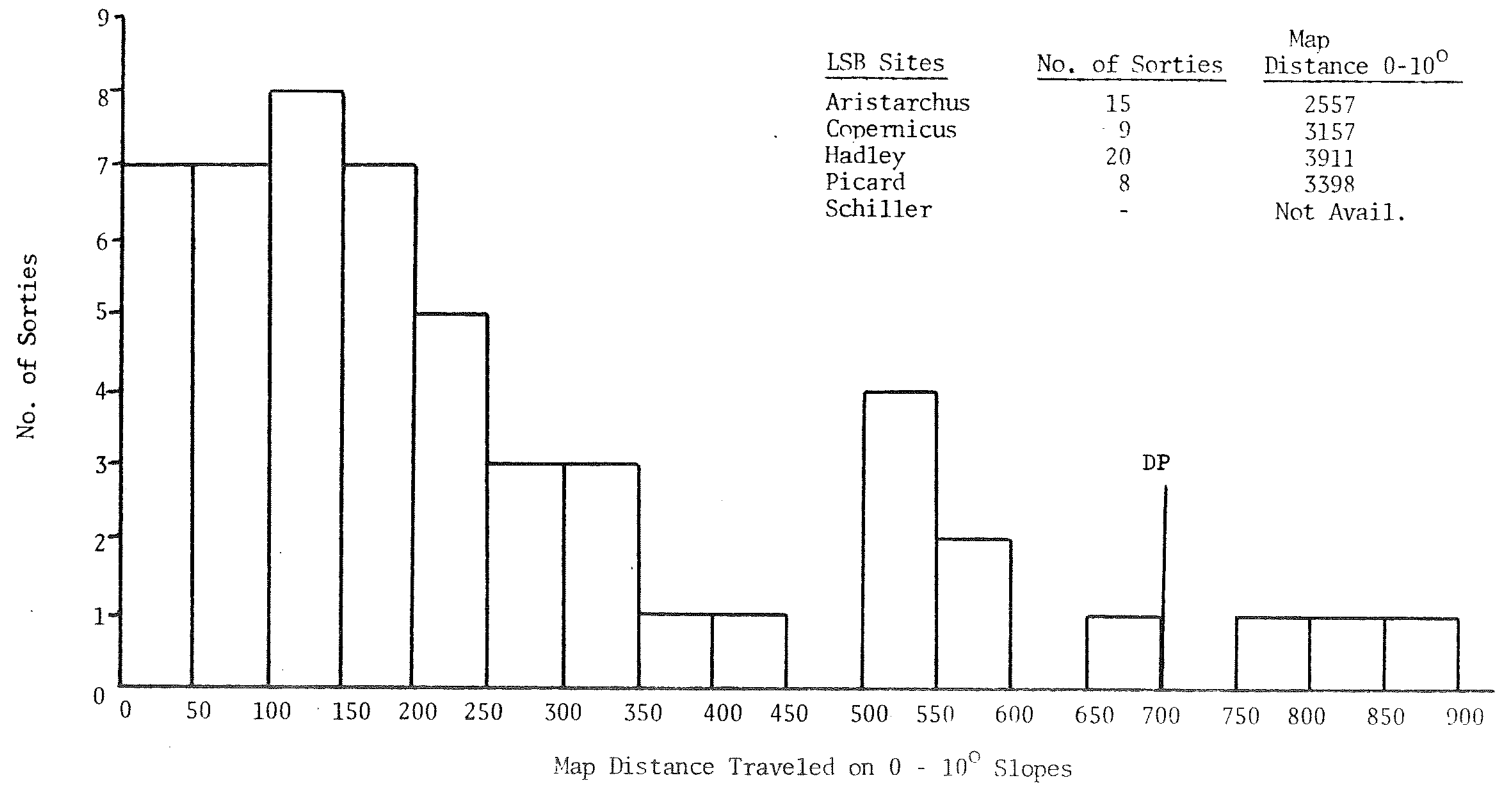
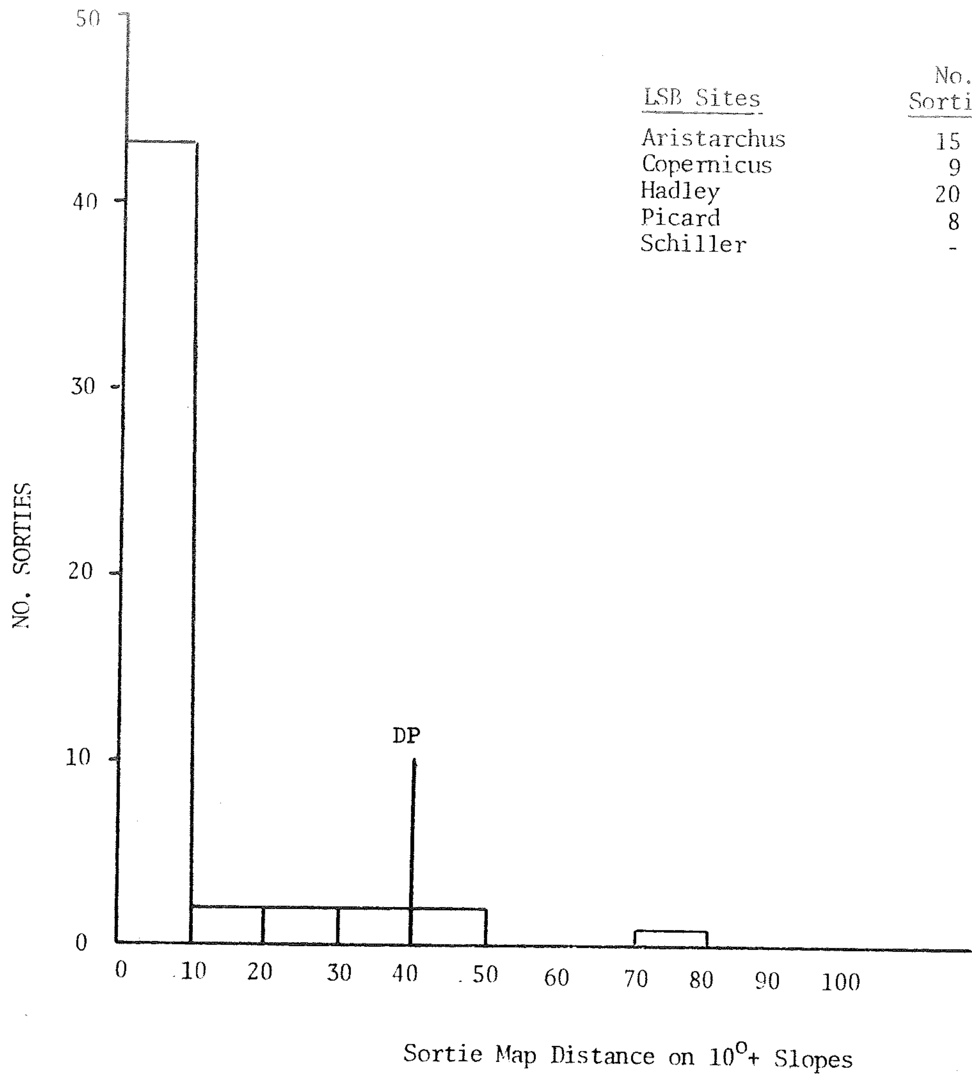
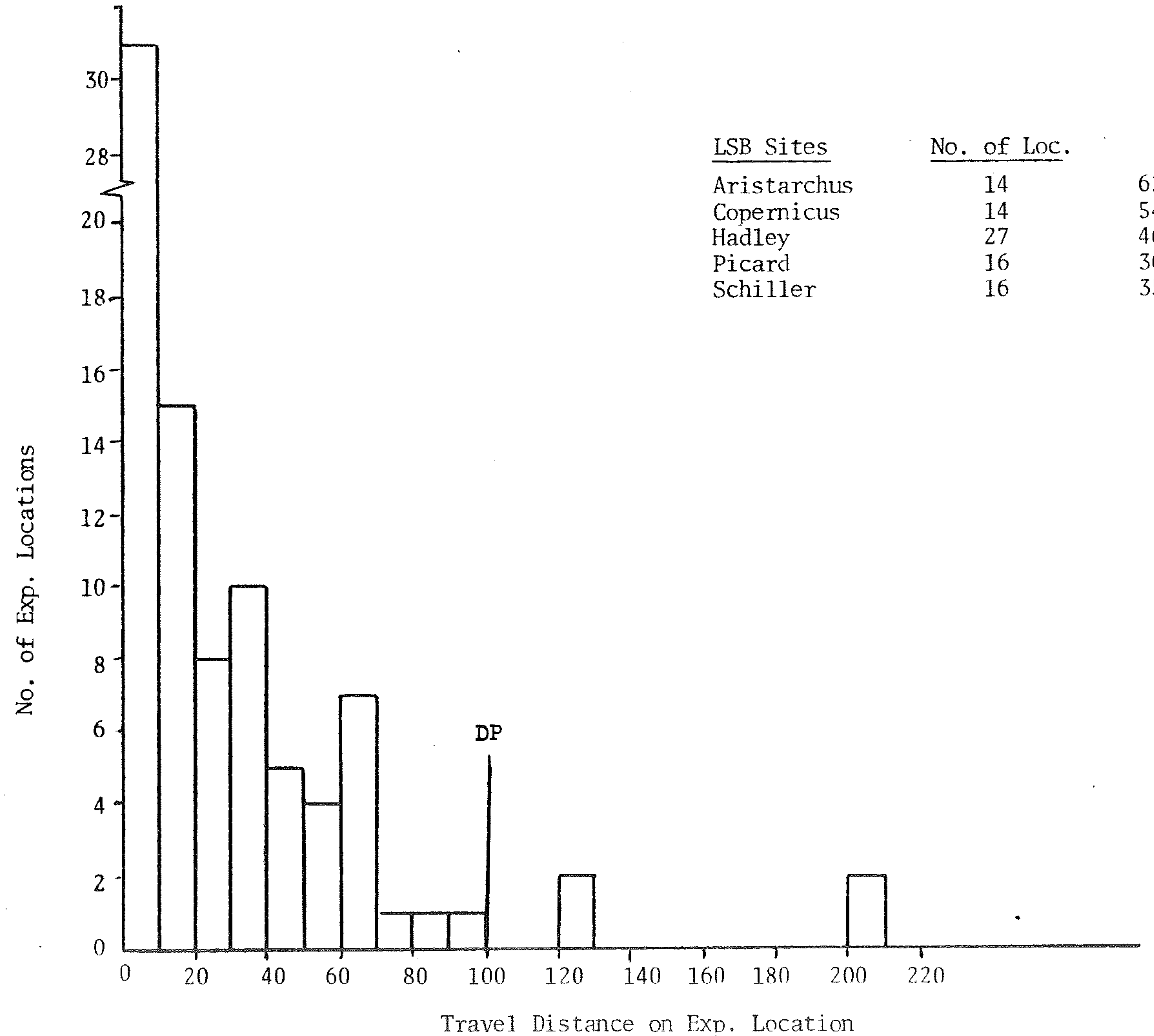


