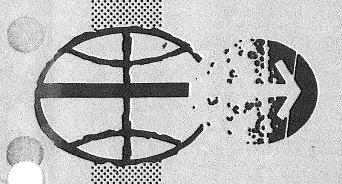NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LUNAR SURFACE EVA
PLANNING GUIDELINES

APOLLO J-MISSIONS

NOVEMBER 25, 1970

APOLLO SPACECRAFT PROGRAM OFFICE
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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LUNAR SURFACE EVA
PLANNING GUIDELINES

APOLLO J-MISSIONS

Contract NAS 9-8166

Prepared by TRW Systems

for

Apollo Spacecraft Program Office

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

Submitted by *K. L. Thomas*
K. L. Thomas
Systems Engineering Division

Concurrence *R. W. Kubicki*
Ronald W. Kubicki, Acting Chief
Systems Engineering Division

Approved by *James A. McDivitt*
Col. James A. McDivitt, Manager
Apollo Spacecraft Program

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1. INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide a single program reference containing the primary information required to define the lunar surface operational guidelines for the Apollo J Missions. Data and guidelines presented in this document are those that have been concurred with for use in current lunar surface operations planning and study. Maintenance of this document will be terminated when the information is incorporated into the Apollo Spacecraft Operational Data Books, Lunar Surface Operations Plans and Procedures and other official NASA source documents.

1.2 SCOPE

Information presented in this document is the basic data and guidelines required to define the envelope of lunar surface operational capability. The level of detail is limited to that required to uniquely define an essential aspect of the capability envelope for current and near term needs. Required information that is not fully approved or that is not presently available in the desired form is included herein in the best form available. Where uncertainties exist in basic data or guidelines needed for completeness of lunar surface planning, reasonable limits or bounds are identified. In cases where needed data are not available in any reasonable form, it is identified as "TBD".

2. GUIDELINES SUMMARY

Guidelines for Apollo J missions EVA planning are summarized in this section, based upon the data and assumptions that are discussed in the succeeding sections.

2.1 LUNAR SURFACE STAY GUIDELINES

2.1.1 LM Staytime

The LM staytime on the lunar surface is planned to be 65-1/3 hours from touchdown to liftoff.

2.1.2 Extravehicular Activities

Three periods of extravehicular activity (EVA) on the lunar surface are planned during the LM lunar stay. Each EVA period is defined as the interval during which the LM cabin pressure is less than 3.5 psia.

1st EVA: Duration up to 6 hours - limited by crew work/ rest cycle requirements, and EVA start time of touchdown plus 4 hours.

EVA Overhead*   1-3/4 hours initial
                    3/4 hour final

2nd EVA: Duration up to 7 hours** - limited by PLSS battery and crewman's ability to function properly in a PGA.

EVA Overhead   3/4 hour initial
                  3/4 hour final

3rd EVA   Duration up to 7 hours - limited by PLSS battery and crewman's ability to function properly in a PGA.

EVA Overhead   3/4 hour initial
                  1 hour final

---

*EVA Overhead is the time required to perform necessary EVA tasks which do not contribute directly to scientific activities or lunar surface exploration.

**Contingent upon sufficient LRV riding time to reduce the crew average metabolic rate to a level at which the PLSS consumables are adequate for 7 hours.

2.2 EVA GUIDELINES

It is assumed in EVA planning that both LM crewmen participate jointly in all excursions away from the immediate vicinity of the LM and remain within sight of each other at all times.

2.2.1 Crewman Metabolic Rates

Activity	Metabolic Rate ($\mathring{Q}_{met}$)
LRV Riding	700 BTU/hr
Normal Working	1050 BTU/hr
Contingency Walking @ 3.3 km/hr	1440 BTU/hr

2.2.2 PLSS Consumables

Life support for J-mission lunar surface EVA's will be provided by the -7 PLSS. Minimum PLSS performance guaranteed by the specification is noted in Appendix A. PLSS consumables performance capability is expected to be greater than the specification minimum; specifically in the quantities of oxygen and feedwater available. These lunar surface EVA planning guide-lines are developed around the "current expected" PLSS consumables capability as discussed below.

Lunar surface EVA planning should allow a 30-minute PLSS consumables reserve to remain at the end of each period. This consumables reserve is based on the normal working metabolic rate of 1050 BTU/hr.

PLSS battery capability provides 7 hours EVA capability, plus the 30-minute reserve.

The PLSS is expected to provide 1.34 pounds of oxygen for use during an EVA, plus the additional 30-minute reserve. This is greater than the specification minimum (see Appendix A). For EVA planning purposes, the PLSS oxygen is used at the rates shown in Table 2.2-1.

Table 2.2-1

Oxygen Consumption Rates (lbs/hr)

Activity (O_2 leak rate, $\dot{W}_{lk}$)	EVA-1 (0.01 lbs/hr)	EVA-2 (0.02 lbs/hr)	EVA-3 (0.03 lbs/hr)
LRV Riding	0.1255	0.1355	0.1455
Normal Working	0.1833	0.1933	0.2033
Contingency Walking	0.2476	0.2576	0.2676

The -7 PLSS is expected to provide 10.62 pounds of usable feedwater, corresponding to 11,000 BTU of cooling capacity for nominal EVA use. The required 30-minute feedwater reserve is provided by the quantity remaining in the slave to the sublimator. This expected capability is in excess of the specification minimum performance (see Appendix A). Effective heat rates at which the feedwater is used are summarized in Table 2.2-2.

Table 2.2-2

Effective Heat Rates (BTU/Hr)

Activity (Heat Leak, $\dot{Q}_{hl}$)	EVA-1 (0)	EVA-2 (100 BTU/hr)	EVA-3 (200 BTU/hr)
LRV Riding	1021	1121	1221
Normal Working	1456	1556	1656
Contingency Walking	1942	2042	2142

The PLSS LiOH cartridge provides more than 7 hours of CO_2 removal capability, with at least 30 minutes reserve, at the planned metabolic expenditure rates.

2.2.3 Traverse Distance

LRV speed for normal traverse planning is 8 kilometers per hour over the lunar surface distance traveled.

EVA traverse plans must account for greater distances to be traveled over the lunar surface than measured point-to-point map distances. Recommended corrections to map distances to obtain distances for lunar surface

2-3

EVA planning are as follows:

Terrain Type	Surface Distance Traveled per Unit Map Distance
Smooth Mare	1.16
Rough Mare	1.18
Hummocky Uplands	1.24
Rough Uplands	1.31

The maximum return distance to the LM from any point in a traverse is limited to 9.5 kilometers. This constraint is to allow the crewmen to make an emergency return to the LM on the LRV using the Buddy-Secondary Life Support (BSLSS) System in case of a PLSS failure during an EVA. LRV average return speed under emergency conditions is assumed to be 10 kilometers per hour.

The maximum BSLSS/OPS duration of 1.25 hours allows 5 minutes for connecting the buddy hose and 13 minutes to ingress the LM, with 0.95 hour available to return to the LM.

Following an LRV failure, it is assumed the crew would drop all payload and walk back to the LM via the most direct route. The PLSS walk back capability limit (at contingency walking speed of 3.3 kilometers per hour) is a function of time and is shown in Figures 2-1 through 2-3.
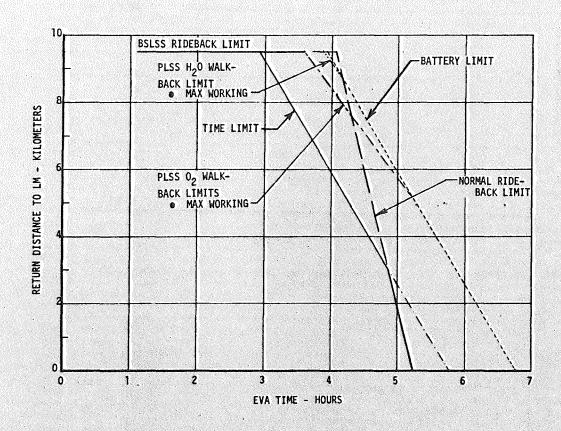
Figure 2-1.   Contingency Walkback Limits - EVA I
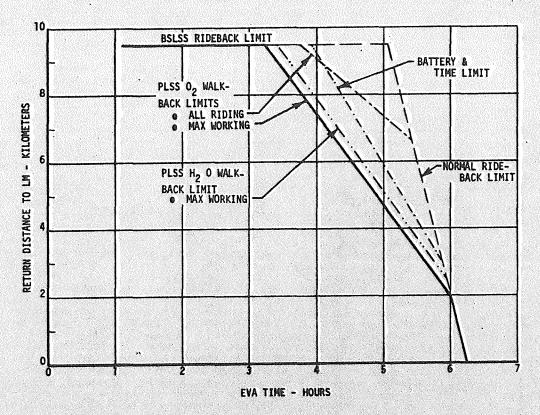
Figure 2-2. Contingency Walkback Limits - EVA 2
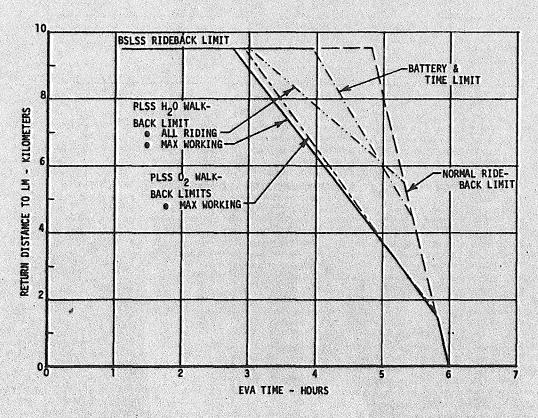
Figure 2-3. Contingency Walkback Limits - EVA 3

3. LUNAR SURFACE MISSION PLANS

To achieve mission objectives and maximize the scientific and technical
return, lunar surface missions must be planned to efficiently utilize the
limited staytime on the lunar surface. For the J-1 mission a lunar surface
staytime of 65-1/3 hours, with three EVA periods, is planned. The profile
of this lunar surface stay is shown in Figure 3-1.

