ALSEP Flight System 6 (Array E) System Level Failure Mode Effects and Criticality Analysis

This ATM contains the system level Failure Mode, Effect, and Criticality Analysis (FMECA) and Single Point Failure summary (SPFS) for the Array E ALSEP. It has been prepared in accordance with the requirements of the reliability program plan for NASA/MSC Contract NAS 9-5829.

This document was originally issued prior to the PDR, and has been previously updated (rev. A) to reflect changes in the central station between the PDR and CDR. This revision (B) reflects the changes that have been made since the CDR.

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INTRODUCTION

The objective of this FMECA is to identify those failure modes constituting single point failures and other failure modes peculiar to the Array E design which exist in the ALSEP Flight 6 system.

The reliability of the Central Station has been increased from the 93.2% for one year of lunar surface operation to 98.8% over two years of operation. This improvement has been achieved through redesign of the most critical assemblies, additional redundancy, and the use of integrated circuits which have a higher reliability than their equivalent discrete counterparts. In the central station, five of the electronic components have been redesigned: the Command Decoder (CD) Data Processor (DDP/ADP), Power Conditioning Unit (PCU), Power Distribution Unit (PDU) and the S-band Transmitter (XMTR). The redundant command receiver (RCVR), diplexer filter and diplexer switch are the same type units as flown in Array D.

The experiments do not have the redundancy that the central station possesses because of weight, power, and volume constraints. Failure modes exist which can degrade or cause partial loss of the scientific and engineering data; however, for this report, the reliability predictions shown represent the probability of success for each experiment after two years of lunar operation. LSPE is an exception, in this case mission success requires only 200 hours during the two year lunar lifetime.

FMECA AND SPFS

In this analysis, failure modes of the following type are considered:

I. loss of all scientific data
II. loss of uplink or control of system
III. partial loss of scientific data
IV. partial loss of housekeeping data.

Failures in which functionality may be restored by switching to a redundant unit are of second order importance and have not been included in this systems analysis.

Failure modes with a criticality rank of I or II (see above) are termed "System Single Point Failure Modes". These failures are summarized below:

Assembly	Failure Mode	Failure Probability $Q \times 10^{-5}$
Antenna Assembly	1. Open or short in impedance matching transformer	92.00
	2. Mechanical binding or cold welding of antenna aiming mechanism	
	3. Mechanical damage to antenna elements prior to ALSEP deployment	
	4. Defective connectors or coaxial cabling problems	
Diplexer Circulator Switch	1. Connector failures	0.28
	2. Mechanical damage to construction of either circulator	
Diplexer Filter	1. Open in band pass filter coaxial elements	108.00
	2. Mechanical damage to cavity elements - pick-offs and tuning stubs	
	3. Connector or internal junction failures	
Receiver	1. Open or short in RF connector	2.62
Command Decoder Output Gates	1. Short in Output transistor in output gates for CLOOLIZN signal and EXFZN signal.	2.20

Although each of the failure modes of criticalities I and II identified above constitutes a potential loss of system, it has been established through acceptance and qualification testing of the ALSEP systems that the design safety margins and redundancy utilized have provided a reliable design and that a successful lunar surface performance for two or more years can be confidently expected.

Failure modes of criticality rank III and IV are less serious than I and II, since even though system capability would be reduced, partial science data is still available. All failure modes of criticality ranks I through IV existing in the Array E central station design have been summarized in Appendix A, with the appropriate ranking noted in the last column. The critical failure modes in each of the Array E experiments are identified in the experiment level FMECA's:

ATM - 1008 Lunar Seismic Gravimeter Experiment (LSG)

ATM - 1013 Lunar Ejecta & Micrometeorite (LEAM)

ATM - 970 Lunar Mass Spectrometer (LMS)

ATM - 976 Lunar Seismic Profiling Experiment (LSPE)