Figure E-6. Map Distance Traveled on 0 - 10° Slopes Histogram



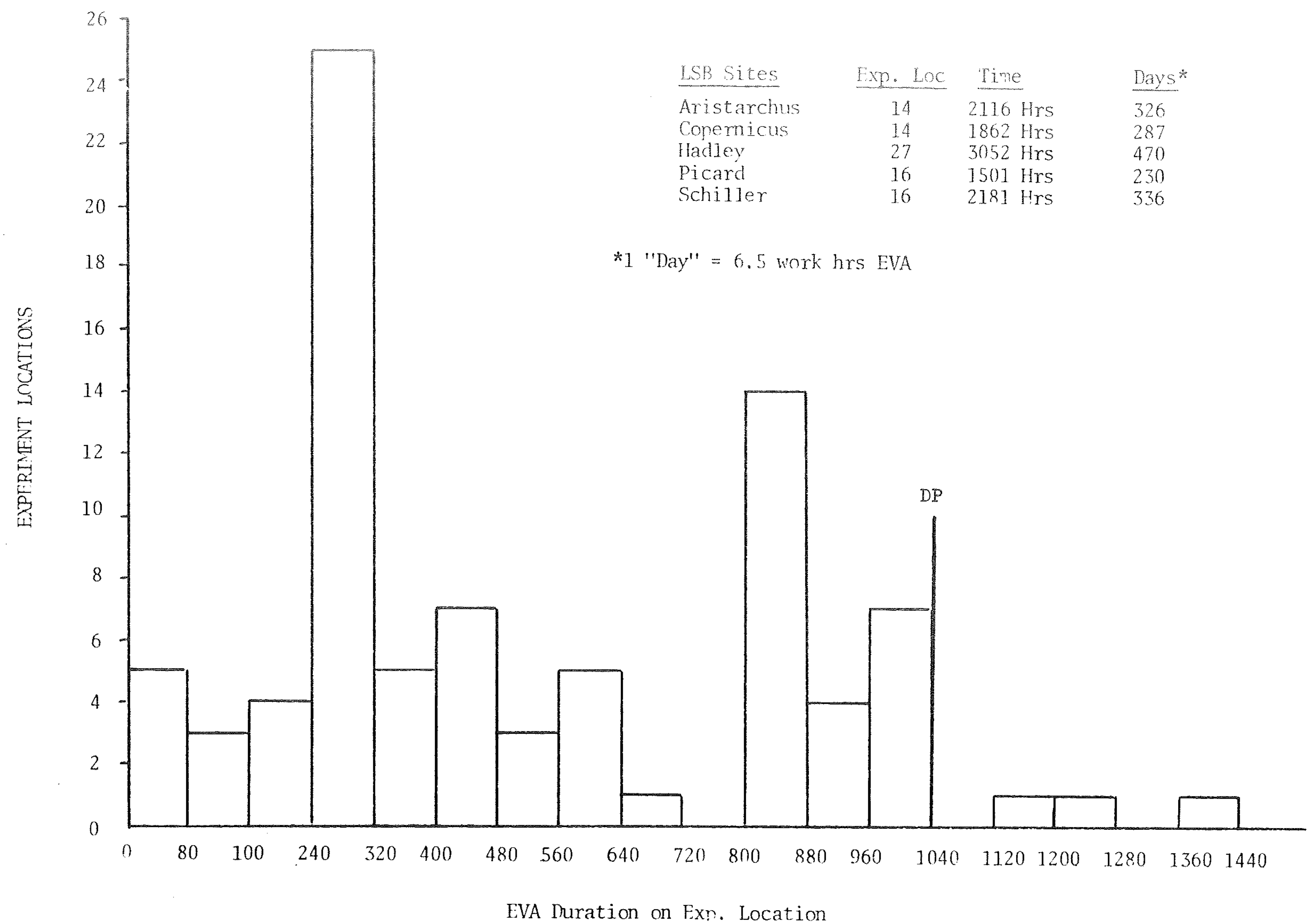
LSB Sites	No. Sorties	Dist on 10^{o}+
Aristarchus	15	165
Copernicus	9	160
Hadley	20	41
Picard	8	49
Schiller	-	Not Avail.

Figure E-7. Sortie Map Distance on 10° + Slopes Histogram



LSB Sites	No. of Loc.	
Aristarchus	14	635
Copernicus	14	549
Hadley	27	466
Picard	16	306
Schiller	16	353

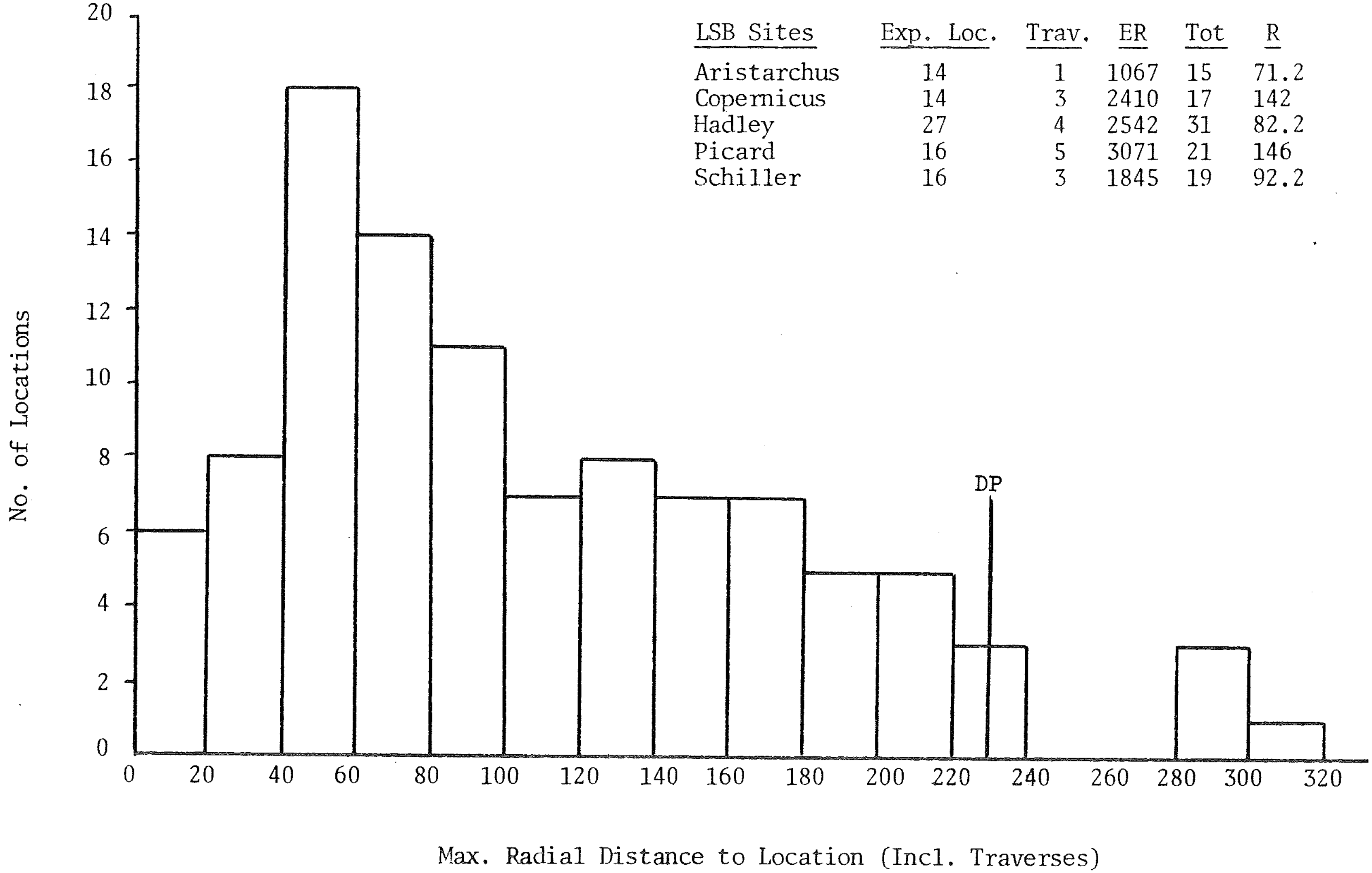
Figure E-8. Travel Distance on Exp. Location Histogram



LSB Sites	Exp. Loc	Time	Days*
Aristarchus	14	2116 Hrs	326
Copernicus	14	1862 Hrs	287
Hadley	27	3052 Hrs	470
Picard	16	1501 Hrs	230
Schiller	16	2181 Hrs	336

*1 "Day" = 6.5 work hrs EVA

Figure E-9. EVA Duration on Exp. Location Histogram



LSB Sites	Exp. Loc.	Trav.	ER	Tot	R
Aristarchus	14	1	1067	15	71.2
Copernicus	14	3	2410	17	142
Hadley	27	4	2542	31	82.2
Picard	16	5	3071	21	146
Schiller	16	3	1845	19	92.2

Figure E-10. Max. Radial Distance to Location (Incl. Traverses) Histogram

LSB SITE	SORTIES	AVG. WT./SORTIE
Aristarchus	15	1174
Picard	8	1468 —DP
Schiller	11	1194
Hadley	20	930
Copernicus	9	933

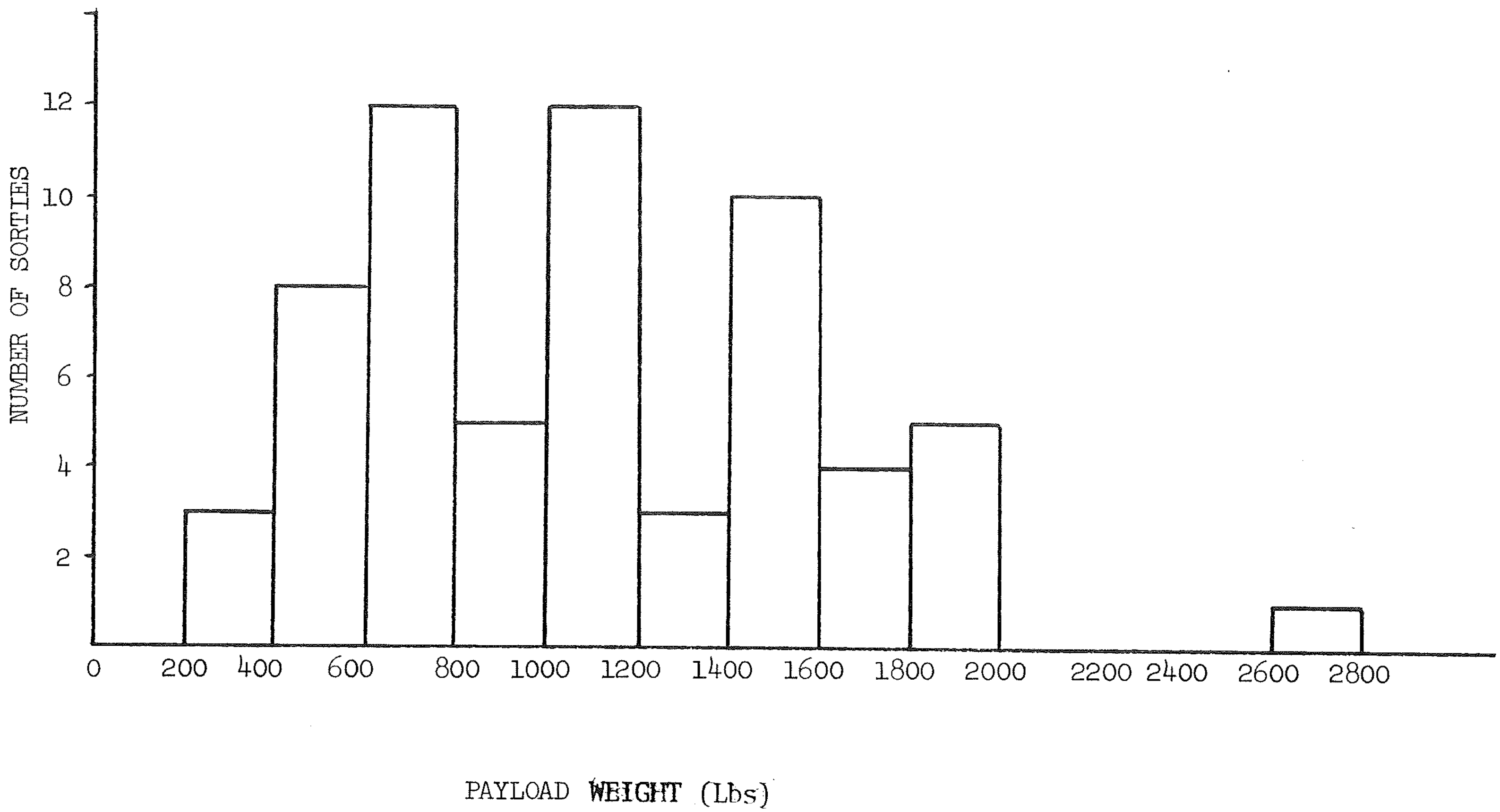


Figure E-11. Payload Weight (Lbs) Histogram

LSB Site	Sorties	Avg. Vol./Sortie
Aristarchus	15	103
Picard	8	109
Schiller	11	123 —DP
Hadley	20	77
Copernicus	9	87

