BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Use of a Battery from the Extended LM to Power a Lunar Roving Vehicle
Case 620

DATE: January 25, 1968

FROM: J. Gillespie

ABSTRACT

Two methods of using an ascent battery from an ELM electrical power system configuration consisting of three ascent batteries and a solar array to power a lunar roving vehicle (LRV) have been examined. The ELM performance is not affected by use of one ascent battery to power the LRV. The ranges and effect of a single battery failure on a LRV are discussed. With battery recharge the LRV can be used for a maximum range even with a single battery failure.

(NASA-CR-93384) USE OF A BATTERY FROM THE EXTENDED LM TO POWER A LUNAR ROVING VEHICLE (Bellcomm, Inc.) 9 p

N79-72946

Unclas
00/44 11092

FF No. 602

CR-93384
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

[redacted]

MAR 1968
RECEIVED
NASA STI FACILITY
INPUT BRANCH

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Use of a Battery from the Extended LM to Power a Lunar Roving Vehicle
Case 620

DATE: January 25, 1968

FROM: J. Gillespie

MEMORANDUM FOR FILE

INTRODUCTION

It has been suggested that the effective landed weight of a lunar roving vehicle can be reduced by transferring a battery from the Extended LM (ELM) to the lunar roving vehicle (LRV).*

One of the electrical power system modifications to the ELM would substitute three ascent batteries and a solar array for the present four LM descent batteries.** There is a battery redundancy to permit a descent and landing with a single battery failure. The number and type of batteries is determined by the electrical current requirements during checkout and descent.

This memorandum examines two methods of using one battery for the LRV from a three ascent battery-solar array approach for the ELM to determine:

1. Energy available to power the LRV and the resulting range

2. Effect of a single battery failure.

LUNAR ROVING VEHICLE SPECIFIC ENERGY REQUIREMENTS

Estimates of specific energy required for a 1000 lb, fully-loaded lunar roving vehicle with an average velocity of 5 miles/hr (8 KM/hr) range from .052 to .082 Kw-Hr/KM. The upper value of .082 Kw-Hr/KM has been chosen for the range calculations presented in this memorandum.

---

* LRV Presentation at MSC, November 13, 1967 by L. Bradford/MSFC.

**"AAP Lunar Mission Study Appendix C.2 Candidate LM Derivatives," Grumman Report 3 78C-17, June 1967.

THREE BATTERIES INITIALLY SHARING LOAD THROUGH ELM DESCENT

The first configuration would employ all three batteries during the descent phase. This would require the removal of one battery from the ELM power supply configuration and its installation in the LRV after descent.

During the descent phase, with each battery equally sharing the load, the energy consumed from each battery is approximately 3.6 Kw-Hr. The ascent batteries are rated at 9.3 Kw-Hr, leaving 5.7 Kw-Hr available for powering the LRV. The single ascent battery would then give a range of 43.5 miles (70 KM) if taken down to a full discharge. However, it would be possible to recharge the ascent battery with the solar array before about 60% depth of discharge.

TWO BATTERIES INITIALLY SHARING LOAD THROUGH ELM DESCENT

The second configuration would employ only two batteries during the descent phase. The third battery would be available to the ELM, but could be located on the lunar roving vehicle. This would offer the advantage of reducing astronaut time, energy, and risk in placing a battery in the LRV. With this configuration the full 9.3 Kw-Hr of the ascent battery would be available for powering the lunar roving vehicle. This would give a range of 72.5 miles (116 KM) if taken down to full discharge.

SINGLE BATTERY FAILURE IN ELM ELECTRICAL POWER SYSTEM

The question of a single battery failure in connection with the two configurations previously discussed should be considered. The effect on the ELM and LRV mission is summarized in Table 1. In all cases of single battery failure the ELM mission can be completed. The LRV mission depends on the time of failure, which affects the battery energy remaining for the LRV, and whether batteries can be recharged on the surface by the solar array. Three failure times are considered: 1) failure at launch, 2) failure at a time when remaining ELM energy requirements first allow use of an LRV, 3) failure after completion of descent.

In all cases, if the batteries can be recharged on the lunar surface, one battery is sufficient for the remaining ELM electrical power profile and the second battery is sufficient to power the LRV for a maximum of 72.5 miles (116 KM).