3.1 LUNAR SURFACE STAYTIME

The limitation on lunar surface staytime is governed primarily by the
amount of LM consumables (electrical power, water and oxygen) available.
The consumable limit on electrical power is encountered first, at approxi-
mately 72 hours (depending on the final estimates of battery capability and
the actual electrical load profiles). Details of the consumables usage
appear in the following sections.

3.1.1 LM Consumables

3.1.1.1 Electrical Power

The LM descent stage batteries supply spacecraft electrical power for
the lunar stay period. LM electrical power requirements can be met for
approximately 72 hours, depending upon the final estimates of battery capa-
bility and the electrical load profiles. Current estimates of the electri-
cal power consumed and the margin remaining for the 65-1/3 hour staytime are
summarized in Tables 3-1 and 3-2.
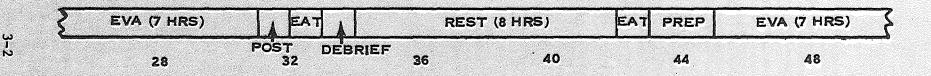
TABLE 3-1

J-TYPE MISSION LM ELECTRICAL POWER, 3 EVA's

Phase/Requirement	Required Amp-Hours	Remaining Amp-Hours
Initial Capacity	------	2000
Prior to T.D.	276	1724
Lunar Stay Requirements[1]	1355	369
Total Unusable[2]	109	260
Contingency Revolution	63	197
Margin	------	9.85%

(1) See Table 3-2 for Lunar Stay Electrical Requirements Detail
(2) See Table 3-3 for Unusable Electrical Power Details

3-1

TOUCHDOWN
(AWAKE 9 HRS)

| C/O | EAT | PREP | EVA (6 HRS) | | EAT | | REST (8 HRS) | EAT | PREP | |

POST   DEBRIEF

0   4   8   12   16   20   24

| EVA (7 HRS) | | EAT | | REST (8 HRS) | EAT | PREP | EVA (7 HRS) |

POST   DEBRIEF

28   32   36   40   44   48

LIFT-OFF   DOCK

POST

| | EAT | REST (8 HRS) | EAT | ASCENT PREP | REND | | SIM ACT | REST |

52   56   60   64   67   75   78

65 1/3
HRS

TIME BETWEEN REST PERIODS: 22-13-12-16
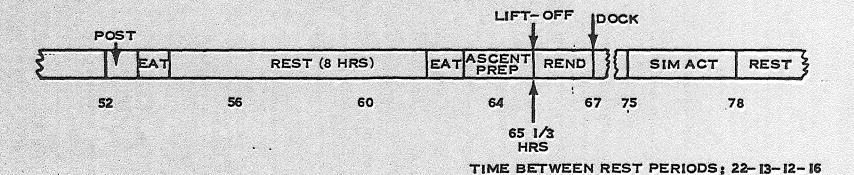
Figure 3-1. Apollo J-1 Mission Lunar Surface Timeline

TABLE 3-2

LM LUNAR STAY ELECTRICAL REQUIREMENTS

Event	Duration (hrs)	Amps	Required Amp-Hours
TD to Power Down	2.0	43.0	86
EVA-1 Prep	2.0	25.0	50
EVA-1	6.0	19.0	114
Post EVA/Eat	3.0	22.0	66
Rest	8.0	20.5	164
Eat/EVA-2 Prep	3.0	22.0	66
EVA-2	7.0	15.0	105
Post EVA/Eat	3.0	22.0	66
Rest	8.0	20.5	164
Eat/EVA-3 Prep	3.0	22.0	66
EVA-3	7.0	15.0	105
Post EVA/Eat	2.0	20.5	41
Rest	8.0	19.0	152
Eat	1.0	20.5	21
Lift-Off Prep*	2.08**	43.0	89
Total Required	65.08**	----	1355

*PNGS power up assumed at beginning of prep period.
**Descent batteries assumed dead faced 15 minutes prior to lift-off.

TABLE 3-3

UNUSABLE LM DESCENT ELECTRICAL POWER

Item	Amp-Hours
Dispersion (2%)	33
MSFN Uncertainty	6
TM Inaccuracy*	70
Total	109

*Pre-mission calibration of ECA's is expected to reduce TM inaccuracy
from 138 amp-hours to the estimated 70 amp-hours.

3.1.1.2 LM Water

The LM descent stage water tanks supply the water used for cooling the LM cabin, crew consumption and PLSS refilling during the LM lunar stay. Current estimates of the descent stage water used and the margin remaining for the 65-1/3 hour lunar staytime are summarized in Table 3-4.

TABLE 3-4

J-TYPE MISSION LM DESCENT STAGE WATER BUDGET
(65-1/3 HOUR LUNAR STAYTIME)

Descent Stage Tank Loading
Unusable
  Tank Residual
  Loading Uncertainty
  Sampling
	
	6.6
	9.7
	12.0
		333.0 lbs.
		-28.3

Available for Mission
Required for Mission
  Sublimation
  Urine Loss
  PLSS Refills
  Condensate Lost
	
	122.5
	7.8
	46.6
	6.7
		304.7 lbs.
		-183.6

Remaining in Tank Dispersion (5%)		121.1 lbs. -9.2
Margin		111.9 lbs.

3.1.1.3 LM Oxygen

The LM descent stage oxygen supplies all oxygen required by the ECS for replenishing losses due to crew metabolic consumption and cabin leakage, for cabin repressurization following EVA and for PLSS refilling. Estimated descent stage oxygen use and margin remaining for the lunar stay period is summarized in Table 3-5.

TABLE 3-5

J-TYPE MISSION LM DESCENT STAGE OXYGEN BUDGET
(65-1/3 HOUR LUNAR STAYTIME)

Descent Stage Tank Charge		48.00 lbs.
Unusable		-3.65
Tank Residual	0.84	
Loading Uncertainty	0.26	
End-to-End Error, ACE	1.73	
System Leak	1.32	
Available For Mission		44.35 lbs.
Required For Mission		-28.27
Metabolic	3.50	
Cabin Leakage	1.53	
Cabin Regulator Check	0.25	
PLSS Refills*	7.21	
Cabin Repressurizations**	15.78	
Remaining in Tank		16.07 lbs.
Dispersion (5%)		-1.41
Margin		14.66 lbs.

* PLSS refills require 1-8 lbs. per PLSS.
** Cabin repressurization requires 5.26 lbs.

3.2 EVA PERIODS

The lunar surface EVA periods planned for the J-1 mission (Figure 3-1) result primarily from consideration of crew work/rest cycle guidelines and life support system capability. Crew work/rest cycle guidelines strongly influence the number of EVA periods while the duration of an EVA is basically dependent upon the capability of the portable life support system (PLSS) employed and the rate at which it is used. Details of the PLSS consumables capability are discussed in Appendix A, and use rates are discussed in Section 4.

Crew/work/rest cycle guidelines are summarized as follows:

- The crew work/rest cycle during the lunar stay includes EVA, at least two eating periods and one rest period and should be planned to be as close to 24 hours in duration as possible.

- The planned continuous awake time for normal mission operations should not exceed 16 hours. For planned contingency operations this continuous awake time can be extended to 22 hours, provided it is followed by an eight hour sleep period and a return to the normal sleep-awake cycle.

- One EVA period on the day of lunar landing is the maximum allowable
  for planning. Only one EVA period should be planned for each
  succeeding work/rest cycle. Back-to-back EVA periods are undesir-
  able and should be employed only when science gain justifies such
  a strenuous timeline.

- In order for the crewman to remain comfortable and function properly
  during EVA the uninterrupted time in a pressurized PGA should be
  limited to 7 hours.

The three EVA periods of 6-7-7 hours duration shown in Figure 3-1 occur
during crew awake periods of 22-13-12 hours durations respectively. An
eating period is scheduled both prior to and after each EVA, and an 8 hour
rest period follows each work period. The lunar lift-off work day for the
LM crew follows an 8 hour rest period and is 16 hours in duration.

Both EVA-2 and EVA-3 are scheduled to have the maximum duration of 7
hours. The 6 hour duration of EVA-1 provides the crew the opportunity to
egress to the lunar surface at the earliest time after touchdown, but is
constrained in duration in order to avoid crew fatigue, consistent with the
crew work/rest cycle guidelines.