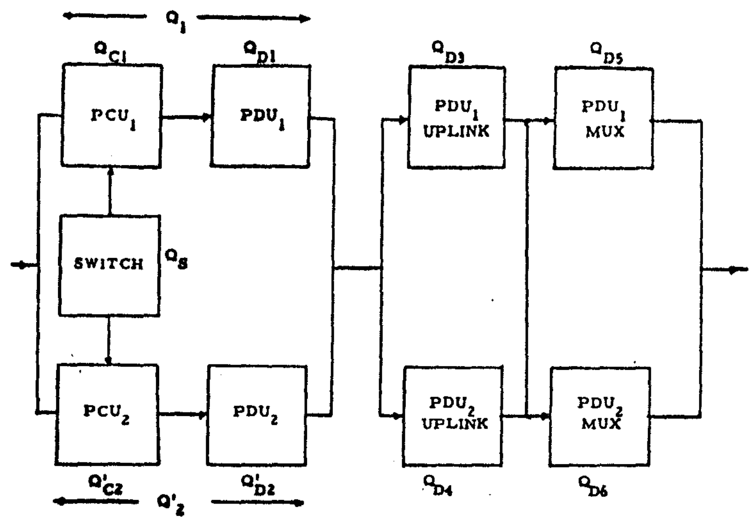
ATM - 501B-1 Heat Flow Experiment (HFE)

The Parts Application Analyses and FMECA's for each of the central station components has been reviewed for change since CDR. Appendix B identifies these documents and summarizes the FMECA changes. The PAA changes are identified in Reliability memorandum 9721-2927, dated 16 August 1972.

RELIABILITY PREDICTION

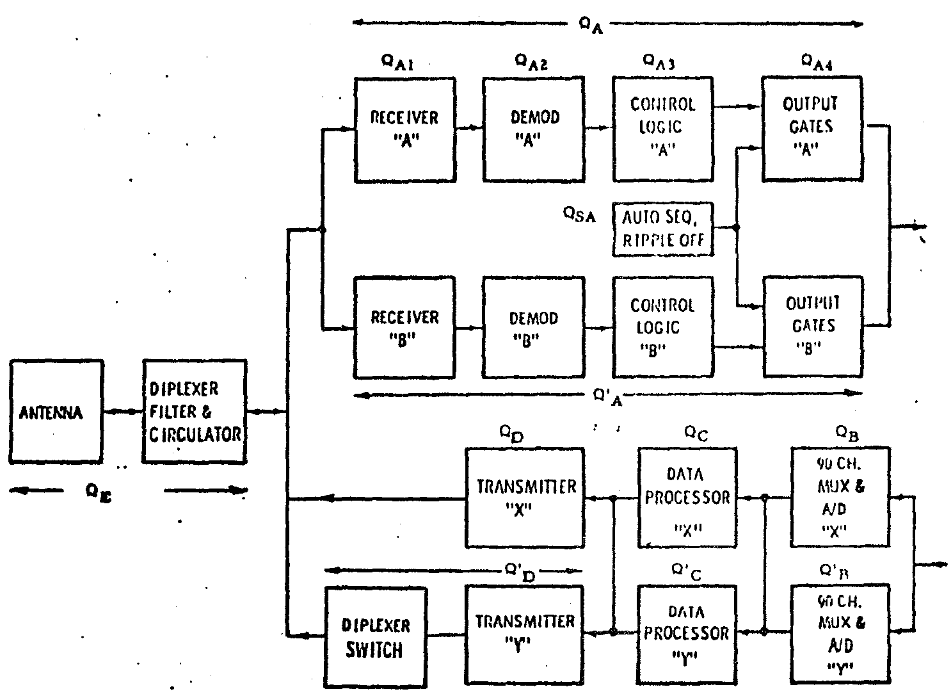
The reliability prediction for the central station, (data and power subsystems) is based upon the math models shown in figure 1. The prediction for the central station has increased to .9878 for 2 years over the Array D prediction of .9320 for 1 year. Table I presents these predictions, broken down to the major component level for ease of comparison. The redesign of the power subsystem and the added UPLINK redundancy are primarily responsible for this significant improvement in the overall reliability. In Figure 1, Q is the symbol for probability of failure in two years; Q_P is the power subsystem's failure probability and Q_{DATA} is the data subsystem's.