For the case of no battery recharge, the LRV mission depends on the time of failure and the battery configuration.

If there is a single battery failure before approximately 2.4 Kw-Hr of energy consumption in the three battery method, the LRV cannot be used. After this period the range of the LRV varies from 32.5-43.5 miles (52-70 KM), depending on time of failure.

If there is a single battery failure before approximately 0.8 Kw-Hr of energy consumption in the two battery case, the LRV cannot be used. The battery reserved for the LRV then must be used in conjunction with the remaining battery in the electrical power supply system in order to satisfy ELM requirements. After landing, the battery reserved for the lunar roving vehicle must remain with the solar array and the partially discharged ELM battery used for the rover. This battery will give the rover a range of 30 miles (48 KM). The calculation of 2.4 Kw-Hr and .8 Kw-Hr is discussed in Appendix I.

BATTERY FAILURE IN THE LUNAR ROVING VEHICLE

The question of battery failure as a single point failure in the LRV must be considered.

It has been suggested as a safety feature that the LM ascent battery might be modified to be split into two independent segments of ten cells each. Normal operation would be on 20 cells in series; however, half could power the LRV independently of the other. Thus, if one half failed there would be a degraded mode of operation at half voltage for astronaut return to the ELM. A second battery could be taken from the ELM and used to complete the LRV sorties without affecting the ELM mission.

The most likely failure would occur in a single cell.* This suggests that the battery might be modified so that individual cells could be bypassed in case of failure. This would require a cell testing device for location and individual cell connections for isolation of the failure. This approach is more complicated than simply splitting the battery into two segments, but reduces battery voltage and available energy for degraded mode operation by only 1/20 rather than 1/2. In this case, it is less likely that the astronaut would have to transfer a second battery from the ELM to continue LRV operations.

---

*Private communication, B. W. Moss, Bellcomm.

Table I

EFFECT OF SINGLE BATTERY FAILURE

THREE BATTERIES EQUALLY SHARING LOAD THROUGH ELM DESCENT

TIME OF FAILURE	RESULT IF BATTERIES NOT RECHARGED ON SURFACE	RESULT IF BATTERIES RECHARGED ON SURFACE
At Launch	Mission can be completed but without use of LRV	Mission can be completed with use of LRV. Range: 72.5 miles (116 KM)
After consumption of 2.4 Kw-Hr of energy	Mission can be completed with use of LRV. Range: 32.5 miles (52 KM)	LRV Range increased to 72.5 miles (116 KM)
After Descent	Mission can be completed with use of LRV. Range: 43.5 miles (70 KM)	LRV range increased to 72.5 miles (116 KM)

TWO BATTERIES EQUALLY SHARING LOAD THROUGH ELM DESCENT

At Launch	Mission can be completed but without use of LRV	Mission can be completed with use of LRV. Range: 72.5 miles (116 KM)
After consumption of 0.8 Kw-Hr of energy	Mission can be completed with use of LRV. Range: 30 miles (48 KM)	LRV range increased to 72.5 miles (116 KM)
After Descent	Mission can be completed with use of LRV. Range: 30 miles (48 KM)	LRV range increased to 72.5 miles (116 KM)

SUMMARY AND CONCLUSION

1. The ELM performance is not affected by use of one ascent stage battery to power the LRV.

2. An ascent battery may be installed in the LRV before launch with the two battery method reducing astronaut time, energy, and risk.

3. The two battery method offers greater LRV range if no battery failure occurs.

4. Battery recharge gives maximum LRV range with both methods even with a single battery failure.

5. The three battery method offers greater LRV range than the two battery method if a single battery failure occurs.

6. Batteries will be discharged at equal rates with the three battery method if a single battery failure occurs.

7. With the two battery method if a failure occurs after .8 Kw-Hr of energy consumption the lunar roving vehicle may be used. This compares with a requirement of 2.4 Kw-Hr energy consumption in the three battery case.

8. In the case of a battery failure on the LRV the ascent battery could be designed to isolate single cell failures, thus providing a degraded mode of operation.