4. EVA OPERATIONS

4.1 EVA OPERATIONAL REQUIREMENTS

Lunar surface EVA operations encompass both the basic requirements which are characteristic of all lunar surface EVA's and those operations that are unique for the specific mission being planned. Each period of lunar surface extravehicular activity is preceded by a period of EVA preparation and followed by a period of EVA termination activities, as shown in Figure 4-1. The EVA period itself is defined as the interval during which the LM crew members are dependent upon the EMU for life support; i.e., when the LM cabin pressure is less than 3.5 psia.
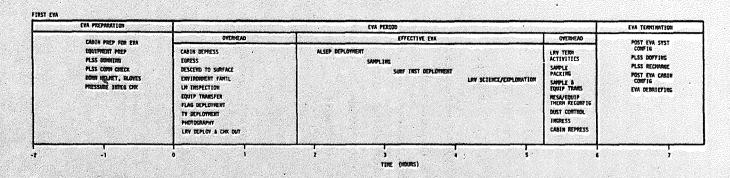
Near the end of EVA preparations, the extravehicular suit is sealed and a pressure integrity check is performed, followed by LM cabin depressurization. PLSS oxygen consumption begins when the suit is sealed.
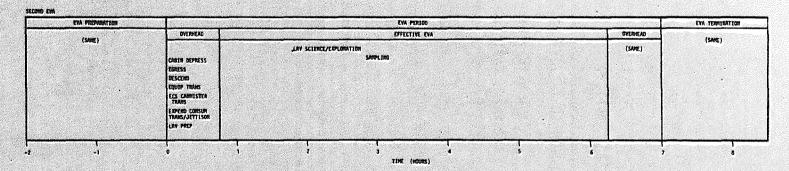
The crewman's time during the EVA is devoted partially to effective EVA and partially to EVA overhead tasks. Effective EVA includes such tasks as the deployment of ALSEP and other scientific instruments, surface exploration and sampling. EVA Overhead includes activities which are necessary during an EVA, but are not part of scientific activities or lunar surface exploration; e.g., LM egress and ingress, equipment transfer, LM inspection, LRV deployment and checkout, etc.

4.1.1 EVA Overhead Requirements

The times alloted for EVA overhead tasks on the J-missions (Figure 4-1) are as follows:

EVA	Overhead Time, Hours
1	Initial = 1-3/4 Final = 3/4
2	Initial = 3/4 Final = 3/4
3	Initial = 3/4 Final = 1

FIRST EVA

EVA PREPARATION	EVA PERIOD			EVA TERMINATION
	OVERHEAD	EFFECTIVE EVA	OVERHEAD	
CABIN PREP FOR EVA EQUIPMENT PREP PLSS DONNING PLSS COMM CHECK DONN HELMET, GLOVES PRESSURE INTEG CHK	CABIN DEPRESS EGRESS DESCEND TO SURFACE ENVIRONMENT FAMIL LM INSPECTION EQUIP TRANSFER FLAG DEPLOYMENT TV DEPLOYMENT PHOTOGRAPHY LRV DEPLOY & CHK OUT	ALSEP DEPLOYMENT SAMPLING SURF INST DEPLOYMENT LRV SCIENCE/EXPLORATION	LRV TERM ACTIVITIES SAMPLE PACKING SAMPLE & EQUIP TRANS RESA/EQUIP THERM RECONFIG DUST CONTROL INGRESS CABIN REPRESS	POST EVA SYST CONFIG PLSS DOFFING PLSS RECHARGE POST EVA CABIN CONFIG EVA DEBRIEFING

TIME (HOURS): -2 -1 0 1 2 3 4 5 6 7

SECOND EVA

EVA PREPARATION	EVA PERIOD			EVA TERMINATION
	OVERHEAD	EFFECTIVE EVA	OVERHEAD	
(SAME)	CABIN DEPRESS EGRESS DESCEND EQUIP TRANS ECS CANNISTER TRANS EXPEND CONSUM TRANS/JETTISON LRV PREP	LRV SCIENCE/EXPLORATION SAMPLING	(SAME)	(SAME)

TIME (HOURS): -2 -1 0 1 2 3 4 5 6 7 8

THIRD EVA

EVA PREPARATION	EVA PERIOD			EVA TERMINATION
	OVERHEAD	EFFECTIVE EVA	OVERHEAD	
(SAME)	(SAME)	(SAME)	SAMPLE PACKING SAMPLE/EQUIP INVENTORY SAMPLE & EQUIP TRANS INGRESS CABIN REPRESS	(SAME EXCEPT EQUIPMENT JETTISON)

TIME (HOURS): -2 -1 0 1 2 3 4 5 6 7 8

Figure 4-1. Apollo J-Missions Generalized EVA Timelines

These overhead times are based on Apollo 11 and 12 missions experience and lunar surface simulations adapted to the J-missions lunar surface operations. EVA overhead activities are summarized in Figure 4-1.

4.2 EVA LIFE SUPPORT

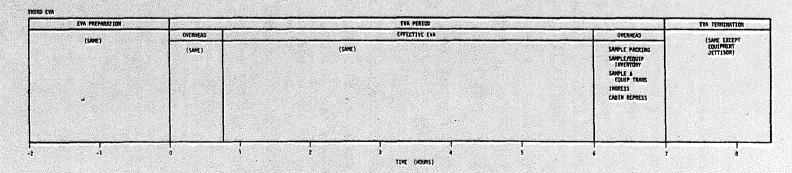The duration of an EVA is primarily dependent upon the capacity of the life support system employed and the rate at which it is used. Lunar surface EVA life support on J-missions will normally be provided by the -7 portable life support system (PLSS). For other than electrical power, the PLSS consumables performance is determined by the average metabolic energy demand of the crewman during the EVA. PLSS consumables performance guidelines for use in preliminary EVA planning are summarized in the following sections. These guidelines are based on expected -7 PLSS performance which is somewhat higher than the minimum performance allowed by the specification. Details of the PLSS consumables performance, from Reference 1 and 2, are provided in Appendix A.

4.2.1 PLSS Consumables Guidelines

Nominal lunar surface mission planning should provide PLSS consumables reserves at the end of each EVA period that will be adequate for 30 minutes additional life support at a metabolic rate of 1050 BTU per hour.

4.2.1.1 PLSS Battery

The -7 PLSS battery provides the electrical power requirements for 7 hours of EVA capability with approximately thirty minutes reserve power. The 7-hour capability coincides with the planned EVA duration for the second and third EVA's on the J-1 mission, and provides 1 hour of capability in excess of the first EVA duration.

4.2.1.2 Oxygen

PLSS oxygen is normally the limiting consumable in EVA plans having a high percentage of working activity in comparison to LRV riding. There are 1.34 pounds of oxygen expected to be available in the -7 PLSS for use during an EVA with an additional 30-minute reserve. For EVA planning

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purposes, the crewman is assumed to have a R.Q.* of 0.85, and the oxygen is consumed at the rate:

$$\dot{W}_{O_2} = 1.65 \times 10^{-4} (\dot{Q}_{met}) + \dot{W}_{lk}$$

where

$\dot{W}_{O_2}$ = rate at which PLSS oxygen is used, lbs/hr

$\dot{W}_{lk}$ = oxygen leak rate from system, lbs/hr

$\dot{Q}_{met}$ = crewman metabolic rate, BTU/hr (see Section 4.3)

Average O_2 leak rates ($\dot{W}_{O_2}$) recommended for use in preliminary lunar surface EVA planning are as follows:

EVA	$\dot{W}_{lk}$(lbs/hr)
1	0.01
2	0.02
3	0.03

4.2.1.3 Feedwater

For normal EVA plans, the expected PLSS feedwater quantity will provide a longer duration capability than will the PLSS oxygen quantity. The 10.62 pounds of feedwater expected to be available in the reservoir (see Appendix A) for cooling during the EVA period corresponds to an 11,000-BTU cooling capacity. An additional 30-minutes reserve is provided after the feedwater reservoirs have been depleted. The effective rate for an R.Q. = 0.85 at which the -7 PLSS feedwater is used is:

$$\dot{Q}_t = 1.245 \, \dot{Q}_{met} + \dot{Q}_{hl} + 149 \text{ BTU/hr}$$

where

$\dot{Q}_t$ = effective heat rate on the PLSS, BTU/hr.

---

*R.Q. = Respiratory Quotient, the volumetric ratio of CO_2 produced to O_2 utilized by an individual.

$\dot{Q}_{met}$ = crewman metabolic rate, BTU/hr (see Section 4.3)

$\dot{Q}_{hl}$ = external heat leak, BTU/hr

Based on the nominal 65-1/3 hour J-1 mission lunar surface staytime (Figure 3-1), the recommended average external heat leaks to be used for EVA planning are as follows:

EVA	$\dot{Q}_{hl}$ (BTU/hr)
1	0
2	100
3	200

4.2.1.4 Lithium Hydroxide (LiOH)

For nominal EVA planning purposes, the LiOH cartridge does not constrain the EVA duration; both oxygen and feedwater limits are encountered earlier. Appendix A illustrates the -7 PLSS LiOH performance capability.

4.3 CREW METABOLIC RATES

Effective metabolic rates for crewmen during three basic types of lunar surface activities are estimated (Reference 3) for use in determining the rate at which the PLSS consumables are being used. These basic activities are 1) working, 2) LRV riding and 3) contingency walking, as discussed in the following sections.

4.3.1 Working Metabolic Rate

Lunar surface working tasks are expected to be carried out at a comfortable level of effort that can be maintained without fatigue. Strenuous task requirements will be offset by periods of relatively low activity (photography, terrain feature observation/describing tasks, etc). Working activities include both the EVA overhead tasks, ALSEP deployment and science station activities. For EVA planning purposes, the recommended metabolic rate for lunar surface working activity is 1050 BTU per hour.