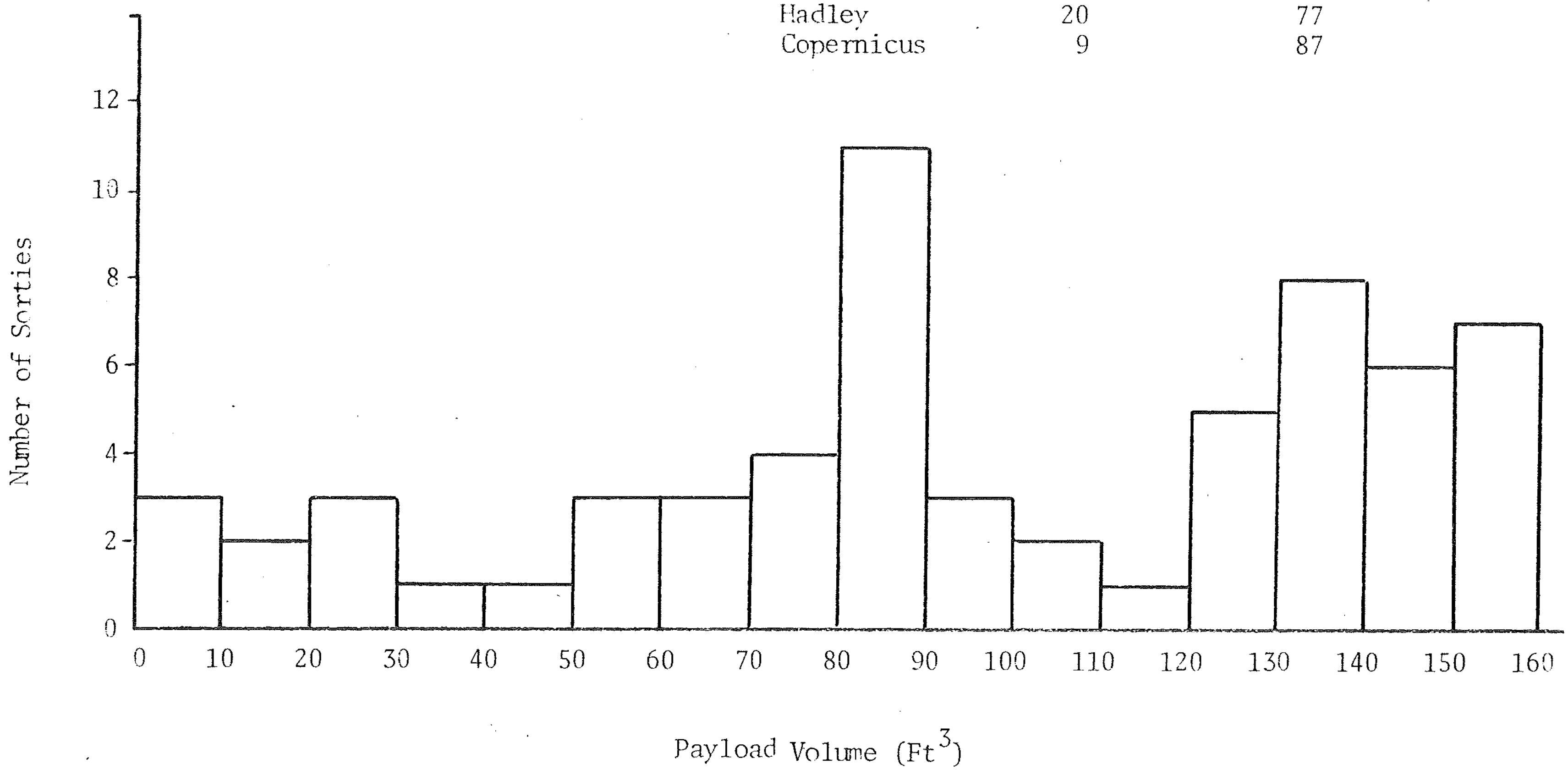


Figure E-12. Payload Volume (Ft^3) Histogram

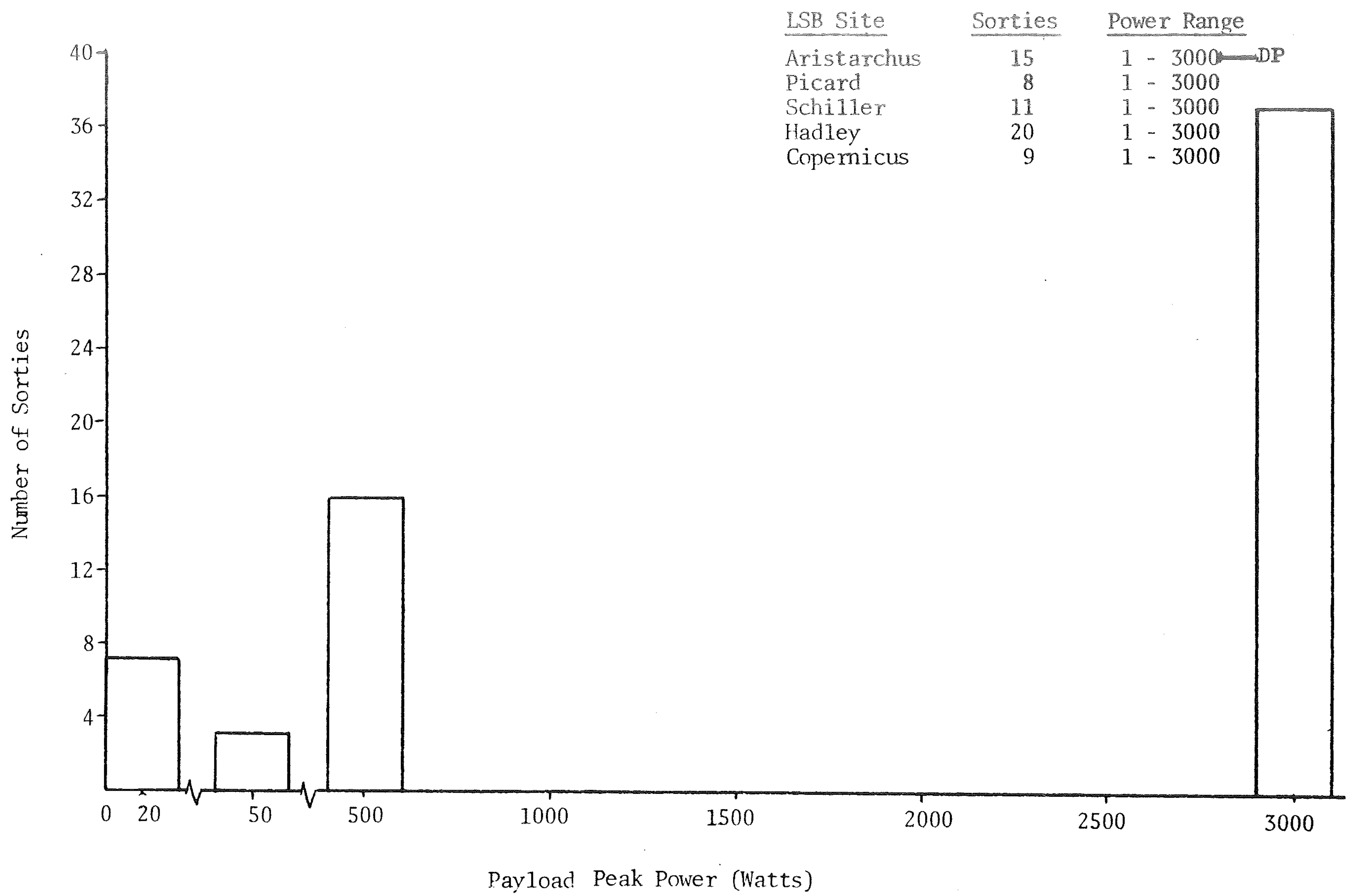


Figure E-13. Payload Peak Power (Watts) Histogram

Table E-1. LSB Site Model

Figure Number	Curve Fit Equation
E-1	$Y = 7.67 - 2.8 \times 10^{-3}X - 2.7 \times 10^{-5}X^2 + 2.0 \times 10^{-8}X^3$
E-2	$Y = 2.34 + .45X - 7.8 \times 10^{-3}X^2 + 3.5 \times 10^{-5}X^3$
E-3	$Y = 9.04 + .044X - 3.2 \times 10^{-4}X^2$
E-4	$Y = 19.33 - .078X + 8.1 \times 10^{-5}X^2$
E-5	$Y = 21.33 - .097X + 1.2 \times 10^{-4}X^2$
E-6	$Y = 8.85 - .024X + 2.2 \times 10^{-5}X^2 - 1 \times 10^{-8}X^3$
E-7	$Y = 68.85 - 6.30X + .25X^2 - 4.9 \times 10^{-3}X^3 + 4.7 \times 10^{-4}X^4 - 1.8 \times 10^{-7}X^5$
E-8	$Y = 40.66 - 2.23X + .061X^2 - 8.6 \times 10^{-3}X^3 + 5.8 \times 10^{-6}X^4 -1.0 \times 10^{-8}X^5$
E-9	$Y = 6.04 + .012X - 2.4 \times 10^{-5}X^2 + 1 \times 10^{-8}X^3$
E-10	$Y = 7.40 + .118X - .001X^2 + 1.9 \times 10^{-6}X^3$

Table E-2. Normalized Model

Figure Number	Curve Fit Equation
E-1	$Y/Y_o = .986 - .306\ X/X_o - 2.36\ (X/X_o)^2 + 1.75\ (X/X_o)^3$
E-2	$Y/Y_o = -.252 + 4.49\ X/X_o - 7.2\ (X/X_o)^2 + 3.02\ (X/X_o)^3$
E-3	$Y/Y_o = .636 + .71\ X/X_o - 1.21\ (X/X_o)^2$
E-4	$Y/Y_o = 1.07 - 1.85\ X/X_o + .82\ (X/X_o)^2$
E-5	$Y/Y_o = 1.12 - 2.17\ X/X_o + 1.09\ (X/X_o)^2$
E-6	$Y/Y_o = 1.19 - 2.82\ X/X_o + 2.24\ (X/X_o)^2 - .538\ (X/X_o)^3$
E-7	$Y/Y_o = 1.60 - 10.99\ X/X_o + 32.4\ (X/X_o)^2 - 48.09(X/X_o)^3 + 34.92(X/X_o)^4 - 9.82\ (X/X_o)^5$
E-8	$Y/Y_o = 1.31 - 9.01\ X/X_o + 30.96(X/X_o)^2 - 54.45\ (X/X_o)^3 + 45.71\ (X/X_o)^4 - 14.49\ (X/X_o)^5$
E-9	$Y/Y_o = .442 + 1.22\ X/X_o - 3.40\ (X/X_o)^2 + 1.77\ (X/X_o)^3$
E-10	$Y/Y_o = .520 + 2.57\ X/X_o - 7.06(X/X_o)^2 + 4.01\ (X/X_o)^3$

Table E-3. Normalizing Values

Figure No.	Y_o	X_o
E-1	9	825
E-2	13	92.5
E-3	18	230
E-4	18	425
E-5	19	425
E-6	8	875
E-7	43	75.0
E-8	31	125
E-9	25	1400
E-10	18	310

Figures E-14 through E-18 present the remote sortie timelines for all exploration missions originating from the five LSB sites analyzed. These timelines were formulated to determine the mission durations of Histogram E-2, the starting time for each mission in order to arrive at the experiment site by sunrise, the amount of night driving time, and the effectiveness of the mission planning of equi-duration missions. Total mission durations including corrections for enroute maintenance and repair and shelter turnaround time were based on these timelines.

