APPENDIX P

APOLLO 15 MISSION REQUIREMENTS

4.3 EMU ASSESSMENT ON LUNAR SURFACE

Assess EMU lunar surface performance, evaluate metabolic rates, crew mobility and difficulties in performing lunar surface EVA operation.

Purpose

The purposes are to demonstrate extravehicular mobility unit (EMU) performance on the lunar surface, evaluate metabolic rates and crew ability to accomplish lunar surface EVA operations.

The functional test objectives are as follows:

FTO 1) Demonstrate the capability of the EMU to provide a habitable environment during the EVA.

FTO 2) Demonstrate the capability of the EMU to provide sufficient mobility, dexterity and comfort to allow the crew to egress/ingress the LM and perform useful work on the lunar surface.

FTO 3) Demonstrate the capability to recharge the PLSS while in the LM on the lunar surface.

FTO 4) Evaluate the capability of the crew to perform EVA tasks on the lunar surface.

FTO 5) Obtain data to provide an indication of the primary water reservoir usage.

FTO 6) Obtain data for determining the metabolic rates as a function of riding the LRV over different types of lunar surface.

Test Conditions

FTO 1)
FTO 2)
FTO 3)
FTO 4) Operational performance will be evaluated during scheduled EVA activities. No specific tasks are required other than those activities in support of the detailed objectives and experiments to be conducted on the lunar surface.

FTO 5) During each EVA period PLSS telemetry data from both crewmen will be used by MCC for real time prediction of EMU water remaining.

During each EVA period the crew will voice transmit to MCC when the low feedwater pressure warning signals come on.

FTO 6) During the EVA periods PLSS telemetry data from both crewmen and voice information concerning departure and arrival times between discrete points will be used for prediction of metabolic rates as a function of riding the LRV over different types of lunar surface. It is highly desirable that the pre-selected points be separated such that at least 6 minutes are required for the astronauts to ride from one point to another point. There is no requirement to maintain a constant or specific driving rate; however, it is highly desirable to obtain data for a period of at least 6 minutes with the LRV continuously in motion. There is no requirement for the riding traverse to be accomplished over any specific type of lunar surface.

In addition, it is highly desirable that the same type of data be obtained during any substantial period of walking traverse.

Success Criteria

FTO 1) The EMU shall provide a habitable environment for the extra-vehicular crewmen on the lunar surface.

Sufficient data shall be obtained to evaluate the performance of the -7 PLSS and to determine the consumables required to perform the EVA.

FTO 2) The lunar surface excursion will be accomplished and completed within the -7 PLSS consumables budget and time allowed. The EMU shall provide sufficient mobility, dexterity and comfort to allow the crew to egress/ingress the LM.

FTO 3) The PLSS recharge procedures and hardware interface shall be satisfactory to the crew.

The battery shall be replaced.

The LiOH cartridge shall be changed.

The oxygen system shall be filled to minimum pressure of 1380 pounds.

The primary and auxillary water reservoirs shall be filled.

FTO 4) Sufficient data shall be obtained to evaluate the astronaut's capability to unload storage compartments, deploy equipment and experiments, operate the TV and still cameras and gather surface samples while in the lunar surface EVA environment.

FTO 5) Notification of when the low feedwater pressure warning signals
FTO 6) come on and PLSS data required to determine metabolic rates shall be obtained along with crew comments and estimates.

Evaluation

FTO 1) The adequacy of the EMU to provide a habitable environment will be assessed. (Astronaut records, MSFN recording of EVA-LM-MSFN conference voice and GT 9991 U)

FTO 2) Mobility, dexterity and comfort of the crew will be assessed. (Astronaut records and TV coverage)

FTO 3) Initial conditions of the PLSS for recharge will be determined. (GT 9991 U)

The oxygen supply pressure available to accomplish the recharge will be determined. (GF 0584 P)

The availability of water to accomplish recharge will be determined. (GF 4501 P)

The quantity of water used to refill each PLSS will be determined from the change in descent stage water tank pressure. (GF 4501 P)

The adequacy of the hardware for battery and LiOH cartridge replacement will be determined. (Astronaut records)

The extent to which the fill was accomplished will be determined. (GT 9991 U)