4.3.2 LRV Riding Metabolic Rate

Riding the lunar rover vehicle (LRV) involves a relatively low level of physical activity for the crewman. Measured metabolic rates of a crewman riding the LRV have not been made at this time and only an estimate of the average rate while riding can be made. It is assumed the LRV riding metabolic rate is independent of vehicle speed and for preliminary planning purposes, this rate is estimated to be 700 BTU per hour in the A7L-B suit.

4.3.3 Contingency Walking Capability

Estimated crewman metabolic rates for walking on the lunar surface are shown in Figure 4-2 for a range of walking speeds. The metabolic rate versus speed relationship shown is representative of an astronaut wearing a presently configured EMU without additional payload. An optimum walking speed range of 3.3 to 4.0 kilometers per hour, corresponding to a range of metabolic rates of 1200 to 1400 BTU per hour, is indicated from these data. On slopes or when carrying additional weight, the astronaut can be expected to adjust his speed downward to maintain a comfortable level of effort. For EVA planning purposes, the recommended contingency walking rate is 3.3 kilometers per hour, with a metabolic rate of 1440 BTU per hour (corresponding to a rate of 1200 BTU per hour plus a 20-percent pad).

4.4 EVA CAPABILITY GUIDELINES

4.4.1 PLSS Consumable Rates

For EVA planning purposes, the PLSS oxygen usage rates are summarized in Table 2.2-1, page 2-3, and the effective heat rates at which the PLSS feedwater is used are summarized in Table 2.2-2, page 2-3.

4.4.2 PLSS Capability Envelope

Figures 4-3 through 4-5 show the -7 PLSS nominal EVA capability envelopes for the J-mission. These envelopes are defined by the trade-off of EVA working time and riding time within the PLSS consumables and EVA time limits. An additional 30-minute reserve capability is available beyond the consumable limit line for each of the three PLSS consumables noted.

FT/SEC	KM/HR	BTU/HR	BTU/KM
2.5	2.7	1000	370
3.0	3.3	1200	364
3.6	4.0	1400	350
4.5	4.9	2000	408
5.0	5.5	2400	436

-7 PLSS
A7L SUIT
SMOOTH TERRAIN
SHAPE BASED ON 1 g DATA
MAGNITUDE BASED ON APOLLO 11
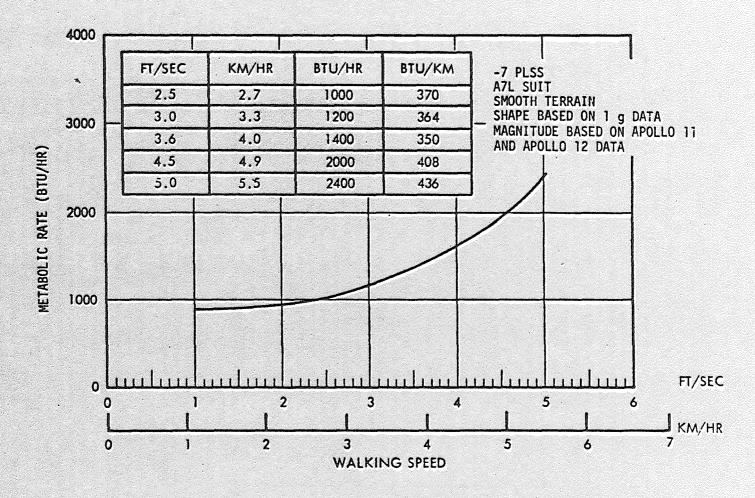AND APOLLO 12 DATA

Figure 4-2. Predicted Lunar Surface Metabolic Rate
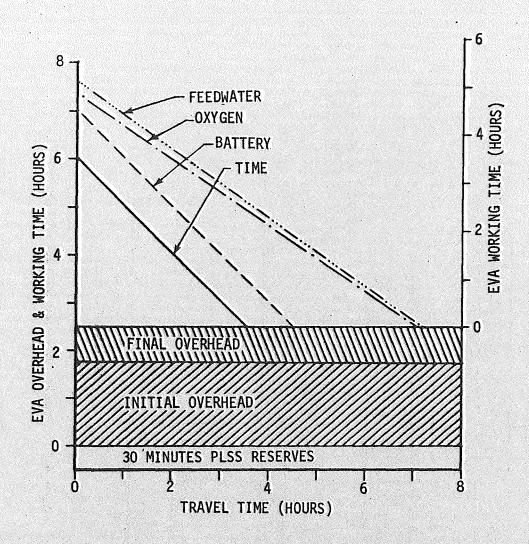for Average Walking Speeds

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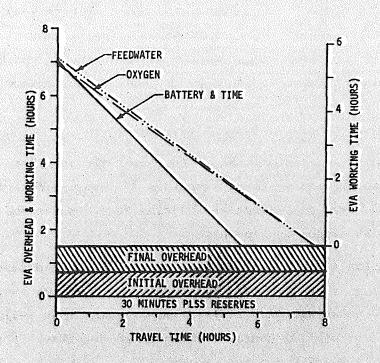Figure 4-3.   PLSS Capability Envelope EVA-1
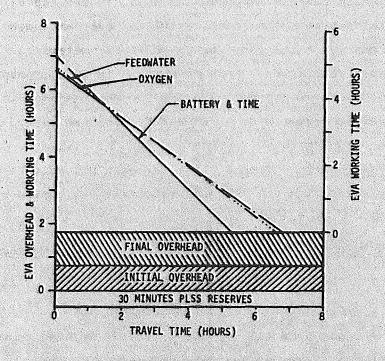
Figure 4-4. PLSS Capability Envelope EVA-2

Figure 4-5. PLSS Capability Envelope EVA-3

The 6-hour time constraint planned for EVA-1 (Figure 4-3) results in a conservative margin on all PLSS consumables. The 3.5 hours available for effective EVA time (6 hours minus 2.5-hours overhead) can be planned for normal working/riding activities as desired without consumables restriction.

Nominal EVA-2 capability (Figure 4-4) is limited by the 7-hour battery and time constraint for planned LRV riding times greater than 1/2 hour, and limited by oxygen for riding times less than 1/2 hour. With riding times greater than 1/2 hour, the effective EVA time is 5.5 hours and a margin exists on the PLSS oxygen and feedwater.

EVA-3 duration (Figure 4-5) is limited by PLSS oxygen capacity for planned LRV riding times less than 1-1/2 hours and limited by the 7-hour battery and time constraint for riding times greater than 1-1/2 hours. Effective EVA times of 5.25 hours can be planned for EVA-3 if the planned LRV riding time is 1-1/2 hours or greater.

4.4.3 Traverse Capability

The lunar roving vehicle (Appendix B) provides the capability for lunar surface exploration and science activities over extended distances from the LM. A maximum total range of up to 76 kilometers can be traversed during a lunar surface mission. Uses of the LRV include transporting crew tools, cameras and instruments on traverses for activities at selected stations. The LRV preparation task in the EVA overhead periods (Figure 4-1) provides time for stowing the equipment on the LRV. Traverse plans must provide science/exploration overhead time for each LRV science stop for crew dismounting/remounting the LRV and offloading the necessary equipment. Recommended times are as follows:

Type Stop	Science Time	Overhead Time
Minor	Up to 15 minutes	3 minutes
Major	15 minutes and up	6 minutes

EVA traverse plans must account for greater distances traveled over the lunar surface than measured point-to-point map distances. The added distance to be traveled is a function of the terrain roughness which

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includes craters, blocks and slopes. <u>For traverse planning, it is
recommended that point-to-point map distances be increased by the factors
shown in Table 4.4-3. An average LRV traverse speed of 8 kilometers per
hour (Appendix B) over the corrected distance should be used</u>.

Table 4.4-3

Map Distance Correction Factors
(From Reference 4)

Terrain Type	Ground Distance Traveled per Unit Map Distance
Smooth Mare	1.16
Rough Mare	1.18
Hummocky Uplands	1.24
Rough Uplands	1.31

4.5 EVA CONSTRAINTS

A lunar surface EVA timeline can be expected to vary from the nominal
plan because of unfamiliarity with the lunar environment and due to varia-
tions in equipment operation. When a malfunction of lunar surface equip-
ment occurs, a contingency plan must be used to continue the EVA. It is
not the purpose of this "Guidelines Document" to consider contingency EVA
planning; however, contingencies which constrain the nominal EVA planning
are included as planning guidelines in the following sections.

4.5.1 Communications Constraints

To provide for real time monitoring of lunar surface activities, the
extravehicular crewmen shall not be out of communication with Mission
Control, or each other, for more than 5 minutes at a time. RF line of
sight must exist between transmitting and receiving antenna for all lunar
surface communications to avoid complete loss of communications. The
range is limited to 1.6 kilometers between the LM, or the LCRU, and the
EVC-1 (CDR), and to 0.8 kilometer between astronauts to avoid probable
loss of communications.

It is assumed in EVA planning that both LM crewmen participate in all excursions away from the immediate vicinity of the LM and remain within sight of each other at all times.

4.5.2 Traverse Constraints

The maximum radius of operation from the LM on missions with the LRV shall not exceed the ride-back range of the BSLSS (Appendix A), or the walk-back capability of the crew with properly functioning PLSS, whichever is less.