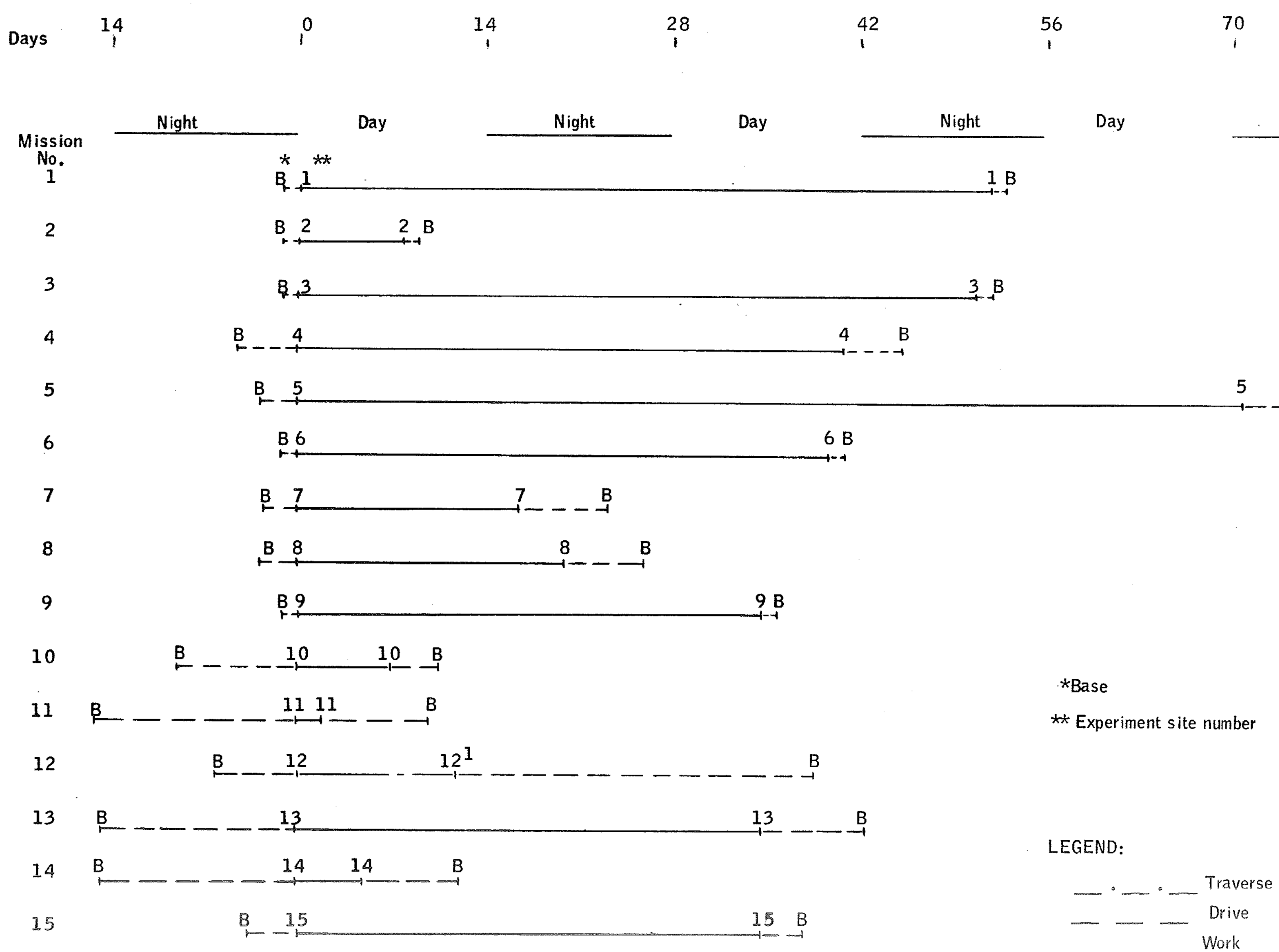


Figure E-14. Remote Sortie Timelines - Aristarchus

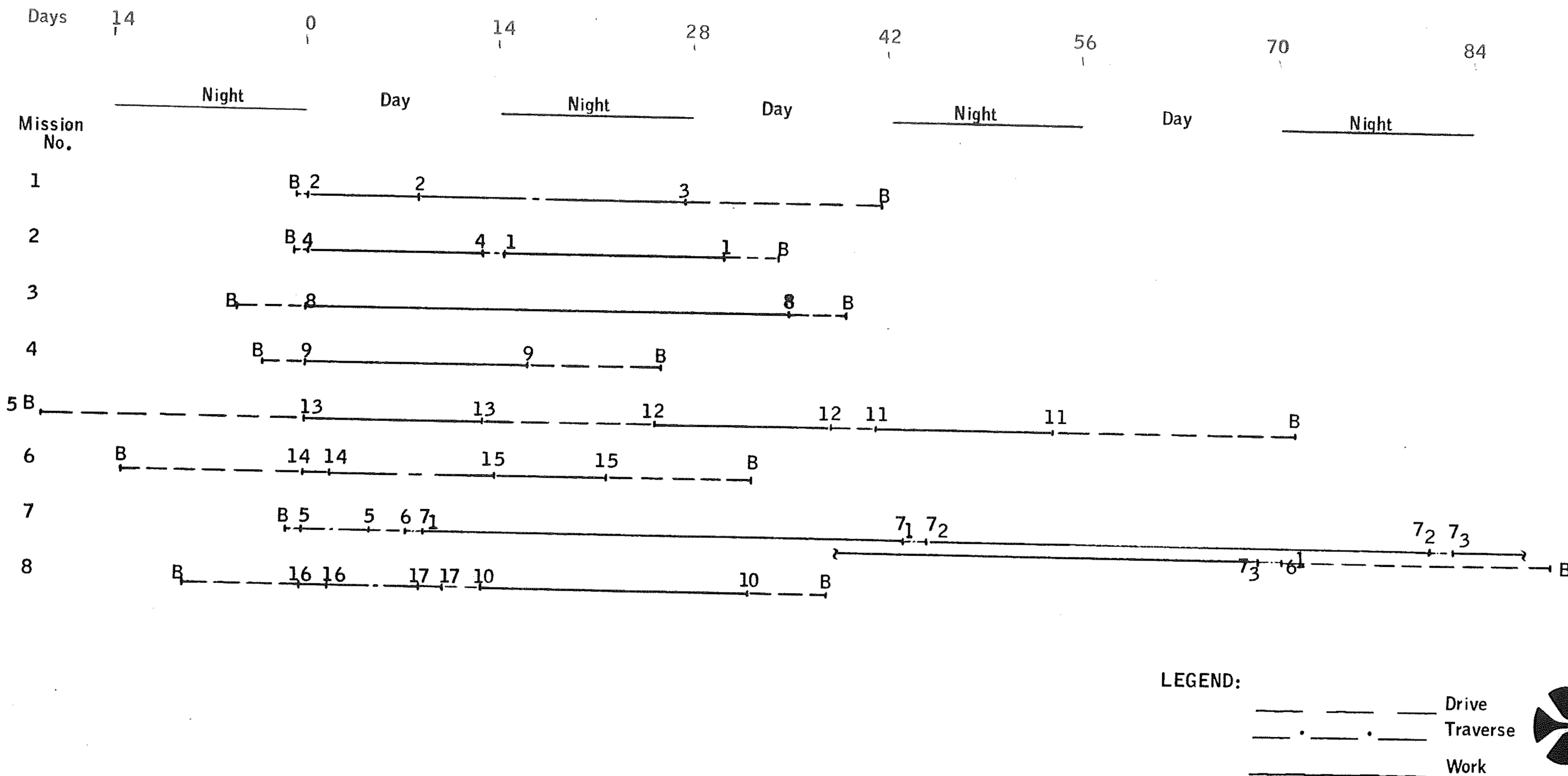


Figure E-15. Remote Sortie Timelines - Picard

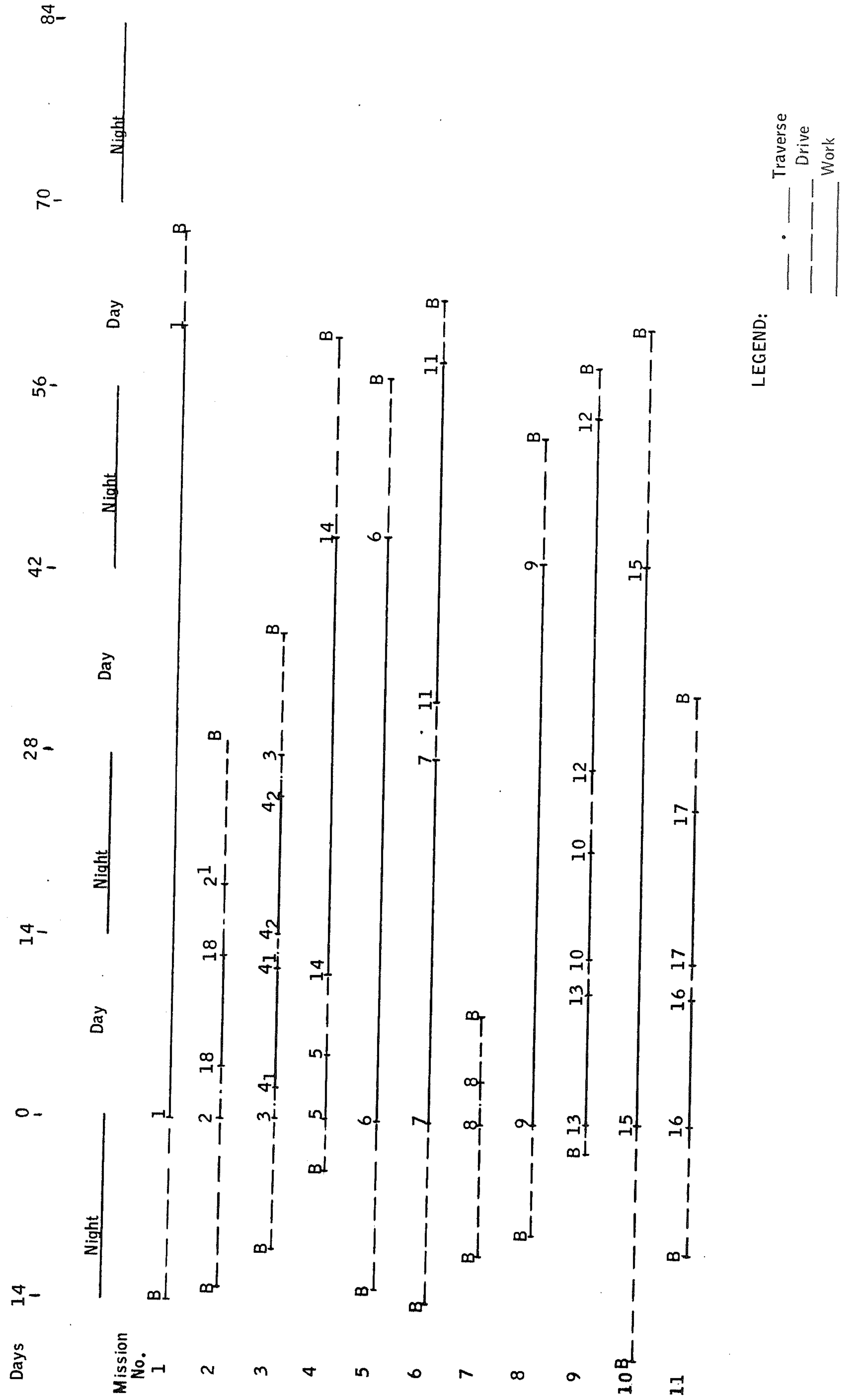


Figure E-16. Remote Sortie Timelines - Schiller

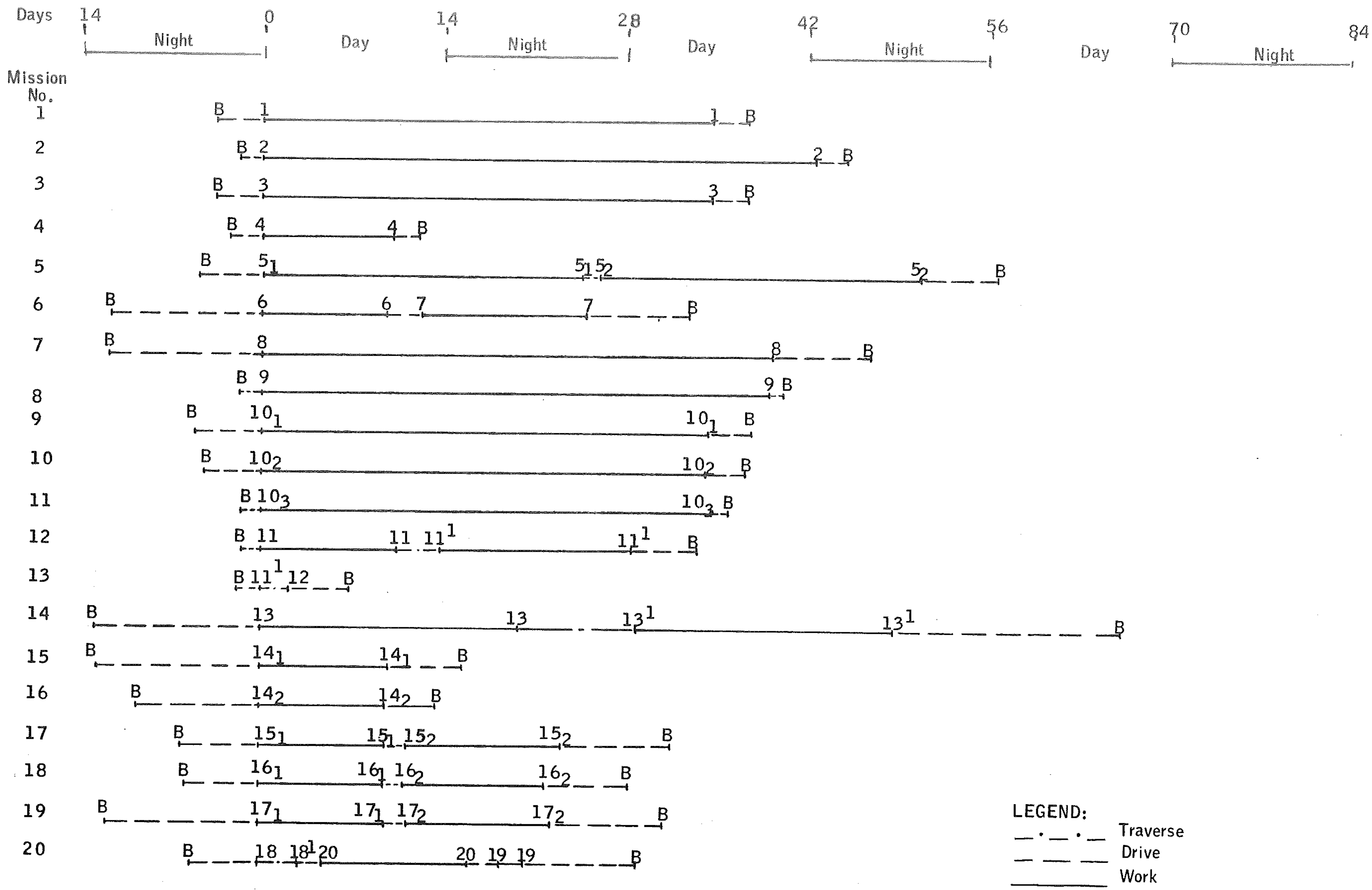


Figure E-17. Remote Sortie Timelines - Hadley

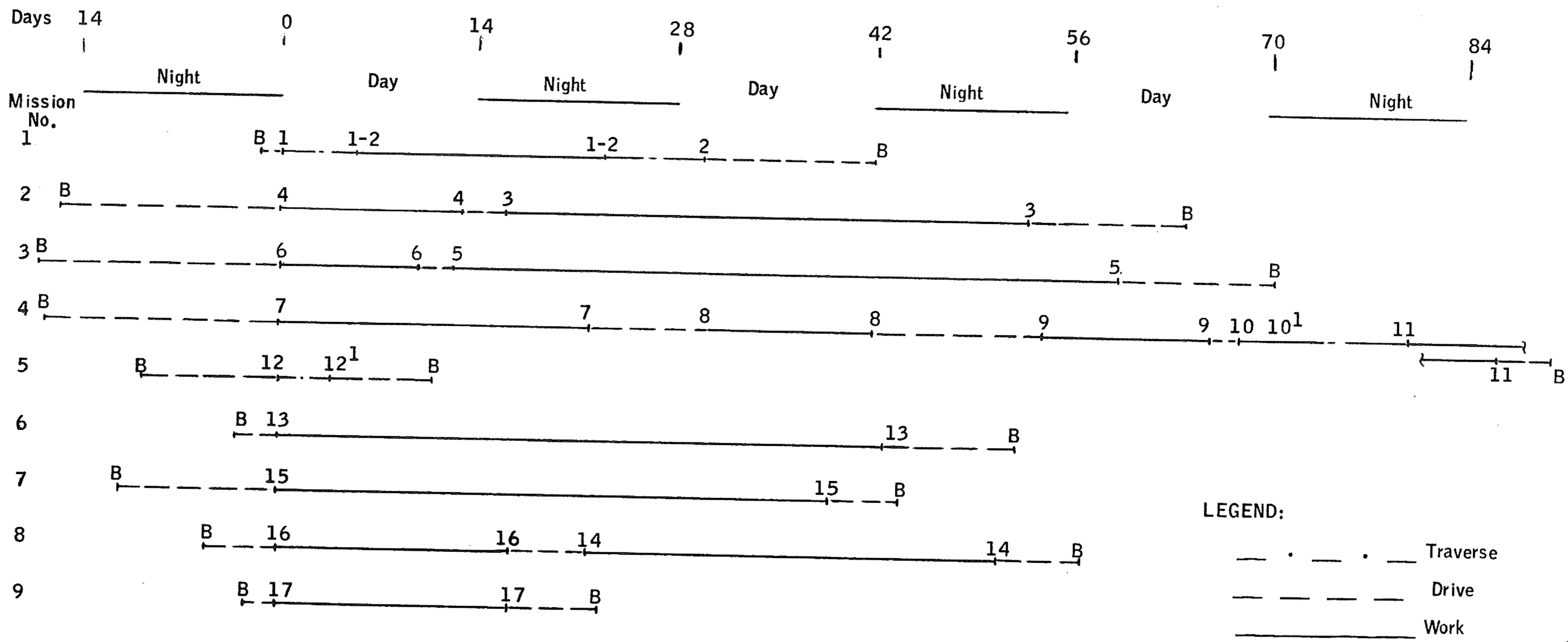


Figure E-18. Remote Sortie Timelines - Copernicus

APPENDIX F. EXPERIMENT MANPOWER ALLOCATIONS

Enclosed are the worksheets by discipline with the EVA and IVA hours by experiment from which all manpower estimates have been made. A chart showing buildup times for the astronomical observatory and radio telescope networks is also included.

Table F-1. Experiments Manpower Requirements - Summary

Experiment Number	First Year					Second Year			
Astronomy	Total Time		Monthly Average			Total Time		Monthly Avg.	
	EVA	IVA	EVA	IVA		EVA	IVA	EVA	IVA
4012	880	720	73.0	60.0		730	720	60.1	60.
4016	1220	1465	102.0	122.0		560	730	46.6	61.
4017	184	42	15.3	3.5			42		3.5
4014	308	1008	25.6	84.0			960		80.0
4015	144	1008	12.0	84.0			1008		84.0
4021	40	392	3.3	32.7					
4022	56	75	4.7	6.2					
4023	32	9	2.6						
4024	62	75	5.2	6.2					
4025	25	15	2.1	1.2					
4026	40	180	3.3	15.0					
4027	56	1008	4.7	84.0			1008		84.0
4028	56	444	4.7	37.0			128		10.7
4029						200	550	16.7	45.8
4030	1130	2875	94.0	240.0		720	2540	60.0	211.0
Time Share 4029	200	1300	17.0	108.0		200	1300	17.0	108.0
Total	3113	6441	259.6	535.8		2100	5881	174.1	490.2
Geology - Geochemistry									
4032	260	120	21.6	10.0		260	120	21.6	10.0
4033	144 159	16	12.0 13.2	1.3	Intermed. Shallow	168 76		14.0 6.3	
4037		2000		167.0			2000		167.0
4038	50		4.2			50		4.2	
4039									
4048	556	4060	46.3	338.0					
4057	102		8.6			102		8.4	
4059	25		2.1			25		2.1	
4060 }									
4061 }		3300		275.0			3300		275.0
Total	1296	9480	108.0	791.3		681	5420	56.6	452.0
Bioscience									
4001	80	66	6.7	5.5			160		13.3
4003	100	50	8.3	4.2		100	50	8.3	4.2
4006		57		4.8		57		4.8	
4009		240		20.0			240		20.0
4011	125		10.2			125		10.2	
Total	305	413	25.2	34.5		282	450	23.3	37.5
Particles & Fields 4050	67	300	5.6	25.0		67	300	5.6	25.0
Lunar Atrmosphere									
4053	100	200	8.3	16.7					
4055	80	20	26.7	1.7					
Total	180	220	35.0	18.4					
Engineering Technology									
4064		720		210.0					
4066		510		72.5					
4071		60		5.0					
Total		1290		287.5					
4074	TBD								
4075	TBE								
4078	180	90	15.0	7.5					
4079	32	36	2.7	3.0					
4081		110		9.1					
4082		65		5.4					
4084		398		33.2					
4085		225		18.7					
4086	425		35.4						
4087	90		7.5						
Total	727	924	60.6	76.9					
Geophysics									
4045	42		3.5						
4046	250		20.8						
4047	10.5		1.0						
4051	12		1.0						
4058	26		2.2						
4088	40		3.3						
Total	380.5		31.8						
Geodesy-Cartography									
4044	32		2.7						

Table F-2. Astronomy-Manpower for Buildup and Operation

Expmt.	Buildup				Operation			
	Mode	Time-hr = days		No. Men	Mode	Time-hr/Month		No. Men
4028	EVA	56	5	2	EVA	None		
					IVA		37	1
4027	EVA	75	6	2	EVA	None		
					IVA		84	1
4016	EVA	100	8	2	EVA	94	122	1
4029	Included in 4016				EVA	17		2
					IVA		46	1
4012	EVA	160	12	2	EVA	60		2
					IVA		60	1
4015	EVA	144	11	2	EVA	None		
					IVA		84	
4014	EVA	308	24	2	EVA	None		
					IVA		84	1
4030	EVA	410	16	4	EVA	60		2
					IVA		211	1

Table F-3. Experiments Manpower Requirements

BIOSCIENCE

Expmt. No.	Equipment Number	Function	EVA Hours Total	Shirtsleeve Hours, Total	EVA Hours Maint. & Servicing	Shirtsleeve Hours Servicing	Remarks	Remote Site Cycles	Cycles at Shelter	Cycle Duration