FTO 4) The adequacy of the hardware and procedures to accomplish lunar surface EVA operations will be determined. (Astronaut records, photographs, TV and GT 9991 U)

FTO 5) The primary water reservoir usage during each EVA period, as determined by crew comment of when the low feedwater pressure warning signals come on, will be compared to the real time predictions. The results will be used to update the present real time prediction model. (Astronaut records, RTCC data, GT 8110 P, GT 8125 J, GT 8154 T, GT 8182 P, GT 8196 T, GT 8210 P, GT 8224 J, GT 8254 T, GT 8282 P and GT 8296 T)

FTO 6) The results will be used to determine metabolic rate as a function of walking rate and for riding on the LRV. (Astronaut records, RTCC data, topographical data, GT 8124 J, GT 8154 T, GT 8170 T, GT 8182 P, GT 8196 T, GT 8224 J, GT 8254 T, GT 8270 T, GT 8282 P and GT 8296 T)

Data Requirements

1) Telemetry Measurements:

Measurement Number	Description	TM	Mode	Priority
GF 0584 P	Press, Descent O_2 Tank No 2	PCM	2	M
GF 4501 P	Press, Descent H_2O	PCM	1	M
GT 8100	EVCS No 1 Sync	FM/FM*	N/A	M
GT 8101 V	Volt, EVCS No 1 Calib 0 Pct	FM/FM*	N/A	M
GT 8102 V	Volt, EVCS No 1 Calib 100 Pct	FM/FM*	N/A	M
GT 8110 P	Press, PLSS Feed No 1 H_2O	FM/FM*	N/A	M
GT 8124 J	Electrocardiogram No 1	FM/FM*	N/A	M
GT 8140 C	PLSS Batt Current No 1	FM/FM*	N/A	M
GT 8141 V	Volt, PLSS No 1 Battery	FM/FM*	N/A	M
GT 8154 T	Temp, LCG H_2O Inlet No 1	FM/FM*	N/A	M
GT 8168 P	Press, PGA O_2 No 1	FM/FM*	N/A	M
GT 8170 T	Temp, PLSS No 1 Subl O_2 Outlet	FM/FM*	N/A	M
GT 8175 P	CO_2 Partial Press PLSS No 1	FM/FM*	N/A	M
GT 8182 P	Press, PLSS O_2 Supply No 1	FM/FM*	N/A	M
GT 8196 T	Delta Temp, LCG H_2O In/Out No 1	FM/FM*	N/A	M
GT 8200	EVCS No 2 Sync	FM/FM*	N/A	M
GT 8201 V	Volt, EVCS No 2 Calib 0 Pct	FM/FM*	N/A	M
GT 8202 V	Volt, EVCS No 2 Calib 100 Pct	FM/FM*	N/A	M
GT 8210 P	Press, PLSS No 2 Feed H_2O	FM/FM*	N/A	M
GT 8224 J	Volt, PLSS No 2 EKG	FM/FM*	N/A	M
GT 8240 C	Curr, PLSS No 2 Battery	FM/FM*	N/A	M
GT 8241 V	Volt, PLSS No 2 Battery	FM/FM*	N/A	M
GT 8254 T	Temp, LCG No 2 H_2O Inlet	FM/FM*	N/A	M
GT 8268 P	Press, PGA No 2	FM/FM*	N/A	M
GT 8270 T	Temp, PLSS No 2 Subl O_2 Outlet	FM/FM*	N/A	M
GT 8275 P	CO_2 Partial Press PLSS No 2	FM/FM*	N/A	M
GT 8282 P	Press, PLSS No 2 O_2	FM/FM*	N/A	M
GT 8296 T	Delta Temp, LCG No 2 H_2O In/Out	FM/FM*	N/A	M
GT 9991 U	EMU TM Outputs	FM/FM*	N/A	M

*Measurements GT 8100 through GT 8296 T are all parts of measurement GT 9991 U.