ALSEP ARRAY E POWER SUBSYSTEM RELIABILITY BLOCK DIAGRAM



$$Q_{PWR} = \frac{(Q_{C1} + Q_{D1})^2}{2} + (1-Q'_2)\, Q_1\, Q_S + \frac{(Q'_{C2} + Q'_{D2})^2}{2} + Q_{D3}\, Q_{D4} + Q_{D5}\, Q_{D6}$$

DATA SUBSYSTEM RELIABILITY BLOCK DIAGRAM



$$Q_{DATA} = Q_E + \frac{Q^2_A}{2} + Q_A\,(1-Q'_A)\,Q_{SA} + \frac{Q'^2_A}{2} + \frac{1}{2}\left(Q^2_B + Q'^2_B + Q_C^2 + Q'^2_C + Q_D^2 + Q'^2_D\right)$$

FIGURE 1

RELIABILITY COMPARISON OF ARRAY D AND E FOR 2 YEAR PERFORMANCE

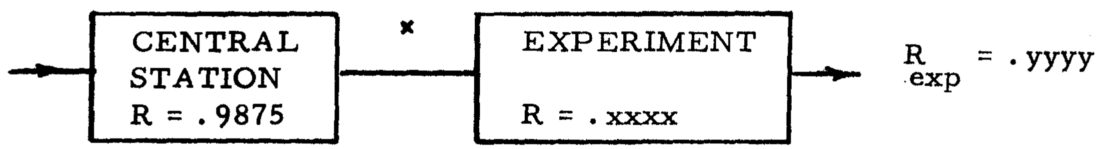
	ARRAY D	ARRAY E
CENTRAL STATION	.7632	.9878
Power Subsystem	.8223	.9991
PCU	.8651	.9998
PDU	.9505	.9995
RTG	1.0000 (assumed)	1.0000 (assumed)
UPLINK	.9412	.9987
CD	.9445	.9993
RCVR	.9994	.9994
ANTENNA	.9948	.9948
DOWNLINK	.9932	.9953
XMTR	.9994	.9996
DDP	.9984	.9995
MUX & A/D	.9953	.9961
ANTENNA	.9948	.9948
DIPLEXER FILTER	.9979	.9979

Table I

Array E C/S Reliability Prediction

The probability of full success for each experiment has been calculated as the product of the central station prediction and each experiment prediction on an individual experiment basis as indicated in figure below. The results of these computations have been summarized in table II below. The digital data processor has a filter capacitor on each data demand line and these critical failure modes are included in the reliability prediction for each experiment.

CENTRAL STATION EXPERIMENT RELIABILITY
BLOCK DIAGRAM



Experiment	2 years	Mission Success	Mission Success Remarks
LSG	.9011	.9096	Excludes HK data
LEAM	.7758	.9345	Assumes East, Up, West sensors function totally for 6 months, and 18 additional months without microphones; excludes HK data
LMS	.8655	.9266	Assumes at least mass count data on all three channels available for 2 years
HFE	.6450	.8040	Previously qualified experiment, assumes one year of lunar operation
LSPE	.9684	.9843	2 year prediction for listening mode only; LSPE CE must work for only 200 hours, times for 90 hours, thermal battery $\leq$ 1 hour.

Table II. Array E Experiment Reliability Prediction

CONCLUSION

Design improvements in the Array E ALSEP design have increased the reliability of the overall ALSEP system for the Apollo 17 flight. Presently ALSEP Arrays A, C, and D are operating reliably on the lunar surface, with the Array A of Apollo 12 having logged in excess of 24,000 hours. Therefore, any improvement in the overall system reliability is an improvement on a unit of demonstrated reliability. It is therefore concluded that ALSEP Flight System 6 will perform its intended function after lunar deployment with a higher probability of mission success than any previous Array.