LIFE DETECTION										
4001	11103	Equip. setup	20		1					
	11104	Sample prep.	20	16	1	0.5	Lab analysis	11/sortie	10	10 hr cyc.
	14026	Processing	40	50	2	5.0	Lab anal. exclusive of incubation			
			80	66						
	14018									
	11083									
	14017									
	90014									
	90015									
TERRESTRIAL CONTAMINATION										
4003	14018	In-situ	100		10min					
	14026	Lab analysis		50		10 min.			300/1200	20 min
	14022									
BEHAVIOR/RHYTHM										
4006	90016	Plant seeds		11		5 min.	All lab work		140/1400	25 min.
	90017	Observe		11		5 min	In conj. w/4064			
		Cut and examine		35		15 min				
				57						
REDUCED GRAVITY EFFECTS ON MAN										
4009	9002	Setup and perform	240			24	Assume 10 crewmen		6/10	crewman
VISION EFFECTS										
4011	None	Operate	125		15min				250/800	250/6 mo
4008	Flicker Vision - Deleted -									

Table F-3. Experiments Manpower Requirements

ASTRONOMY

Experiment Number	Equipment Number	Function	Total EVA Hours	Shirtsleeve Hours Total	EVA Hours Mainten. & Servicing	Shirtsleeve Hours - Servicing	Remarks	Operational Cycles	Cycle Time
X-RAY TELESCOPE									
4012	11092 11097	Installation Activation Maint. and film change Operation	120 40 720 880	720	1/day	60 cy.	Plus travel time	12/36	1 month
1.3 METER OPTICAL TELESCOPE									
4016 Time-sharing 4029	11095 11095	Installation Activation Servicing Operation Operation	90 10 720 400 200 1420	5 360 1100 550 2015	1/day	1/day	Plus travel time 750 man hours/year	1 1	1 year 1 year
2.5 METER OPTICAL TELESCOPE									
4030		Installation Activation ECLSS Activ. Telescope Servicing Operation	325 10 75 720 1130	80 100 150 360 2180 2875	1/day	1/day 6/day		1	1 year
OPTICAL EFFECTS FROM ENVIRONMENT									
4017	90004 90005 90006	Set up-align-calib. Operate Test	184	42				1/10	8-day runs
NOISE SURVEY									
4021	15013	Installation Operation Observe	40	32 360 392	20	1 hr	Observe 1 hr/day for a year	1/2	1 month
RADIO PROPAGATION									
4022	15014 15019	Installation Calibrate Operate	40 16	75	4		4 cycles (10 hr calibration) minimum for year observation	4/32	1 week
IMPEDANCE MEASUREMENTS OF ANTENNA									
4023	15015 15016 15017 30005 11091	Installation Calibrate Operate	20 12	9	10 2	3	3 hr observation/cycle	3/5	57 hours
LUNAR PLASMA EFFECTS									
4024	15018 15020	Installation Calibration Operate	2 60	75	1 1	1+	Observe 2 twice daily/1 hr	30/90	24 hours
ANTENNA DUST ACCUMULATION									
4025	11064 15020	Installation Calibration Operation	4 20	15	2 1	1+	1 hr/day	10/20	24 hours
RADIO TELESCOPE, 300 kHz									
4014	11093	Site preparation Installa.-Antenna " relay station Hardline to LSB Calibration Operation	48 236 12 12 308	48 960 1008	4 80/cy.		Based on C. Turner writeup Recalibrate each cycle 2 years	12/36	1 month
RADIO TELESCOPE 1 TO 15 mHz									
4015 Joint use of relay data processing stations	11094	Site preparation Install. - antenna Calibration Operation	24 120 144	48 960 1008	4 80/cy.		2 years	"	"
RADIO TELESCOPE (PHASE SWITCHING) 0.6 mHz									
4027	11108 and 30011	Install. - antenna " - relay stat. " - data process Hardline to base Calibration Operation	32 12 12 19 75	288 720 1008	16 6 6	24 60	@ 0.6 mi/hr for 11.4 mi of hardline 2 years	12/36	1 month
RADIO TELESCOPE (TEMPORAL VARIATIONS FROM 5 mHz									
4028	11109 and 11110	Install. - antenna " - relay station " - data process Calibration Operation	32 12 12 56	60 384 444	16 6 6	30/mo		15/45	32 hr/cycle 15 cycles/yr
CISLUNAR WAVE PROPAGATION									
4026	30008	Installation Calibration Operation	36 4	180	18 2	0.5 day	0.5 hr/day	1/2	1 year