4.5.2.1 BSLSS Ride-Back Limit

In the event of a PLSS failure during an EVA, the Buddy Secondary Life Support System (BSLSS) will be used to provide the capability of returning to the LM (BSLSS described in Appendix A). On an LRV traverse, the assumption is that the crew would ride back to the LM as rapidly as possible. The BSLSS ride-back limit is defined by the average emergency return speed of the LRV and the BSLSS operating time. Travel time on the BSLSS is 0.95 hour, resulting from the BSLSS operation time (OPS duration of 1.25 hours), less the time required for connecting the transport water buddy hose (5 minutes) and the emergency LM ingress time (13 minutes). For traverse planning purposes, a 10-kilometer per hour LRV emergency return speed (Appendix B) is recommended with a maximum return distance to the LM not exceeding 9.5 kilometers.

4.5.2.2 PLSS Walk-Back Limit

Failure of the LRV during a traverse requires that the crew have the capability to walk back to the LM and ingress. It is assumed that following an LRV failure all payload would be dropped and the crew would walk back to the LM via the most direct route. Life support during the walk back is provided by the PLSS.

The PLSS walk-back capability limit is defined by the consumables remaining and the walk-back speed. For EVA planning purposes, the contingency walking capability (Section 4.3.3) is used to define the walk-back speed of 3.3 kilometers per hour at a metabolic rate of 1440 BTU per hour. The PLSS walk-back limit is shown in Figures 2-1 through 2-3, pages 2-5 and 2-6.

5. SCIENCE MISSION GUIDELINES

5.1 LUNAR SURFACE EXPERIMENTS

Lunar surface activities on Apollo J-missions include scientific investigations and deployment of experiments. Experiments assigned to the J-missions by the NASA Office of Manned Space Flight are summarized in Table 5-1. The purposes and descriptions of these lunar surface experiments are summarized in Reference 5. Experiment characteristics are discussed in terms of their potential interaction with other scientific traverse activities in Reference 6.

5.1.1 Experiment Deployment

Apollo Lunar Surface Experiments Packages (ALSEP) consist of the sub-sets of the experiments noted in Table 5-1, together with a Central Station to provide and distribute electrical power and to handle experiment data. ALSEP requires participation of both crewmen for deployment, with estimated times required as shown in Table 5-2.

Two experiments, in addition to ALSEP, require astronaut participation in deploying experiment instruments; Laser Ranging Retro-Reflector (S-078), and Far UV Camera/Spectroscope (S-201). The Laser Ranging Retro-Reflector (LR^3) is similar to the one deployed on Apollo 11 and requires the same basic deployment tasks; transportation, cover removal, erection, leveling and azimuth alignment. This experiment is normally deployed along with ALSEP, requiring approximately four minutes. The FAR UV Camera/Spectroscope requires a crewman to remove the instrument from the LM and to set it up in the shadow of the LM. Astronaut participation is required for pointing the instrument at areas of interest in the sky, and at earth and obtaining required sequences of exposures. Time required for this activity is estimated to be TBD minutes.

5.1.2 Site Survey Experiments

Experiments which are to be used during a survey of the lunar landing region, utilizing instruments which are either hand carried or carried on the LRV, are the Portable Magnetometer Experiment (S-198), Seismic Profiling Experiment (S-203) and the Surface Electric Properties Experiment (S-204).

TABLE 5-1

APOLLO J-MISSIONS LUNAR SURFACE
EXPERIMENTS ASSIGNMENTS

EXPERIMENT	APOLLO MISSION			REMARKS
	J-1	J-2	J-3	
ALSEP ARRAY	A-2	D	E	
S-031 PASSIVE SEISMIC (1)	X	X	(X)	(1) S-031, PASSIVE SEISMIC OR S-207, LUNAR SURFACE GRAVIMETER WILL BE FLOWN ON APOLLO J-3, BUT NOT BOTH.
S-033 ACTIVE SEISMIC		X		
S-034 LUNAR SURFACE MAGNETOMETER	X	X		
S-035 SOLAR WIND SPECTROMETER	X			(2) CAN BE PERFORMED OR POSSIBLY ADAPTED FOR USE WITH LRV.
S-036 SUPRATHERMAL ION DETECTOR	X			
S-037 HEAT FLOW	X	X	X	
S-058 COLD CATHODE ION GAGE	X			
M-515 LUNAR DUST DETECTOR	X			
S-203 LUNAR SEISMIC PROFILING (2)			X	
S-205 LUNAR ATMOSPHERIC COMPOSITION			X	
S-207 LUNAR SURFACE GRAVIMETER (1)			(X)	
S-059 LUNAR GEOLOGY INVESTIGATION (2)	X	X	X	
S-078 LASER RANGING RETRO-REFLECTOR	X			
S-152 COSMIC RAY DETECTOR (SHEETS)		X		
S-198 LUNAR PORTABLE MAGNETOMETER (2)		X		
S-199 LUNAR GRAVITY TRAVERSE (2)			X	
S-200 SOIL MECHANICS (2)	X	X		
S-201 FAR UV CAMERA/SPECTROSCOPE		X		
S-202 LUNAR EJECTA AND METEORITES			X	
S-204 SURFACE ELECTRICAL PROPERTIES (2)			X	

The Portable Magnetometer Experiment (S-198) is to obtain measurements of the lunar magnetic field in the vicinity of the LM landing site and to obtain additional measurements at widely separated points during traverses away from the LM. It requires TBD minutes for calibration at the first station and TBD minutes for each station thereafter.

The Seismic Profiling Experiment (S-203) is used to determine the seismic velocity structure of the upper few kilometers of the moon in the vicinity of the landing site. During LRV traverses, explosive charges will be emplaced at preselected locations for subsequent detonation after the manned phase of the mission is over. The seismic waves resulting from the detonation of charges will be detected by a geophone array deployed near the LM, and the data is telemetered to earth through the ALSEP Central Station.

The Surface Electrical Properties Experiment (S-204) is designed to detect discontinuities in the electrical properties of the lunar subsurface. A stationary transmitter is deployed about 100 meters from the LM and a portable receiver is used to establish the baseline for the interferometry. The receiver should be carried 2 or 3 kilometers along a line normal to the axis of the transmitter dipoles. Optimistic estimates of the time required for the initial deployment of the antenna arrays and the retrieval of the tape after the traverse are 23 minutes for one astronaut and 15 minutes for two astronauts working together. In addition, is the time required for the traverse with the receiver, estimated to be a minimum of one hour on a walking traverse or TBD hour on LRV traverse.

The Lunar Field Geology Experiment (S-059) can be accomplished during lunar surface traverses on the lunar roving vehicle (LRV). Documented lunar material samples will be collected, and photographs/observations of lunar topographic features obtained at selected sites along the planned traverse routes.

Data can be obtained for the Soil Mechanics Experiment (S-200) at selected stations along a planned traverse route. Lunar material samples, photographs, observations and other data pertaining to the characteristics and mechanical behavior of the lunar soil at both the surface and subsurface at several stations along the traverse can be obtained.

TABLE 5-2

ESTIMATED ALSEP DEPLOYMENT TIMES

APOLLO MISSION	ALSEP ARRAY	ALSEP TRAVERSE AND SITE SURVEY (Min)	ALSEP SYSTEM INTERCONNECT (Min)	DEPLOY ALSEP SUNSHIELD AND ANTENNA - ACTIVATE CENTRAL STATION (Man-Min)	EXPERIMENT DEPLOYMENT (Man-Min) S-031 / S-033 / S-034 / S-035 / S-036 / S-037 / S-058 / S-203 / S-205 / S-207	PHOTOGRAPH ALSEP SITE AND RECHECK EXPERIMENTS	ALSEP DEPLOYMENT TIME (Hrs:Min)
J-1	A-2	12	10	25	100	11	1:30
J-2	D	TBD	TBD	TBD	TBD	TBD	TBD
J-3	E	TBD	TBD	TBD	* ... TBD ... *	TBD	TBD

*Either S-031 or S-207 will be flown on the Apollo J-3 Mission, but not both.

6. EXAMPLE TRAVERSE

6.1 MARIUS HILLS LANDING SITE

A preliminary traverse plan, based on the U. S. Geological Survey studies (Reference 7), is presented as an illustrative example. The example traverse plan is for the second EVA at the Marius Hills landing site.

The northwestern Marius Hills landing site is dominated by four positive masses surmounted by prominent cones around craters interpreted to be volcanic vents. Broad geologic objectives of the lunar mission to this landing site include acquiring samples and observing structural relationships of the materials composing the several types of morphologic features.

Three EVA periods are planned for exploration and scientific tasks at the Marius Hills landing site (Figure 6-1). The ALSEP is planned to be deployed during the first EVA period. Also during the first EVA, the LRV will be deployed and a short traverse made to the north of the LM landing site. The second and third EVA periods are planned as LRV traverses to explore and sample various features, and to conduct related lunar surface experiment tasks, such as lunar gravity measurements and emplacing seismic charges.

6.2 EVA-2 PLANS

The traverse route and planned stations (2 through 18) for the second EVA are shown in Figure 6-1.