2) Astronaut Logs or Voice Records:

a) The crew will notify MSFN of the initial and final positions of the PLSS water diverter valve, primary oxygen shutoff valve, and water shutoff/relief valve each time they are changed. (M)

b) The crew will notify MSFN whenever the following PLSS remote control unit status indicators and audible warning tone come on. (M)

(1) High O_2 flowrate

(2) Low vent flow

(3) Low feed water pressure

(4) PGA pressure low

c) The crew will record EMU radiation dosimeter readings prior to and after completion of the extravehicular activities. (M)

d) The crew will notify MSFN whenever the following occur. (HD)

(1) Noxious odors, if any

(2) Condensation, if any, on the visor assembly

e) The crew will comment on their estimated energy expenditure and comfort as compared to their simulation experience. (HD)

f) Comments on the adequacy of procedures for oxygen refill, water refill, battery replacement and LiOH cartridge replacement. (M)

g) Comments on difficulties, if any, encountered during the use of LM and PLSS hardware for oxygen refill, water refill, battery replacement and LiOH cartridge replacement. (M)

h) Comments on the adequacy of hardware and procedures, and the time required to perform the egress from the LM, the lunar surface EVA operations and the ingress to the LM. Records may be obtained from postflight debriefings, from voice records recorded by MSFN, DSEA or DSE, or from written logs. (M)

i) Subjective comments on estimations of workload for EVA tasks. (HD)

j) Estimate of general surface conditions and maximum speed reached while riding the LRV between each set of discrete points. (M)

k) GET for departure and arrival times at discrete points in the riding traverse. (M)

l) GET for departure and arrival times at discrete points in any walking traverse. (HD)

m) GET for start and stop of any rest period during any riding traverse between discrete points. (M)

n) GET for start and stop of any rest period during any walking traverse between discrete points. (HD)

3) Sequence Photographs: (HD)

a) A crew member descending to the lunar surface.

b) A crew member walking on the lunar surface.

c) A crew member performing lunar surface EVA operations.

4) Television: (HD)

Ground recorded television signals of:

a) A crew member descending to the lunar surface.

b) A crew member performing lunar surface EVA operations to include:

- Carrying and deploying the ALSEP
- Mounting and demounting the LRV
- Unstowing and preparing the LRV for traverse

c) A crew member ascending the LM ladder and ingressing into the LM.

5) MSFN recording of EVA-LM-MSFN and EVA-MSFN conference voice. (M)

6) RTCC data: (M)

RTCC data reduction of metabolic data for correlation to water flow data.

7) Topographical data: (M)

Distance and terrain profile between the selected points in the traverse as determined from photomaps.

4.3 EMU ASSESSMENT ON LUNAR SURFACE

Background and Justification

This objective is essential on the mission since the success of the lunar surface operations is dependent on the capability of the extra-vehicular mobility unit to provide the astronauts a habitable environment. This is the first time the -7 PLSS's and the A7LB PGA will be used on the lunar surface.

The -7 PLSS is similar to the -6 PLSS with the following additions:

- Increased charge pressure and capacity of O_2. The initial nominal charge pressure is increased from 1020 psia to 1410 psia for a useable O_2 quantity of 1.35 pounds, as opposed to 0.96 pounds. A
- Increased H_2O capacity from 7.39 to 10.86 pounds. A
- Increased battery capability from 5.67 to 7.5 hours of PLSS operation.
- Increased LiOH

The LM recharge station has been modified to provide a regulated minimum output O_2 pressure at 1380 as compared to the previous 980. However, after the O_2 reservoir is depleted below 1380 psia the regulator locks up.

The A7LB PGA contains modifications to the A7L PGA as follows:

- Addition of a joint in the neck area to improve mobility and downward visibility.
- Addition of a bellows joint in the waist to allow forward bending mobility.
- Addition of a total bladder and convolute abrasion reinforcement to increase gas retention layer mobility.
- Movement of the torso zipper from the crotch to the chest area necessitated by the waist bellows. This results in better leg mobility.
- Modification of the shoulder area to reduce torque requirements for shoulder movement.
- Addition of a thumb joint for greater grasping ability.

- Enlargement of the wrist ring to permit easier and faster glove donning and doffing.
- Increase of the available liquids to be used for drinking.

One PLSS was recharged on Apollo 9 in an earth orbit zero-g environment with no problems reported. Although the mission provided flight experience it was not the -7 PLSS and it did not provide the combination of environmental factors experienced during a lunar surface PLSS recharge.