GEOLOGY-GEOCHEMISTRY

Table F-3. Experiments Manpower Requirements (Cont'd)

Experiment Number	Equipment	Function	EVA Hours - Total	Shirtsleeve Hours - Total	EVA Hours- Maint. & Serv.	Shirtsleeve Servicing - Hours	Remarks	Remote Site Cycles	Cycles at Shelter	Total No. Cycles	Cycle Duration
SURFACE GEOLOGICAL MAPPING											
4032	11111 90018 90019 90020 14025	In-situ observations Instrument measur.	260	120	6.5	6.0	Exclusive of travel Time to site	18	6/20	38	13 hrs
SUBSURFACE DRILLING & SAMPLING											
4033	50009	Survey site	80		40						
		Prepare site	2		1						
		Transport equip.	12		6						
		Set up 3m drill	5		2.5						
		Drill	60		2		5 holes per 100 ft hole		15		
			159								
		Drill 30 m holes									
		Drill	78		13		3 holes per 1000 ft hole		3		
		Core removal	18		3						
		Raise and lower drill	12		2						
		Add and retract drill	12		2						
		Analyze core	12	16		16					
		Secure and transport	12		6						
		Transport deep drill to site	12		6						
			144	16							
			303 16								
			319				24.5 days				
PETROGRAPHIC ANALYSIS (LAB)											
4037	90008 50006	Lab analysis		2000		2	per sample Average 6 samples/day		2000		
MINERALOGIC IDENTIFICATION, IN-SITU											
4038	11086 14025 14026	Operation	50	0.5			0.5 hr/sample	15	50		
INVESTIGATE SITES OF TRANSIENT ACTIVITY											
4039	14005 12001 11088	Atmos. monitoring Outgassing sites Setup and calibrate				1.5 2	6 hrs min., not chargeable In-situ examination	6			Not used at base
DEEP DRILLING 300M HOLES											
4048	50008	Site preparation	130		65		10 days @ 6.5 hr EVA		2		1923 hr per hole 2-man crew
		Setup and C/O	130		65		includes move to 2nd site				
		Operation	1250		250		Drilling @ 4 ft/hr				
		Changing barrels	34		17		+ factor of 2.5				
		Raising and lowering	340		170						
		Maint. and repair	39		19.5		3 days maint. per hole				
			1923		586.5		90 working days per hole				
		Site preparation and drill assembly	960				37 days (4033 24.5 days)				
		Shelter erection	78		19.5		3 days		2		1581 m/hr per hole
		Operation		2000		500	50 days + factor of 2				
		Disassembly	65		32.5		5 days				
		Transport	24		12		1 day				
		Maint. at LSB		60		30	3 days				
		Transport to site					(24.5 days of pre ops, 4033)				2308 hr per hole
		Set up equipment	162		81.10		12.5 days				
		Install shelter	39		19.5		3 days				
		Drilling		2000		500	50 days + factor of 2				
		Secure and disassem.	65		32.5		5 days				
		Transport to base	12		6		1 day				
		Maint. and repair		30		30	3 days				
			278	2030			74.5 days				
IN-SITU RADIATION MONITORING											
4057	11005	Set up on site Measurement	25		0.5		I man hour per hole including setup	12	25		11 min. cycle
SUBSURFACE LOGGING											
4059	11079	Set up Operate	30		1.5			5	10		10 min/4 hr 1.5 hr avg.
MINERALOGIC LAB ANALYSIS											
4060	11096 90008 50006	Set up Operate					1 man full time for lab sample work for 4060 and 4061		2000		Continuous lab operation
INSTRUMENTAL CHEMICAL LAB ANALYSIS											
4061	14005 11086 14018	Set up Operate							2000		

EXPLOITATION

Table F-3. Experiments Manpower Requirements (Cont'd)

Experiment Number	Equipment Number	Function	Total EVA Hours	Shirtsleeve Hours Total	EVA Hours Maint. & Servicing	Shirtsleeve Hours - Servicing	Remarks	Operational Cycles	Cycle Duration
MINING/TRANSPORT EQUIPMENT									
4074	TBD						Manpower not defined		
WATER EXTRACTING PROCESSES									
4075	TBD						Manpower not defined		Continuous
LUNAR STRATA EM PROTPAGATION									
4078	90024	Site preparation Antenna placement Transmit Dismantle	120 30 30 180	90	4 1 1	6		15/20	24 hours
LUNAR SURFACE TRANSMISSION									
4079	90025	Setup Operate Dismantle	16 16 32	36	8 8	1.5	1.5 hrs/day, 24 days	5/15	28 days
HEAT TRANSFER-LIQUIDS									
4081	90026	Setup Expmt. liquid Liq. walls Dismantle		20 80 10 110	1	4 2	Lab experiment 16 hours 12 hours	5/15	40 hours
HEAT TRANSFER - FILM									
4082	90027	Setup Operate Dismantle		10 50 5 65		2 10 1	Base lab	5/15	14 hours
METALS JOINING									
4084	90028	Setup Welding Dismantle		100 198 100 398		1 6 1	3 samples/day,33 days	100/400	8 hours
DIFFERENTIAL THERMAL ANALYSIS							Utilize samples from 4038		
4085	90029	Setup Calibration Heat-cool Mech. testing		25 100 100 225		0.25 1 1	2 hours not chargeable	100/300	3 hours
CHARACTERISTICS - LUNAR ORES									
4086	90030	Sample preparation Load testing Dismantle	50 350 25 425		1 7 0.5			25/75	9 hours
LUNAR DRY CEMENT AND CONCRETE									
4087	90031	Sample prepar. Mix Application	30 15 45 90		3 1.5 4.5		1.1 mh/hr EVA buddy will take care of 0.1 hr	5/50	9 hours

ENGINEERING TECHNOLOGY

Table F-3. Experiments Manpower Requirements (Cont'd)

Expmt. Number	Equipment	Function	Shirtsleeve Hours - Total	Shirtsleeve Hours-Serv.	Remarks	Total Number of Cycles	Cycle Duration
BIOLOGICAL MONITOR AND ECOLOGY							
4064	90021	Measurements	360	1hr	daily (setup included with 4066)		1 year
		Animal and equipment care	360	1 hr	daily		
			720				
LUNAR EFFECTS ON PLANTS							
4066	9022	Setup	60		Setup time, 1 man week	200/800	1 year
		Measurements	90	30 min	/day on alternate days		
		Plant and equipment care	360	1 hr	/day on alternate days		
THIN FILM BEARINGS							
4071	90023	Setup	10	1 hr	10 setups	50/125	10 days
		Testing	20	2 hr	2 hrs/day/10 cycles/50 bearings		
		Evaluation	20	2 hr			
		Dismantle	10	1 hr			
			60				

GEOPHYSICS
(GEODESY-CARTOGRAPHY*)

Table F-3. Experiments Manpower Requirements (Cont'd)

Experiment Number	Equip. Number	Function	EVA Hours Total	Eva Hours Maint. & Servicing	Remarks	Remote Site Cycles	Cycles at Shelter	Cycle Duration
GEODETIC GRID CONSTRUCTION								
4044	11112	Setup	4.0	1.0		12	2	8 hr cycle
	11082	Marker construction	10.0	2.5				
	11081	Operation	16.0	4.0				
		Dismantle	2.0	0.5				
			32.0					
GRAVITY PROFILING								
4045	11112	Calibration	16	2.0	In conjunction with 4058	11	4/20	8.5 hr cycle
		Operate	26	6.5				
			42					
SEISMICITY ACTIVE								
4046	40005	Drill 10 ft hole	50	1.0		8	25/50	5 hrs/cycle
	11087	Setting geophones	100	2.0				
	50010	Calibration det.	50	1.0				
	50012	Equip. collection	50	1.0				
			250					
SEISMICITY PASSIVE								
4047	11088	Installation	4.5	1.5	3 sites less driving time		1	Continuous
		Calibrate	6.0	1	Automated operation			
			10.5					
MAGNETIC FIELD TEMPORAL VARIATIONS								
4051	15011	Setup	10	5				Continuous
	15008	Calibration	2	1				
	15010	Operate	12		Automated operation	-	1	
	15011							
MAGNETIC PROFILING								
4058	15021	Mounted on Rover			In conjunction with 4051	10	4/20	6.5 hours
	15022	Operate	26	6.5	Local traverse at LSB			
NEAR SURFACE TEMPERATURE GRADIENT								
4088	11116	Set up and fill	20	2		5	5/20	Continuous
	40009	Calibrate	20	2				
		Operate			Automated operation			
			40					

Table F-3. Experiments Manpower Requirements (Cont'd)

PARTICLES AND FIELDS*
LUNAR ATMOSPHERE

Expermt. No.	Equip. No.	Function	EVA Hours - Total	Shirtsleeve Hours - Total	EVA Hours - Maint. & Servicing	Shirtsleeve Hours - Servicing	Remarks	Number of Cycles	Cycle Duration
SOLAR WIND AND PARTICLE MEASUREMENTS									
4050*	14001	Setup	6		3			60/120	1 year
	14002	Calibrate	60		1				
	14020	Measurements		300		2			
	11088		1			.5			
			67	300					
TOTAL PRESSURE									
4053	12001	Set up base	40		2		Base readout 2 months	50/200	60 days
	14005	Set up away	40		2		General readout continuous		
	14019	Data analysis		200			10 setups		
		Dismantle	20			1			
			100						
ESCAPE AND TRANSPORT RATES									
4055	14029	Instru. setup	80		4			10/100	18 hours
	14032	Sample rel.					Not chargeable		
		Observe		20		2			
		Reconfigure					Continuous operation - automated		
MAGNETIC TEMPORAL VARIATIONS									
4051	15011	Setup	10		5		Continuous		1 year
	15018	Calibrate	2		1				
	15010	Operate	12				Automated data readout, 10 min. twice daily		

APPENDIX G. SURFACE MISSION TRADE STUDIES

The computational details of the trade studies conducted to select the optimum transportation concepts for conducting the remote sorties and deep drilling operations and the optimum siting concept for the observatory are presented in this section. The summary results were given earlier in Section 1.0 of Part 2.

Ten remote sortie concepts are evaluated in Tables G-1 through G-10. In each evaluation the concept is defined in terms of its significant events and their individual and total duration. The initial mass of equipment to be delivered to the experiment site is established along with the number of round trips required to complete the exploration and the mass of spares and consumables required on each trip. All requirements are based on those developed earlier for a typical LSB site. This site, for example, has an average of 17.4 experiment sites and this is what determined the number of round trips necessary in concept No. 1. The total program mass, the primary criterion for optimization, is the sum of the initial mass and the total resupply mass required to be delivered to lunar orbit in order to complete the exploration. The program duration is the product of the individual sortie duration and the number of sorties required.

While many of the absolute values of the individual task durations and weights have been obsoleted since these trades were performed, the results and conclusions remain valid because the relative differences within sortie are essentially unchanged.

Some deep drilling concepts have been studied and evaluated in a manner similar to that employed on the remote sorties. The operational concept, the initial and resupply mass in lunar orbit, the total program mass and duration for each of these concepts is given in Tables G-11 through G-17.

The observatory - LSB-OLS combinations are similarly analyzed in Tables G-18 through G-22.

Table G-1.

SORTIE CONCEPT DESCRIPTION 1.0, OLS-TUG SORTIE, NO LSB AVAILABLE

Operational Concept

(a) Tug sortie concept is assembled at OLS (14-day turnaround)
(b) T-S is dispatched from OLS to each locale with crew and all equipment required (1 day)
(c) Explore locale and live in Tug CM (16 days)
(d) Return to OLS after explorations of locale (1 day)
(e) Repeat (a) through (d) for 17 locales.

(32 days/sortie)

Initial Mass (Delivered and Returned Mass) 17 RT's

Tug	21,600	
Mtg. Struc.	1,200	
Science Equip.	1,850	
Mobility	6,900	
Power	3,00	34.6 klb

Resupply Requirement

Tug Fuel	55,000	
Crew Consum.	1,094	
Mobility Spares	350	
Science Spares	151	
	56.6 klb x 17 =	962.2 klb

Min. Program Mass 996.8 klb

Min. Program Duration 32 x 17 = 544 days

Table G-2.