6.2.1 Overhead Budget

An EMU oxygen leak rate of 0.02 pounds per hour and an EMU heat leak of 100 BTU per hour is assumed throughout the second EVA. A 45-minute period is provided at the beginning of the second EVA for accomplishing initial overhead tasks, including crew egress from the LM, equipment transfer and LRV preparation for the traverse. PLSS oxygen and feedwater used for the initial overhead period is:

Oxygen
$$W_{O_2} = [(1.65 \times 10^{-4})(1050 \text{ BTU/hr}) + 0.02 \text{ lbs/hr}] \, [3/4 \text{ hr}]$$
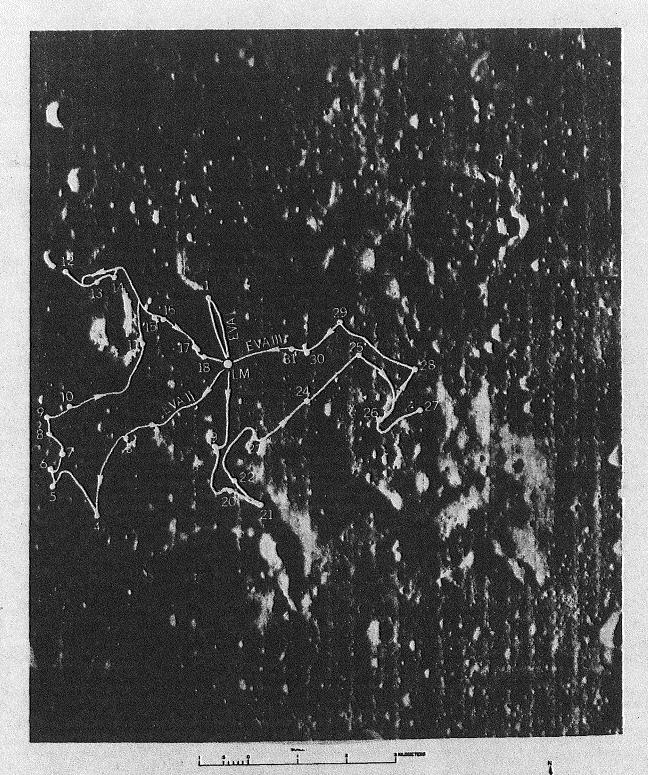$$= 0.145 \text{ lbs}$$

Figure 6-1. Reference Mission Traverses Marius Hills-
Northwestern Site

Feedwater

$$Q_t = [1.245(1050 \text{ BTU/hr}) + 149 \text{ BTU/hr} + 100 \text{ BTU/hr}] \, [3/4 \text{ hr}]$$

$$= 1167 \text{ BTU}$$

Plans for the second EVA also provide 45 minutes for final overhead activities, including LRV terminal activities, sample packing, sample and equipment transfer, MESA thermal reconfiguration and LM ingress. The PLSS oxygen and feedwater quantities provided for the final overhead activities are equal to the quantities provided for the initial overhead activities; i.e.

Oxygen

$$W_{O_2} = 0.145 \text{ lbs}$$

Feedwater

$$Q_t = 1167 \text{ BTU}$$

The planned consumables usage, including these initial and final overhead budgets, must be within the -7 PLSS capacity of 1.34-pounds oxygen and 11,000-BTU feedwater cooling capability. The EVA period is limited to 7 hours by the PLSS battery capacity. These limits provide for an additional 30 minutes in -7 PLSS consumables.

PLSS oxygen capacity available for the LRV traverse is:

O_2 available for EVA		1.34
Overhead budget		-0.29
Initial	-0.145 lbs	
Final	-0.145 lbs	

O_2 available for traverse   1.05 lbs

PLSS feedwater cooling capacity for the LRV traverse is:

Feedwater cooling capability		11,000 BTU
Overhead budget		-2,334
Initial	1167 BTU	
Final	1167 BTU	

Feedwater available for traverse   8,666 BTU

6.2.2 Contingency Limits

Sufficient life support capability must be provided for contingency return to the LM and emergency ingress. For both the LRV failure (PLSS Walk-Back) and PLSS failure (BSLSS Ride-Back) cases the emergency ingress requires 13 minutes, with 0.042-pounds O_2 and 335-BTU feedwater capacity consumed.

For the PLSS failure case, the BSLSS provides life support for 1.25 hours. Five minutes are required for the two crewmen to transfer to the BSLSS and, allowing for emergency ingress, the return to the LM must be made in 0.95 hour. For the emergency return to the LM, the average LRV speed is assumed to be 10 kilometers per hour; hence, the maximum return distance to the LM from any point in the traverse should not exceed 9.5 kilometers.

Failure of the LRV requires the crew to walk-back to the LM. Traverse planning must ensure that sufficient PLSS consumables are available for this contingency walk-back from any point in the traverse (Sections 4.3.3 and 5.2.2).

6.3 TRAVERSE PLAN

The 17 stations visited on the EVA-2 traverse route are shown in Figure 6-1 by the numbered circles on the heavy line. The U. S. Geological Survey has determined the Marius Hills lurain to be composed of both smooth and rough mare. Map distances measured along each segment of the traverse routes between stations have been increased by the appropriate factor (Table 4.4-3, page 4-11) to account for the greater distances to be traveled because of lurain slopes, craters and blocks. Contingency return routes to the LM from each station have been determined and these distances have also been corrected by the appropriate factor for lurain type.

A detailed summary of this traverse plan, outlining geologic features, operations and PLSS consumables used, is presented in Table 6-1.

Table 6-1

Second EVA Traverse Plan for Marius Hills Northwestern Site

Station	Corrected Distance (km)	Geologic Features	Operations	Time (min)	BTU Consumed	Oxygen Consumed lbs	EVA Time (hrs:min)	BTU Remaining *	Oxygen Remaining* (lbs)	Contingency Return Distance (km)	Ride-back Time (hrs)	Walk-Back and Ingress Requirements Time (hrs:min)	(BTU)	(lbs O₂)
LM	—	—	—	—	—	—	0:45	8666	1.0500					
	2.31		travel	17	318	.0385	1:02	8348	1.0115					
2		high plateau	overhead	3						2.31	0.23	0:55	1765	0.223
			sampling	3	156	.0194	1:08	8192	0.9921					
	0.61		travel	5	94	.0113	1:13	8098	0.9808					
3		small fissure cone	overhead	5						2.92	0.29	1:06	2145	0.270
			gravity measurement, sampling, photo panorama	10	388	.0485	1:28	7710	0.9323					
	1.91		travel	14	262	.0317	1:42	7448	0.9006					
4		impact crater in discontinuous ridge, low dome, and high plateau	overhead	5						4.83	0.48	1:39	3315	0.419
			gravity measurement, sampling, photo panorama & features	15	518	.0646	2:02	6930	0.8360					
	1.57		travel	12	225	.0271	2:14	6705	0.8089					
5		impact crater in discontinuous ridge	overhead	3						4.67	0.47	1:38	3225	0.407
			sampling	3	156	.0194	2:20	6549	0.7895					
	0.30		travel	2	38	.0045	2:22	6511	0.7850					
6		discontinuous ridge, and impact crater in fissure cone	overhead	5						4.55	0.46	1:36	3145	0.397
			gravity measurement, sampling, photo panorama & features	15	518	.0646	2:42	5993	0.7204					
	0.51		travel	4	75	.0091	2:46	5918	0.7113					
7		small fissure cone	overhead	5						4.01	0.40	1:26	2820	0.356
			gravity measurement, sampling, photo panorama & features	10	388	.0485	3:01	5530	0.6628					
	0.61		travel	5	94	.0113	3:06	5436	0.6515					
8		Crater in dark cone	overhead	3						4.34	0.43	1:32	3015	0.381
			sampling	3	156	.0194	3:12	5280	0.6321					
	0.30		travel	2	38	.0045	3:14	5242	0.6276					
9		impact crater in low dome	overhead	3						4.22	0.42	1:30	2945	0.372
			sampling	3	156	.0194	3:20	5086	0.6082					
	0.56		travel	4	75	.0091	3:24	5011	0.5991					

*Both initial and final overhead requirements have been subtracted.