Apollo 11 and 12 missions provided data on metabolic rate and EMU operation during the lunar surface exploration, emplacement of experiments and performance of other lunar surface EVA tasks. Apollo Mission 12 provided additional data on recharging two PLSS's in the confinement of the LM cabin following an EVA on the lunar surface. However, both the PGA, PLSS and LM recharge stations have been modified from those used for Apollo Missions 11 and 12.

The major concern of the EMU is the heat loads that will be handled by the portable life support system (PLSS) which involve the removal of metabolic and equipment heat generated within the space suit system plus removal of thermal inputs from the lunar environment. The PGA designated for this mission (i.e., A7LB) has been designed to withstand PGA surface temperatures that will be encountered during extended EVA periods on the lunar surface. The portable life support system has also been designed to handle 300 BTU/hr heat leak inward over and above the anticipated crewman's metabolic rate.

Data obtained by this objective will enhance the planning of future missions and provide increased confidence in the models used for prediction of metabolic rates and EMU operation. The crew's ability to perform various EVA tasks and the expected time to perform these tasks will be determined for future missions.

Previous Flight Objectives

Objective Number	Title	Mission
20.35	Extravehicular Activity	9
14	LM ECS Performance	9
B	Lunar Surface EVA Operation	11
C	EMU Lunar Surface Operations	11
C	PLSS Recharge	12

Author file

NOV 3 1971

EC13-71-056

MEMORANDUM

TO: PA/Manager, Apollo Spacecraft Program

FROM: EC/Chief, Cfew Systems Division

SUBJECT: Apollo 15 Objective Assessment Report

As requested in your memorandum PD12/L208-71, the EMU assessments on the lunar surface for Functional Test Objectives 1, 2, 3 and 4 have been prepared, and are enclosed for your information and review.

Original Signed By:
FRANK H. SAMONSKI, JR.
Robert E. Smylie

Enclosure

cc:
PD12/J. Peacock
EC2/J. Gibson

EC13/EJNitsch:drc:10-28-71:4823

EC13/RLS EC13/PFH EC/FHS

ENCLOSURE

FTO 1

During the three EVAs the EMU consumables were constantly monitored by telemetry and crew EMU status checks. Both crewmen indicated they could maintain comfort levels to their individual satisfaction by changing the EMU temperature controls as required. The crewmen stated that at no time did they become concerned about the EMU not maintaining a safe and satisfactory environment.

In summary, the EMU performance during the EVAs was excellent and there are no recommendations for hardware changes to improve the habitability of the EMU as a result of this assessment. Therefore, the requirements for FTO 1 are considered satisfied.

FTO 2

The EMU demonstrated that crew egress/ingress of the LM and lunar surface operations could be performed with reasonable dexterity and comfort. In particular, the crew demonstrated that getting on and off the LRV could be accomplished easier than anticipated and that the EMU did not hinder the LRV operations. The CDR stated that the LRV handled quite well as far as controllability with the EMU and there were no fatigue problems in the arm. Also, there were no visibility problems when driving the LRV.

On the lunar surface, there were no planned tasks which could not be performed because of the limitations imposed by wearing the EMU. However, the crew stated that the new PGA waist joint could not be used to full advantage when bending over on the lunar surface because they would lose their balance and because the soil was so loose they lost their footing.

In summary, the crew demonstrated that the EMU provided sufficient comfort, mobility and dexterity to perform the lunar surface operations and tasks required by the Lunar Surface Procedures, and no EMU hardware changes are recommended as a result of this assessment. Therefore, the requirements of FTO 2 are considered satisfied.

FTO 3

The PLSS oxygen reservoirs were initially charged during the preflight preinstallation tests. Prior to EVA 1, the POS (Primary Oxygen Supply) pressure of PLSS #1 (CDR's) was 1393 PSIA and PLSS #2 (LMP's) was 1370 PSIA as indicated on PLSS telemetry channels GT8182P and GT8282P.