1022-JG-mef

J. Gillespie

Attachment
Appendix I

APPENDIX I

After descent the ascent batteries must supply 4.3 Kw-Hr of energy in conjunction with the solar array in order to complete the surface mission and pre-launch checkout. In the case of a single battery failure, one of the remaining batteries must by itself supply 4.3 Kw-Hr of energy if an LRV is to be used. Thus, one of the remaining batteries must not use more than 5 Kw-Hr of energy during descent if 4.3 Kw-Hr is to remain. This stage is reached at the end of 2.4 Kw-Hr of energy consumption in the three battery case. If a battery failure occurs at this time the remaining two batteries must each supply 4.2 Kw-Hr further energy in order to satisfy the ELM requirements of 10.8 Kw-Hr through descent. Thus each battery has used 5 Kw-Hr during descent and 4.3 Kw-Hr is available in each battery for completion of the ELM mission and powering an LRV. In the two battery case, the battery reserved for the LRV must use only 5 Kw-Hr if the LRV is to be used. This would occur if battery failure occurred at .8 Kw-Hr in the two battery method. It should be emphasized that these values assume that the batteries are fully discharged.

The energy requirements for each battery with and without a single battery failure are summarized below:

ELM:	Descent requirement	10.8 kw-hr
	Lunar stay and pre-ascent checkout requirement (before going to ascent stage batteries)	4.3 kw-hr
	Total ELM requirement	15.1 kw-hr

Battery energy: 9.3 kw-hr per-battery to full discharge

Configuration: 3 batteries and solar array (used only during lunar stay).

Three battery case

- Descent - 3 batteries on line sharing load equally
- Lunar stay & pre ascent - 2 batteries on line sharing load equally
  - 1 battery in LRV during stay

Two battery case

- Descent - 2 batteries on line sharing load equally
- Lunar stay - 2 batteries on line sharing load equally
  - 1 battery reserved for LRV during descent and stay

ENERGY REQUIREMENTS PER BATTERY (KW-HR)

3 Battery Case: No Failure

		Battery A	Battery B	Battery C	TOTAL A+B+C
ELM	Descent	3.6	3.6	3.6	10.8
	Stay	2.15	2.15	-	4.3
	LRV	-	-	5.7	5.7
	Energy Per Battery	5.75	5.75	9.3	

3 Battery Case: One Battery Failure

ELM	Descent before failure	0.8	0.8	0.8	2.4
	after failure	4.2	4.2	Fail	8.4
	Stay	4.3	-	-	4.3
	LRV	-	4.3	-	4.3
	Energy Per Battery	9.3	9.3	Fail	

2 Battery Case: No Failure

ELM	Descent	5.4	5.4	-	10.8
	Stay	2.15	2.15	-	4.3
	LRV	-	-	9.3	9.3
	Energy Per Battery	7.55	7.55	9.3	

2 Battery Case: One Battery Failure

ELM	Descent before failure 0.8	0.4	0.4	-	.8
	after failure	5.0	Fail	5.0	10
	Stay	-	-	4.3	4.3
	LRV	3.9		-	3.9
	Energy Per Battery	9.3	Fail	9.3	

BELLCOMM, INC.

Subject: Use of a Battery from the Extended LM to Power a Lunar Roving Vehicle

From: J. Gillespie

Distribution List

NASA Headquarters

Messrs. R. J. Allenby/SL
D. A. Beattie/MTL
H. Cohen/MLR
P. E. Culbertson/MLA
J. H. Disher/MLD
J. A. Edwards/MLO
L. K. Fero/MLV
J. P. Field, Jr./MLP
P. Grosz/MLT
R. W. Johnson/MTL
T. A. Keegan/MA-2
C. W. Mathews/ML
W. T. O'Bryant/SL
M. Savage/MLT
L. R. Scherer/SL

MSC

Messrs. S. M. Andrich/ET
H. E. Gartrell/KF
W. N. Hess/TA
W. R. Humphrey/ET
T. R. Kloves/KF
A. J. Meyer/ET
W. E. Stoney/ET

MSFC

Messrs. L. L. Bradford/R-AS-P
R. D. Stewart/I-SS-AA
O. H. Vaughn/R-AERO-Y

Bellcomm

Messrs. A. P. Boysen
D. R. Hagner
W. C. Hittinger
B. T. Howard
J. Z. Menard
I. D. Nehama
I. M. Ross
R. Sehgal
D. R. Valley
R. L. Wagner
Div. 101 Supervision
All Members Dept. 1021, 1022, 1024
Department 1023
Central File
Library