SORTIE CONCEPT DESCRIPTION 2.0, OLS - TUG SORTIE GROUPED LOCALES, NO LSB

Operational Concept

(a) Tug sortie concept assembled at OLS (with mobile shelter)
(b) T-S is dispatched from OLS to locale grouping (1 day)
(c) Explore locale grouping, tug quiescent, live in mobile shelter (3 locales at 16 days each + 3 driving = 51 days)
(d) Return to OLS after each locale group (1 day)
(e) Repeat (a) through (d) for six groups (14-day turnaround)

(65 days/sortie)

Initial Mass (Delivered and Returned to OLS)

Prog. Tug	21,600	
Science Equip.	1,850	
Mobility	6,900	
Power Trailer	3,150	
Mobile Shelter	5,800	
Mtg. Struc.	1,200	40.5 klb

Resupply Requirement

Tug Fuel	70,000	
Crew Consumables	3,131	
Mobility Spares	600	
Science Spares	208	
	73,938 x 6 =	443.6 klb

Program Mass 484.1 klb

Min. Program Duration, 65 x 6 = 390 days

Table G-3.
SORTIE CONCEPT DESCRIPTION 3.0, OLS & LSB, SURFACE RESUPPLY, CREW BY TUG, LIVE IN TUG

Operations

(a)	Tug delivers mobility to LSB	
(b)	Mobility dispatched, unmanned to locale	(6 days)
(c)	Crew dispatched to locale by second tug landing	(1 day)
(d)	Explore one locale only, live in tug	(16 days)
(e)	Crew and science return to OLS via tug	(1 day)
(f)	Mobility dispatched unmanned to next locale	(6 days)
(g)	Repeat (c) through (f) for 17 locales	
		(22-day/sortie)

Initial Mass

Program Tug	21,600	
Mobility & Power	12,923	
Fuel to Land Mobility	35,000	
Science Equipment	1,800	71.4 klb

Resupply Requirement (17 times)

Tug Fuel	35,000	
Mobility Spares	350	
Crew Consumables	1,094	
Science Consumables	151	
	36,6 klb x 17 =	622.2
		693.6 klb

Min. Program Duration (22 x 17) = 374 days

Table G-4.

SORTIE CONCEPT DESCRIPTION 4.0, OLS & LSB SURFACE RESUPPLY, CREW BY TUG, USE MOBILE SHELTER

Operations

(a)	Tug delivers mobility, power and shelter to LSB	
(b)	Vehicle train dispatched unmanned to first locale group, travels continuously at low speed.	(6 days)
(c)	Crew dispatched by tug to locale group	(1 day)
(d)	Locale grouping explored, crew lives in mobile shelter, tug is quiescent (3 locales @ 16 days each + 3 driving).	(51 days)
(e)	Mobility dispatched to next locale group	(6 days)
(f)	Crew returns to OLS for rotation	(1 day)
(g)	Repeat (c) through (f) for six locale groupings	
		(63 days/ sortie)

Initial Mass Required

Program Tug	21,600	
Mobility Shelter and Power	18,719	
Fuel to Land Mobility	40,000	
Science Equip.	1,850	82.3 klb

Resupply Required (6 times)

Tug Fuel	35,000	
Mobility Spares	720	
Crew Consumables	3,040	
Sci. Consumables	308	
	38,968 x 6 =	233.8 klb
Program Mass		316.1 klb

Program Duration 63 x 6 = 378 days

Table G-5.

SORTIE CONCEPT DESCRIPTION 5.0, LSB TO INDIVIDUAL LOCALES OVERLAND, LSB AVAILABLE

Operational Concept

(a)	Ship sortie convoy to LSB	
(b)	Make up sortie convoy at LSB	
(c)	Dispatch convoy over lurain to locale	6 days
(d)	Set up camp and explore locale	16 days
(e)	Return over lurain to LSB	6 days
(f)	Debrief, repair vehicles, rotate crew and vehicles	14 days
(g)	Repeat steps (c) through (f) for 17 sorties	
		42 days/sorties

Initial Mass

2 Prime Movers	6,880		
Power Trailer	3,170		
Supply Trailer	1,200		
Program Science	1,850		
Deployable Shelter	2,700	15.8 klb	
Tug Fuel		25 klb	40.8 klb

Resupply Requirement (17 times)

For systems and personnel	2,562	
Sci. Consumables	151	
Vehicle Spares	341	
	3,054 x 17 =	51.9 klb
	Tug Fuel	52.1
	Program Mass	144.8 klb

Program Duration

42 days/sortie x 17 sorties = 714 days
Preparation Time = 30 days
744 days

Table G-6.

SORTIE CONCEPT DESCRIPTION 6.0, LSB TO GROUPED LOCALES OVER LURAIN, LSB AVAILABLE

Operational Concept

(a)	Ship surface convoy to LSB	
(b)	Assemble surface convoy at LSB	1 day
(c)	Dispatch expeditions to first locale group	6 days
(d)	Set up camp and explore first locale	16 days
(e)	Break camp and travel over lurain to 2nd locale	1 day
(f)	Set up camp and explore second locale	16 days
(g)	Break camp and travel over lurain to 3rd locale	1 day
(h)	Set up camp and explore third locale	16 days
(i)	Return over lurain to LSB	6 days
(j)	Debrief, repair and exchange vehicles, rotate crew	14 days
		77 days/sortie
(h)	Repeat steps (b) through (j) for six sorties	

Initial Mass (Delivered to LSB)

2 Prime Movers	6,880		
Supply Trailer	1,200		
Power Trailer	3,170		
Program Science	1,850		
Mobile Shelter	5,796	18,896	
Tug Fuel		28,000	46.9 klb

Resupply Requirement (6 times)

Systems & Personnel Consumables		3,843
Science Consumables		215
Vehicle Spares		700
		4,758 x 6 = 28,548
Tug Fuel	35,000	63,548
Program Mass	110,444 pounds	

Min. Program Duration = 77 x 6 = 462 days
Buildup = 30
492 days

Table G-7.

SORTIE CONCEPT DESCRIPTION 7.0, SYSTEMS & SUPPLIES BY UNMANNED SURFACE VEHICLE, PERSONNEL BY FLYER, LSB AVAILABLE

Operational Concept

(a)	Ship surface vehicles, flyer, personnel and fuel to LSB	
(b)	Make up unmanned sortie convoy at LSB	
(c)	Dispatch sortie convoy over lurain to first locale (nearly continuous travel at low speed)	6 days
(d)	Fly personnel to first locale	1 day
(e)	Explore locale	16 days
(f)	Drive to second locale	1 day
(g)	Explore locale	16 days
(h)	Drive to third locale	1 day
(i)	Explore locale	16 days
(j)	Drive to flyer site and prepare convoy for return	1 day
(k)	1. Dispatch sortie convoy to LSB (6 days) 2. Fly personnel to LSB (1 day)	1 day
(l)	Debrief, repair vehicles, rotate crew and surface veh.	14 days
(m)	Repeat steps (b) through (l) for six sorties	67 days/ sortie

Initial Mass (Delivered to LSB)

2 Prime Movers	6,880		
Supply Trailer	1,200		
Power Trailer	3,170		
Program Science	1,850		
Mobile Shelter	5,800		
Flyer (4 men)	840	19.7 klb	
Tug Fuel		29 klb	48.7 klb

Resupply Requirements (6 times)

Systems and Personnel Consum.	4,087	
Sci. Consumables	215	
Surf. Veh. Spares	700	
Flyer Spares	80	
Flyer Fuel	3,800	
	8,882 x 6	53,292
Tug Fuel		55,000
		108,292

Program Mass = 156,992 pounds

Min. Program Duration 67 x 6 = 402 days

Table G-8.

SORTIE CONCEPT DESCRIPTION 8.0, SURFACE TO SURFACE TUG SORTIE, LSB AVAILABLE

Operational Concept

(a)	Ship vehicles, personnel and fuel to LSB	
(b)	Assemble tug sortie at LSB	1 day
(c)	Fly to locale grouping and set up camp	1 day
(d)	Explore first locale	16 days
(e)	Drive to second locale	1 day
(f)	Explore second locale	16 days
(g)	Drive to third locale	1 day
(h)	Explore third locale	16 days
(i)	Return to tug and load on vehicles	2 days
(j)	Fly to LSB, debrief, rotate crew and turnaround	15 days
(k)	Repeat (b) through (j) for six sortie groups	68 days/sortie

Initial Mass Required (Delivered to LSB)

2 Prime Movers	6,880	
Supply Trailer	1,200	
Power Trailer	3,170	
Program Science	1,850	
Mobile Shelter	5,796	
Program Tug	21,600	
	40,500	
Tug Fuel	28,000	
		68.5 klb

Resupply Requirements (6 times)

Systems & Personnel Consumables	4,148	
Sci. Consumables	215	
Surf. Veh. Spares	550	
Tug Spares	148	
Tug Fuel	33,000	
	38,061 x 6 =	228.4 klb
	Tug Fuel	230.0 klb
Program Mass		527 klb

Min. Program Duration 68 x 6 = 408 days

Table G-9.

SORTIE CONCEPT DESCRIPTION 9.0, AUTONOMOUS MOBILE BASE, TUG RESUPPLY DIRECT, NO LSB REQUIRED

Operational Concept

(a)	Assemble mobile base on tug in earth or lunar orbit	
(b)	Ship base by tug to first locale	
(c)	Deploy and assemble mobile base constituents	
(d)	Explore locale	16 days
(e)	Drive to next locale	1 day
(f)	Explore locale	16 days
(g)	Drive to next locale	1 day
(h)	Explore locale	16 days
(i)	Meet resupply tug, perform repairs, rotate crew, transfer cargo to mobile base	14 days
(j)	Travel to next locale group	6 days
(k)	Repeat steps (d) through (j) for six cycles	70 days

Initial Mass to Lunar Orbit

Mobile Base	44 klb		
Program Science	1.9		
Program Tug	20.6	66.5 klb	
Tug Fuel		46.5 klb	113.0 klb

Resupply Requirement (6 times)

Systems & Personnel Consumables	4,331
Science Consumables	3,790
Vehicle Spares	1,650
	9,771
Tug Fuel	38,000
	47,771 x 6 = 286,626 pounds

Program Mass 400 klb

Min. Program Duration = 70 x 6 = 420 days
Buildup = 30
450 days

Table G-10.

SORTIE CONCEPT DESCRIPTION 10.0, AUTONOMOUS MOBILE BASE, RESUPPLIED BY OVERLURAIN LRV, LSB REQUIRED

Operational Concept

(a)	Mobile base delivered by tug to first locale	
(b)	Deploy and assemble base constituents	
(c)	Explore locale	16 days
(d)	Drive to next locale	1 day
(e)	Explore locale	16 days
(f)	Drive to next locale	1 day
(g)	Explore locale	16 days
(h)	Meet overlurain resupply convoy, perform repairs, exchange crew, exchange mobility units	2 days
(i)	Travel to next locale grouping	6 days
		58 days
(j)	Repeat (c) through (i) for six groupings	

Initial Mass (In Lunar Orbit)

Mobile base concept	44 klb		
Program Science Equip.	1.9 klb		
		46 klb	
Tug Fuel		46.5 klb	
			92.5 klb

Resupply Requirements

Systems & Personnel Consum.	3,538
Science Consumables	
- Lab	2,970
- Field	215
Vehicle Spares	1,350
Sortie Resupply =	8,073

Logistic Sortie Requirements

Systems & Pers. Consumables (14 day RT)	854
Vehicle Spares	170
	1024

Total Resupply, 9.1 klb x 6 =

	54.6 klb
Tug Fuel	55.4 klb

Program Mass = 202.5 klb

Program Duration = 58 x 6 = 348 + 12 = 360 days

Table G-11.