FTO 3 (continued)

The initial water charge of both PLSS's for EVA 1 is unknown and cannot be directly determined from LM data. However, metabolic determination indicated both PLSS's had good charges even though the LMP's PLSS was at an estimated 30° angle during recharge which did not allow proper venting. The 30° angle allowed a gas bubble to remain in the feedwater reservoir which displaced approximately .26 pounds of feedwater. This did not affect the EVA 1 durations but did give an initially high feedwater pressure at the beginning of the EVA.

Oxygen recharges prior to EVA II were completed at 120:45 GET. Top-offs on both PLSS's were completed at 129:35. PLSS telemetry channels GT8182P and GT8282P indicated both PLSS's had good oxygen charges as the CDR and LMP PLSS's begin EVA II with POS pressures of 1360 and 1365 PSIA, respectively.

As in EVA 1, metabolic determinations indicate that both crewmen had good water recharges prior to EVA II. The LMP's PLSS was topped off a second time with the PLSS in the vertical position to ensure a gas bubble was not trapped in the reservoir. The fact that a higher than normal feedwater pressure did not occur at the beginning of the EVA also indicated a full recharge.

The POS pressures at the start of EVA III were 1385 PSIA and 1390 PSIA for PLSS #1 and PLSS #2 respectively indicating good oxygen recharges. Initial recharges were completed at 150:00:00, and top-offs were completed at 152:05:00 and 153:00:00 in PLSS #1 and PLSS #2 respectively.

The water recharges on the PLSS's in EVA III were extended from a 5 to a 10 minute period due to a lower than normal LM water pressure. Because of the short EVA III time, metabolic determination could not be adequately used to verify a full water recharge. However, visual observations of the vent sight glass by the crew and normal feedwater pressures at the beginning of the EVA indicated good water charges.

The battery and LIOH cartridge replacements were uneventful and normal for all three EVAs based on the voice tapes and debriefing questions.

In summary, the capacity to recharge the PLSS's in the LM has been adequately demonstrated and no EMU hardware changes were recommended by the crew. Therefore, the requirements for FTO 3 are considered satisfied.

FTO 4

FTO 4 assessments are covered in FTO 2.

PD12/L208-71

OCT 01 1971

TO: Distribution

FROM: PA/Manager, Apollo Spacecraft Program

SUBJECT: Apollo 15 Objective Assessment Report

Reference is made to the Apollo 15 Mission Requirements document dated July 1971.

The above reference assigned 90-day reports to the individual points of contact for the following detailed objectives and operational tests:

Detailed Objectives	Point of Contact
Lunar Rover Vehicle Evaluation	FC9/J. H. Cooper MSFC/W. R. Perry, PM-SAT-LRV
EVA Communications with LCRU/GCTA	
FTO 1, 3, 4, 5	EE16/R. L. Sinderson
FTO 2, 5	EE2/W. E. Perry
FTO 2 (for use of TV on lunar surface after LM liftoff)	TN6/W. C. Phinney
EMU Assessment on Lunar Surface	
FTO 1, 2, 3, 4	EC/R. E. Mayo
FTO 5, 6	DD5/G. F. Herbert
LM Landing Effects Evaluation	ES12/W. F. Rogers
SM Orbital Photographic Tasks	TD4/S. N. Hardee
CM Photographic Tasks	TD4/S. N. Hardee

Detailed Objectives	Point of Contact
SIM Thermal Data	ES16/J. A. Smith
SIM Bay Inspection During EVA	CG3/J. F. Ellis
SIM Door Jettison Evaluation	ES12/G. W. Sandars
LM Descent Engine Performance	EP2/W. R. Hammock
Visual Observations from Lunar Orbit	TD4/S. N. Hardee
Visual Light Flash Phenomenon	DC7/R. E. Benson

Operational Tests	Point of Contact
Lunar Gravity Measurement	TF5/R. L. Nance
LM Voice and Data Relay	EE7/A. D. Travis

These reports should be addressed to the Manager, Apollo Spacecraft Program with a copy to PD12/James M. Peacock, Apollo 15 Mission Staff Engineer.

If additional data or information are required to complete the assessment, please contact PD12/James M. Peacock, extension 2457.

Original Signed By
JAMES A. McDIVITT

James A. McDivitt
Colonel, USAF

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