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Table 6-1

Second EVA Traverse Plan for Marius Hills Northwestern Site (Continued)

Station	Corrected Distance (km)	Geologic Features	Operations	Time (min)	BTU Consumed	Oxygen Consumed (lbs)	EVA Time (hrs:min)	BTU Remaining *	Oxygen* Remaining (lbs)	Contingency Return Distance (km)	Ride-back Time (hrs)	Walk-Back and Ingress Requirements		
												Time (hrs:min)	(BTU)	(lbs O₂)
10		impact craters in low dome	overhead	4						3.81	0.38	1:22	2695	0.340
			sampling	6	258	.0323	3:34	4753	0.5668					
	2.31		travel	17	318	.0385	3:51	4435	0.5283					
11		fissure cone	overhead	4						1.88	0.19	0:47	1495	0.189
			gravity measurement, sampling, photo features	6	258	.0323	4:01	4177	0.4960					
	3.12		travel	23	430	.0520	4:24	3747	0.4440					
12		impact crater in high plateau	overhead	5						4.47	0.45	1:34	3095	0.391
			gravity measurement, emplace seismic charge, sampling, photo panorama	7	310	.0387	4:36	3437	0.4053					
	0.94		travel	7	131	.0158	4:43	3306	0.3895					
13		impact crater in high plateau	overhead	3						3.53	0.35	1:17	2520	0.318
			sampling	3	156	.0194	4:49	3150	0.3701					
	0.36		travel	3	56	.0068	4:52	3094	0.3633					
14		fissure cone and high plateau	overhead	10						3.25	0.33	1:12	2345	0.296
			gravity measurement, emplace seismic charge, sampling, photo panorama & features	15	648	.0806	5:17	2446	0.2827					
	1.63		travel	12	225	.0271	5:29	2221	0.2556					
15		impact crater in linear trough	overhead	3						1.83	0.18	0:47	1465	0.185
			sampling	4	181	.0226	5:36	2040	0.2330					
	0.18		travel	2	38	.0045	5:38	2002	0.2285					
16		impact crater at edge of linear trough	overhead	3						1.65	0.17	0:43	1355	0.171
			emplace seismic charge, sampling, photo panorama	4	181	.0226	5:45	1821	0.2059					
	0.86		travel	6	112	.0136	5:51	1709	0.1923					
17		impact craters in low cone	overhead	4						1.07	0.11	0:33	996	0.126
			emplace seismic charge, sampling, photo features	3	181	.0226	5:58	1528	0.1697					
	0.36		travel	3	56	.0068	6:01	1472	0.1629					
18		impact craters in low cone	overhead	4						0.53	0.05	0:23	663	0.083
			emplace seismic charge, sampling, photo features	5	233	.0290	6:10	1239	0.1339					
	0.53		travel	4	75	.0091	6:14	1164	0.1248					
LM														

Total   18.97

*Both initial and final overhead requirements have been subtracted.

APPENDIX A

LIFE SUPPORT SYSTEMS

1. PORTABLE LIFE SUPPORT SYSTEM

The -7 portable life support system (PLSS) will be used by crews on Apollo J-missions as the primary system for extravehicular activities on the lunar surface. PLSS consumables performance, with the exception of the battery, is determined by the average metabolic energy demand of the crewman during the EVA. Between EVA periods, the PLSS oxygen and feed-water must be replenished and the battery and lithium hydroxide (LiOH) cartridge must be replaced.

1.1 PLSS CONSUMABLES

Expected consumables performance of the -7 PLSS is summarized below (References 1 and 2). The expected PLSS performance generally exceeds the -7 PLSS minimum performance specification (see Sections 1.1.2 and 1.1.3 below).

1.1.1 Battery

The -7 PLSS battery capability is:

Battery rating, spec. minimum*	23.0 ampere-hours
Pre-EVA checkout usage	-1.1 ampere-hours
Remaining capability	21.9 ampere-hours

The electrical requirements for the -7 PLSS during an EVA is 2.6 amperes. At this load, with an additional 0.243-ampere telemetry uncertainty, the battery provides 7.6 hours of capability. This corresponds to a 7-hour EVA capability with approximately 36 minutes battery reserve.

1.1.2 Oxygen

The primary oxygen bottle volume is 370 cubic inches which provides the nominal capability as follows:

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*Based on battery use within 2-year life.

Charge weight, nominal		1.803 lbs
Penalties and residuals		-0.356 lbs
EVA prep	0.092	
LM cabin repress	0.031	
Instrumentation error	0.058	
Reg. press, residual	0.175	
Usable O_2		1.447 lbs
30 minute O_2 reserve		0.102 lbs
Available O_2 for EVA		1.345 lbs

NOTE: The -7 PLSS specification minimum performance provides an initial oxygen charge weight of 1.74 pounds which results in 1.282 pounds of O_2 available for use during an EVA.

The rate at which this oxygen supply is consumed during the EVA is proportional to the average metabolic rate of the crewman and the leak rate from the system. Oxygen used by the crewman (at R.Q. = 0.85*) is:

Pounds O_2 used per hour $= 1.65 \times 10^{-4} \ (\dot{Q}_{met}) + \dot{W}_{lk}$

where

Q_{met} = crewman metabolic rate, BTU/hr (See Section 4.3)

$\dot{W}_{lk}$ = oxygen leak rate from system, lb/hr

Experience has shown that the oxygen leak rate from the system steadily increases during operation. An average O_2 leak rate for each EVA period, increasing stepwise for subsequent EVA's, should be used for nominal lunar surface mission planning. The following leak rates are recommended:

EVA	O_2 Leak Rate, lbs/hour
1	0.01
2	0.02
3	0.03

---

*R.Q. - Respiratory Quotient, the volumetric ratio of CO_2 produced to O_2 utilized by an individual.

1.1.3 Feedwater

PLSS feedwater cooling capability is expected to be as follows:

		Main Tank	Aux. Tank
Initial loading		8.50 lbs	3.16 lbs
Losses		-0.96 lbs	-0.08 lbs
Nonexpellable	0.23		
Slave	0.60		
Transport water makeup	0.13		
Usable feedwater		7.54 lbs + 3.08 lbs = 10.62 lbs	

The required 30-minute feedwater reserve is provided by the quantity remaining in the slave to the sublimator after the reservoir has been depleted (warning tone comes on); hence the 10.62 pounds of usable feedwater is available for use during the EVA. This quantity of feedwater, at 1036 BTU per pound heat of vaporization, corresponds to 11,000 BTU cooling capacity of the PLSS during the EVA period.

> NOTE: The -7 PLSS specification minimum performance is based
> on a usable feedwater quantity of 9.8 pounds, with heat
> of vaporization equal 1027 BTU per pound, corresponding
> to a cooling capacity of 10,065 BTU.

The feedwater provides cooling for the crewman's metabolic heat rate and PLSS parasite heat loads,

$$\dot{Q}_t = \dot{Q}_{met} + \dot{Q}_p$$

where

$\dot{Q}_t$ = effective heat load on the PLSS, BTU/hr

$\dot{Q}_{met}$ = crewman metabolic rate, BTU/hr (See Section 4.3)

$\dot{Q}_p$ = parasitic heat rate, BTU/hr

Parasitic heat loads on the PLSS include the electrical heat load from internal equipment, the heat release from the LiOH reaction in removing the CO_2 from the oxygen and the EMU heat leak rate from the lunar surface environment. Parasitic heat load rate on this PLSS is

$$\dot{Q}_p = \dot{Q}_{elec} + \dot{Q}_{LiOH} + \dot{Q}_{hl}$$

A-3

where

$\overset{\circ}{Q}_{elec}$ = electrical equipment heat load

= 149 BTU/hr, 2σ maximum

$\overset{\circ}{Q}_{LiOH}$ = $LiOH/CO_2$ reaction heat release rate

= 0.245 Q_{met} for a R.Q. of 0.85

R.Q. = Respiratory Quotient, the volumetric ratio of CO_2 produced to O_2 utilized by an individual

$\overset{\circ}{Q}_{hl}$ = external heat leak, BTU/hr

Hence the parasitic heat load on the PLSS is,

$$\overset{\circ}{Q}_p = 149 \text{ BTU/hr} + 0.245 \overset{\circ}{Q}_{met} + \overset{\circ}{Q}_{hl}$$

The total heat rate which is removed by the PLSS feedwater is:

$$\overset{\circ}{Q}_t = 1.245 \overset{\circ}{Q}_{met} + 149 \text{ BTU/hr} + \overset{\circ}{Q}_{hl}$$

The heat leak on the EMU is estimated from the sun elevation angle during the EVA and the terrain characteristics. From the nominal 65-1/3 hour lunar surface stay timeline (Figure 3-1), the sun elevation angle for each EVA period is estimated as shown in Figure A-1. For nominal EVA planning, the average heat leak on the PLSS for each EVA period is recommended as follows:

EVA	Heat Leak, BTU/hr
1	0
2	100
3	200

1.1.4 Lithium Hydroxide

The carbon dioxide level in the extravehicular mobility unit (EMU) is controlled by passing the PLSS oxygen through an expendable LiOH and activated charcoal cartridge in the oxygen ventilation loop. The LiOH consumption rate is proportional to the CO_2 production rate of the crewman, which in turn is a function of the crewman's metabolic rate. LiOH cartridge time versus average metabolic rates are shown in Figure A-2.
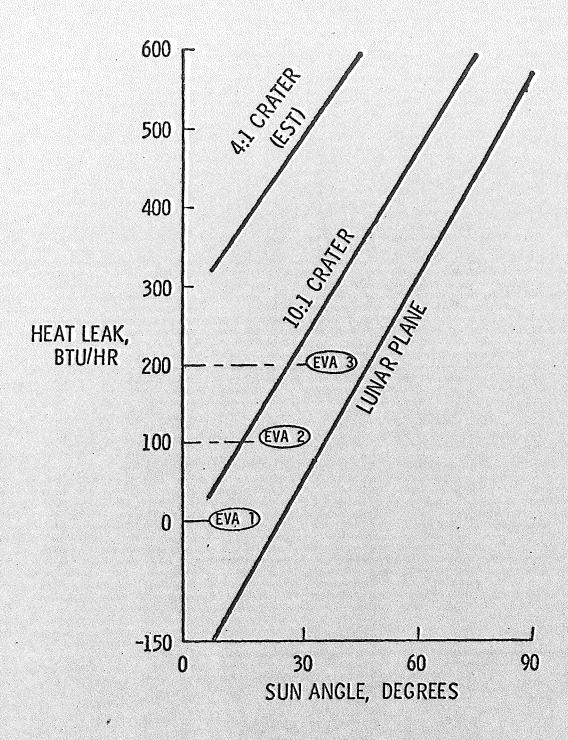
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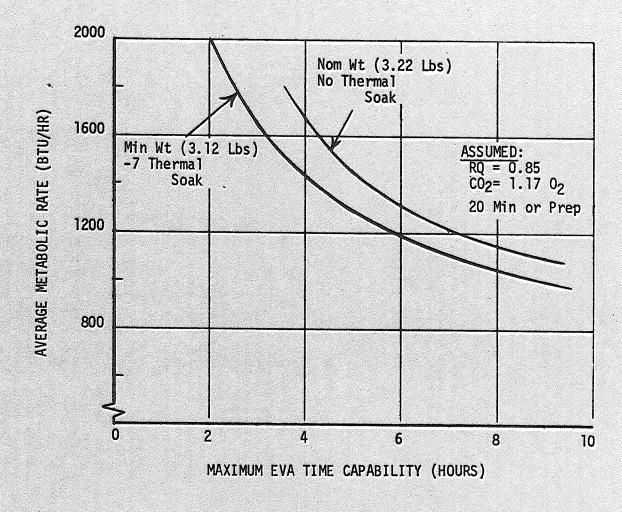Figure A-1. EMU Sun Heat Leak vs. Sun Angle