DEEP DRILL MISSION CONCEPT DESCRIPTION 1.0, OLS-TUG SHELTER, EVA DRILLING OPERATIONS

Operational Concept		Time (Days)
(a)	Mission assembled at OLS	3
(b)	Mission systems and personnel dispatched by tug to site	1
(c)	Drill location and assembled on first location	31
(d)	Drilling operations conducted EVA, crew lives in tug	72*
(e)	Drill disassembled and overhaul	8
(f)	Tug and crew rotation with resupply at 60-day intervals	
(g)	Drill relocation, identification and assembly	31
(h)	Drilling operations, second hold	72*
(i)	Disassembly, stow and return crew to OLS	NA
		218
	*Contingency for EVA drilling operations, factor of 2.5	213
		431
	7 tug and crew rotation and resupply @ 60-day intervals @ 2 days	14
	Program Duration	447 -

Initial System Mass Requirement (In Lunar Orbit)

Program Tug	20,600		
Deep Drill	4,022		
Prime Mover	3,440		
Power Trailer	3,170	31,232	
Tug Fuel** (Based on 14.8 klb)		56,000	87.2 klb

Consumables Requirement for 60-Day Cycle

Vehicle Stores	354	
Crew & Systems (3 men)	1,360	
Drill Spares	214	
Bit Replacements	181	
EPS Cryogens (Tug)	2,340	
Lab	100	
	4.5	1st 4.5 klb
Tug Fuel	36.	
	40.5 x 6 =	243. klb

Program Mass = 335 klb

Program Duration = 447 days

**Includes delivery of first consumables load

Table G-12.

DEEP DRILL MISSION CONCEPT DESCRIPTION 2.0, OLS - DEPLOYED SHELTER AND EVA DRILLING OPERATIONS

Operational Concept	Time (Days)
(a) through (i) same as 1.0 except add	431
(c') Deploy shelter	1
2 tug and crew rotations @ 140-day intervals	4
Program Duration	436

Initial Mass Requirement

Deep Drill	4022		
Prime Mover	3440		
2 Power Trailers	6340		
Shelter	4830	18.6 klb	
Tug Fuel		55.0 klb	73.6 klb

Consumables Requirement/140-Day Cycle

Vehicle Spares	400		
Crew & Systems	5250		
Drill Pts.	640		
Bit Spares	550		
Lab Supplies	300		
2 cycles @	7140	1st	7.1 klb
Tug Fuel	36 K ea.		
2 Resupply Missions	43.1 =		82.6 klb
Program Mass			166.9 klb

Table G-13.

DEEP DRILL MISSION CONCEPT DESCRIPTION 3.0, OLS - INTEGRATED SHELTER, IVA DRILLING OPERATIONS

Operational Concept	Time (Days)
(a) Mission assembled at OLS	3
(b) Mission system and personnel delivered to site	1
(c) Drill location and assembly on first location	31
(d) Deploy personnel shelter and camp facilities	2
(e) Drilling operations (IVA)	50*
(f) Drill disassembly and overhaul	8
(g) Drill relocation identification and assembly	31
(h) Camp redeployment	2
(i) Drilling operations (IVA)	50*
(j) Disassembly, stow and return to OLS	NA
	178
*Contingency Factor for IVA Drilling Ops = ~2.0	100
	=====
Program Duration	278
1 Resupply @ 140 days	2
	280

Initial Systems Mass				
Prime Mover	3440			
2 Power Trailers	6340			
Deep Drill	4022			
Personnel Shelter	4830			
Drill Shelter (Tent)	750			
Tunnel/Airlock	470	19.9 klb		
Tug Fuel		45 klb		65 klb

Consumables Requirements (140-Day Cycle)				
Vehicle Spares	400			
Crew & Systems	5250			
Drill Pts.	640			
Bit Spares	550			
Lab. Supplies	300	7.1 klb		1st = 7.1 klb
Tug Fuel		36 klb	43.1 klb	
One required				43 klb
Program Mass				115 klb

Table G-14.

DEEP DRILL MISSION CONCEPT DESCRIPTION 4.0, LSB - LOCAL EVA DRILLING OPERATIONS

Operational Concept		Time (Days)
(a)	Ship mission systems to LSB	NA
(b)	Drill location and assembly on first location	31
(c)	EVA drilling operations on first location (Live @ LSB)	72*
(d)	Drill disassembly and overhaul	8
(e)	Drill relocation identification and assembly	31
(f)	EVA drilling operations on second location	72*
(g)	Disassemble, stow drill system	NA
		214
	*Contingency Factor for EVA drilling ~ 2.5	213
	Program Duration	427

Initial Systems Mass

Deep Drill	4022		
Power Trailer	3170	7.2 klb	
Tug Fuel**		36 klb	43.2 klb

**Based on manned delivery

Consumables Requirement (140-Day Cycle)

Crew and Systems	5250			
Drill Pts.	640			
Drill Bits	550			
Lab Supplies	300	6740	1st =	6.7 klb
Tug Fuel**		35,260	42 klb ea.	
2 Resupplies @ 42 klb	=			84 klb
Program Mass	=			133.9 klb

Table G-15.

DEEP DRILL MISSION CONCEPT DESCRIPTION 5.0, LSB - EVA DRILLING WITH ONE HOUR OF TRAVEL FROM LSB

Operational Concept		Time (Days)
(a)	Ship mission system to LSB	NA
(b)	Exploration, drill location and assembly	37
(c)	EVA drill operation on first location	86*
(d)	Drill disassembly, transport to LSB and overhaul	10
(e)	Drill relocation identification and assembly	37
(f)	EVA drilling operations on second location	86*
(g)	Drill disassembly, transport to LSB and stow	NA
		256
	*EVA drilling contingency factor ~ 2.5	213
	Program Duration	469

Initial Systems Mass

Deep Drill	4022			
Power Trailer	3170			
Prime Mover	3440	10.6 klb		
First Tug Fuel		43.4 klb		54 klb

Consumables Requirement @ 160-Day Cycles

Crew & Systems	6000			
Drill Spares	640			
Drill Bits	550			
Vehicle Spares	420			
Lab Supplies	300	7.9 klb	First	7.9 klb
Tug Fuel		37.1 klb	45 klb ea.	90 klb
2 Resupplies @ 35K				
				152 klb

Table G-16.
DEEP DRILL CONCEPT DESCRIPTION 6.0, LSB - INTEGRATED DRILLING SHELTER
(IVA DRILLING)

Operational Concept		Time (Days)
(a)	Ship mission systems to LSB	NA
(b)	Exploration, drill locations and assembly	31
(c)	Drill shelter and tunnel erection and activation	2
(d)	IVA drilling operations on first location	50*
(e)	Drill disassembly and overhaul	8
(f)	Drill relocation survey, and reassembly	31
(g)	Drill shelter relocation	3
(h)	IVA drilling operation on second site	50*
(i)	Drill disassembly and stow	NA
		175
	*Contingency factor for IVA drilling ops ~ 2.0	100
	Program Duration	275

Initial Systems Mass

Power Trailer	3170		
Deep Drill	4022		
Drill Shelter	750		
Tunnel	470	8.4 klb	
Tug Fuel		42.6 klb	51 klb

Consumables Requirements (138-Day Cycle)

Crew and Systems	5180		
Drill Parts	620		
Spare Bits	550		
Lab Supplies	300	6.65 klb	First 6.7 klb
Tug Fuel (1 flight)		35.35 klb	42.0 klb
			99.7 klb

Table G-17.

DEEP DRILL MISSION CONCEPT DESCRIPTION 7.0, LSB & DRILLING OUTPOST

Operational Concept		Time (Days)
(a)	Ship mission systems to LSB	
(b)	Exploration, drill location and assembly	37
(c)	Outpost and drill shelter erection	3
(d)	IVA drilling operations on first location	50*
(e)	Outpost disassembly and return to LSB	5
(f)	Drill overhaul	3
(g)	Drill relocation survey and reassembly	37
(h)	Outpost and drill shelter erection	3
(i)	IVA drilling operations on second location	50*
(j)	Outpost disassembly and return to LSB	NA
		188
	*Contingency factor for IVA drilling ~2.0	100
	Min. Program Duration	288

Initial Systems Mass

Prime Mover	3440		
2 Power Trailers	6340		
Deep Drill	4020		
Drill Shelter	750		
Tunnel	470		
Mobile Shelter	5800	20.8 klb	
Tug Fuel		52.2 klb	73 klb

Consumables Requirement (140-Day Cycle)

Vehicle Spares	400		
Crew & System	5550		
Drill Spares	640		
Spare Bits	550		
Lab Supplies	300		
	7440	First	7.4 klb
Tug Fuel	38060		
	45,500		
One Resupply			45.5 klb
			125.9 klb

Table G-18. Astronomical Observatory Mission Concept Description, Autonomous Central Observatory, with or without OLS, Near or Farside

Operational Concept	Time (Days*)
a) Ship telescope set and base constituents to preselected site (4 man).	NA
b) Deploy base housing elements & unload Tug	11
c) Perform site selection survey	16
d) Install 5 to 500 MHz telescope	
e) Install 0.6 to 1.2 MHz telescope	38
f) Install 300KHz to 1 MHz telescope	
g) Install 1 Meter X-ray telescope	
h) Install 1.3 Meter Optical telescope	
i) Install 3.0 Meter optical telescope	39
j) Complete Communications* & Power Net	3
Minimum Installation Time	107 days
k) Perform Observatory Operations (4 men)	
l) Perform resupply operations @ 180 days	
m) Perform housekeeping operations	

*For the farside case without the OLS, add surface link deployment.

Table G-19. Observatory Installation Factors

Initial Systems Mass		
Telescope Sets		
5-500 MHz Radio	0.1 K	
0.6 to 1.2 MHz Radio	0.4 K	
1 to 15 MHz Radio	0.4 K	
300 K to 1 MHz Radio	1.5 K	
X-Ray	3.6 K	
1.3 Meter Optical	11.1	
2.5 Meter Optical	49.6 K	66.7
Additional Mass for Autonomous Observatory**		
4 Man Base & Lab	20.1 K	
2 Prime Movers	7.8 K	
Equipment Trailer	1.0 K	
Mobile Power Source	3.2 K	
Mobility Attachment	0.2 K	32.3 K#
Consumable Requirement (180 day cycle)		
Vehicle spares	0.3*	
Personnel & Systems Cons.	9.0	
Lab Supplies, Photo	0.1	
Astro System Spares	1.7	
Astro Consumables	1.1	12.2K#

*Local use only

Tug Fuel (2/4 Men) 56K#

**For farside add 1K# for comm. link

Table G-20. Astronomical Observatory Mission Concept Description Integrated with LSB (Frontside or Farside, with or without an OLS)

Operational Concept	Time (days)
a) Ship telescope sets to LSB	N/A
b) Perform site survey & selection	16
c) Unload telescope sets & deploy to sites	6
d) Install radio telescope sets (3)	38
e) Install optical telescope sets (1.3 & 2.5 meter)	39
f) Deploy communications & power net (local)	3
Minimum Installation Time	102 days

Note: Housing & resupply services provided by the LSB.

Table G-21. Astronautical Observatory Mission Concept Descriptions Separate Facilities on Limb, Part with LSB on Frontside, Part at Backside Outpost

Operational Concept	Time * (Days)
a) Ship radio & X-ray telsecope to LSB	NA
b) Perform local site survey & site selection	9
c) Install X-ray telescope & activate (4012)	11
d) Install 0.6 to 1.2 MHz telescope (4027)	6
e) Install 1 to 15 MHz telescope (4015)	12
f) Install 300K to 1 MHz telescope (4014)	20
g) Travel to farside, Astro location, deploy comm. net & meet Tug	18.0
h) Deploy Astro outpost shelter complex	7.0
i) Perform remote site survey & selection	8.0
j) Unload telescope sets & move to sites	6.0
k) Install 5 MHz to 500 MHz telescope (4028)	4
l) Install 1.3M optical scope	8
m) Install 2.5M optical scope	32
Total Deployment Time	141 days
n) Perform Observatory operations	
o) Perform resupply operation @ 3 mo. intervals	36 days/RT

*4 Men

Table G-22. Extended Communications Link Deployment, Farside to Nearside, without OLS or to Augment OLS Support

Operational Concept	Time (days)
a) Ship mobility systems to Astro site	
b) Make up communications sortie at Astro base	1
c) Travel over lurain to 1st relay site*	
d) Deploy VHF communications relay ($2\frac{1}{2}$ hrs ea)	20
e) Repeat c & d for the required number of cycles to achieve over 300 miles of relay	
f) Set up Astro base to MSFN comm. antenna, power, system & shelter	1
g) Return to Astro base	18
	40 days

Support System Requirements**

2 Prime Movers	6880**		
Power Trailer	3170**		
Supply Trailer	1200**		
Mobile Shelter	5800	Total =	17K lbs

Consumables Requirements for Link Deployment (1 300 mi R/T at 6 mo intervals)

Personnel & Systems	1500		
Vehicle Spares	700		
Communication System	300		
	2500 lbs	Total =	2.5K lbs

Consumables Requirements for Two Independent Sites

2 Three-man Crews	5200		
2 Vehicles Spares	1400		
	6600 lbs	Total =	9.1K lbs

*Distance based on average height of 3200 ft ea point
**May be part of LSB