Figure A-2. -7 PLSS LiOH Performance

2. BACKUP LIFE SUPPORT SYSTEM

In the event of a PLSS malfunction during an EVA, backup life support is provided by the Buddy-Secondary Life Support System (BSLSS).

2.1 Buddy-Secondary Life Support System

The BSLSS utilizes a transport water buddy hose to provide cooling from a properly functioning PLSS to a failed PLSS which, in conjunction with one oxygen purge system, supports both crewmen during an emergency return to the LM.

2.1.1 Oxygen Purge System (OPS)

The OPS, mounted on top of the PLSS for EVA, is an independent high-pressure emergency oxygen supply that can provide oxygen for life support for a limited period of time. With the purge valve in the low flow position, the O_2 flow rate is 4.0 ± 0.2 pounds per hour. At this flow rate, the fully-charged OPS has an operational lifetime of 75 minutes. The OPS is precharged before launch to 5880 ± 80 psig, and there are no provisions for recharging the OPS during a mission.

2.1.2 BSLSS Operation

In the event of a PLSS failure, the crew must have the capability of returning to the LM with reserve metabolic capacity at least equal to emergency overhead and margin requirements. On a LRV mission, the assumption is that they would ride back to the LM.

If failure of a PLSS fan, LiOH cartridge or O_2 supply occurs, the crewman with the failed PLSS will actuate his OPS and place his purge valve in the low flow mode (4 lbs/hr) position, returning to the LM as rapidly as possible. In the event of a failure of a PLSS pump, battery, sublimator, sublimator feedwater supply, etc., both crewmen will then disconnect their LCG's from their PLSS water transport loops. The crewman with the failed PLSS will connect one end of a water umbilical (multiple H_2O connector end) to his PGA water connector. The crewman with the operating PLSS will then connect the other end of the water umbilical to his PGA water connector (flow divider end) and the water loop of his PLSS

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to the umbilical water flow divider. Cooling water flow is split equally between each crewman. A tether is provided as part of the umbilical to prevent straining of the water hoses or connections. Approximately 5 minutes is required for this emergency transfer, and an additional 13 minutes is required for LM ingress.

4.2.1.3 BSLSS Metabolic Capacity

The metabolic capacity of the BSLSS is limited by either; 1) the available feedwater from the functioning PLSS, or 2) the OPS time limit.

Duration of the OPS operating capability, based on the oxygen flow rate of 4 pounds per hour with the purge valve in the low flow position, is 1.25 hours. In general, the OPS capability is the limiting constraint on the BSLSS emergency return time.

Feedwater cooling capacity of the BSLSS for emergency return to the LM depends upon the prior usage of the PLSS before the failure occurred, and on the metabolic rates of the two crewmen during the return. The effective metabolic heat rate which the functioning PLSS feedwater must dissipate in the BSLSS mode is increased over the normal operating mode. The increase in effective metabolic rate is a major portion of the second crewman's metabolic rate plus the heat leak on his life support system. Heat loads from the electrical equipment and the $LiOH/CO_2$ reaction of the failed system do not enter into the effective metabolic rate on the BSLSS. The heat load on the functioning PLSS is:

$$\dot{Q}_{BSLSS} = \dot{Q}_{t_1} + \Delta\dot{Q}_{t_2}$$

where

$\dot{Q}_{t_1}$ = first crewman's effective heat rate on the functioning PLSS, BTU/hr

$\Delta\dot{Q}_{t_2}$ = increased heat rate on the functioning PLSS from the second crewman, BTU/hr

$\quad = [0.8 \, \dot{Q}_{met} + 0.70 \, \dot{Q}_{hl}]$

$\dot{Q}_{met}$ = crewman's metabolic rate, BTU/hr

$\dot{Q}_{hl}$ = EMU heat leak rate, BTU/hr

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LUNAR ROVER VEHICLE (LRV)

1. GENERAL

The crews of the Apollo J-type missions will use the LRV as the primary method of transportation for traverses on the lunar surface. The LRV will allow the astronauts to range further due to the increased speed and the reduced PLSS expendables rate during the transport phase of the traverse. The use of the LRV provides more time for lunar exploration, science experiments, and increased and more diversified lunar surface sampling.

2. DESCRIPTION

The LRV is battery powered, having drive motors on each of four wheels, and steering and control motors for the front and rear wheels. The LRV is designed to carry two astronauts and science payload at velocities up to 16 kilometers per hour on smooth level surface. The vehicle can be operated from either astronaut position as the control and display console is located on the vehicle centerline. The LRV layout, including dimensions, is presented in Figure B-1.

The primary areas of interest to be considered for lunar traverse planning using the LRV are speed and range.

2.1 Speed

The average speed presently used for planning traverses is <u>8.0 kilometers per hour</u> using ground distance. The speed chosen reflects corrections for terrain roughness, slopes, acceleration, deceleration, and soil characteristics.

The LRV Operations Handbook, Appendix A, Performance Data (Reference 8) contains detailed performance curves for LRV capabilities.

The rover speed used for determining the <u>emergency ride-back</u> capability of the rover using the BSLSS is <u>10 kilometers per hour</u>. The higher speed is used in this case because there is no requirement for an allowance for stopping (decelerations, acceleration) and the astronauts will drive as rapidly as possible.
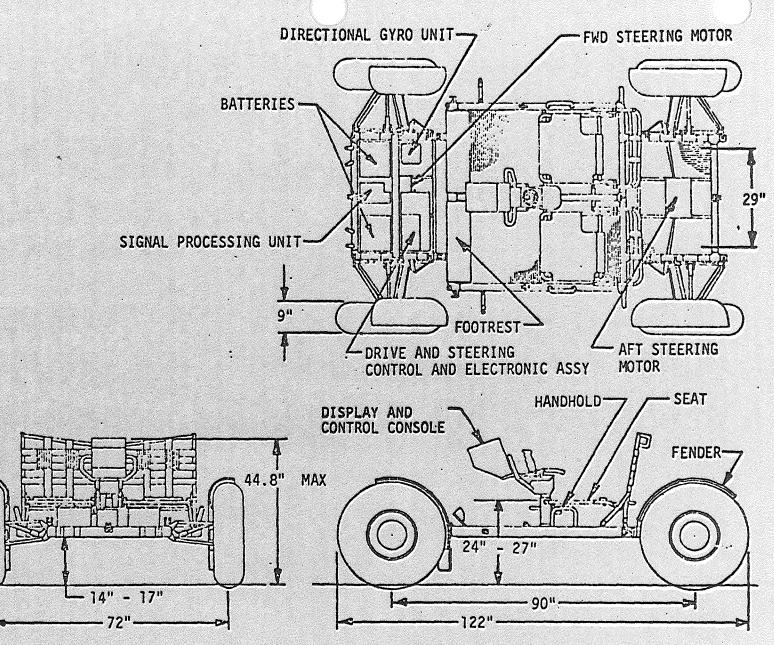
DIRECTIONAL GYRO UNIT — ⎺⎺⎤ ⎡— FWD STEERING MOTOR

BATTERIES —

SIGNAL PROCESSING UNIT —

29"

9"

FOOTREST —

DRIVE AND STEERING
CONTROL AND ELECTRONIC ASSY

AFT STEERING
MOTOR

DISPLAY AND
CONTROL CONSOLE

HANDHOLD — ⎡— SEAT

FENDER

44.8" MAX

24" - 27"

14" - 17"

90"

72"

122"

Figure B-1. Lunar Roving Vehicle

2.2 Range

The total range used for planning is 76 kilometers (Reference 9).

The range of the LRV is influenced by the lunar surface on which the LRV operates, the LRV speed, gross weight, number of starts and stops, and the method of operation (Ref. LRV Operations Handbook, Appendix A, paragraph 2.1.2.2).

This range of 76 kilometers is for the midrange power spectral density (PSD), fully loaded LRV (1502 pounds total weight); soil type B; smooth mare, 27 percent; rough mare, 27 percent; hummocky uplands, 27 percent; and rough uplands, 19 percent.

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9. R. G. Smith, "LRV Weight and Performance Status", NASA/MSFC Letter: PM-SAT-LRV-259-70(E), Sept. 21, 1970.