TABLE

SYSTEM	PREPARED BY	NO.	REV.
ALSEP (Array E)	J.G. Smith	ATM 953	A
END ITEM: Central Station	DWG NO.	PAGE _ of 16	
ASS'Y: Downlink	DWG NO.	DATE 9-30-71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

CIRCUIT OR FUNCTION	ASSUMED FAILURE MODE	CAUSE OF FAILURE	EFFECT OF FAILURE: END ITEM	EFFECT OF FAILURE: SYSTEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1. Antenna	No Signal	A) Mechanical Open or Short B) Lose of Aiming Ability	Loss of Transmitter Data	Loss of All Data	92.00	I
2. Diplexer Filter	No Signal	A) Open or Short B) Mechanical Failure	Loss of Transmitted Data	Loss of All Data	108.00	I
3. Diplexer Circulator Switch	No Signal	Open or Short	Loss of Transmitted Data	Loss of All Data	0.28	I
4. Transmitter	Failure which would cause loss of redundancy	None	None	None	-----	*
5. Data Processor	5.1 Failure which would cause loss of redundancy	5.1 None	5.1 None	5.1 None	-----	*
	5.2 Failures which would cause loss of data from one experiment	5.2 Cap. Short or resistor open on interface board	5.2 Loss of data from one experiment	5.2 Loss of data from one experiment	22.5	III
6. 90 CH. MUX	Failure which would cause loss of redundancy	none, removed since Array C	None	None	-----	*
7. A/D Converter	Failure which would cause loss of redundancy	None, removed since Array A2	None	None	-----	*

*Note: Loss of Redundancy - No affect on performance capabilities.

Appendix A
(Sheet 1)

SYSTEM	PREPARED BY	NO.	REV.
ALSEP (Array E)	J. G. Smith	ATM 953	A
END ITEM: Central Station	DWG NO.	PAGE 7 of 16	
ASS'Y: Up Link	DWG NO.	DATE 9-30-71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

CIRCUIT OR FUNCTION	ASSUMED FAILURE MODE	CAUSE OF FAILURE	EFFECT OF FAILURE: END ITEM	EFFECT OF FAILURE: SYSTEM	FAILURE PROBABILITY Q x 10^-5	CRITICALITY
1. Receiver	Loss of signal through failure of RF connector	A. Short to Ground B. Open both sides	Loss of receiver commands	Unable to modify automatic delayed command sequencer of timer	2.62	II
2. Demodulator	Failure which would cause loss of redundancy	None	None	None	-----	*
3. Command Decoder Control Logic	Failure which would cause loss of redundancy	None	None	None	-----	*
4. Command Decoder	4.1 Failure which would cause loss of redundancy	A) Short in output transistor of gate for CLOO11ZN signal	Loss of All data except for LSPE data	Loss of all data except for For LSPE data	1.1	I
		B) Short in output transistor of gate for EXFZN signal	Loss of all data except for ASI data	Loss of all data except for LSPE data	1.1	I
5. Auto Seq. and Ripple Off	Failure which would cause loss of redundancy	None	None	None	-----	*

*Note: Loss of Redundancy - No affect on performance capabilities.

Appendix A
(Sheet 2)

The changes in Central Station components affecting the FMECA's are summarized herein. The appropriate pages in each of the component FMECA's are identified below. The failure codes utilized are:

Code	
1 DP	Loss of one of the two data processors
LSPE	Loss of timing to LSPE
LHDR	Locked into higher data rate - serious degradation to one of two data processors
SPF	Single Point Failure
1 CD	Loss of One Command Decoder
LDF	Loss of +5V Delay Feature, may allow spurious commands if a PCU fails
RDM	Loss of a redundant delay module, must switch PCU's
PNL	Possible noise on +5V Z line, can switch to redundant PCU but not necessarily.

LIST OF PAA AND FMECA DOCUMENTS FOR ARRAY E CENTRAL STATION

Redundant Command Receiver - No Changes

FMECA - ATM 984
PAA - ATM 983

PSK Transmitter - No Changes

FMECA - ATM 1005
PAA - ATM 1006

Command Decoder (See next page)

FMECA - ATM 949
PAA - ATM 954

ATM 949 - changes

Page	Part	Mode	Was	Is	Comments
18	U25A	L	SPF	None	Removed ASE capability
21	U27A	H	SPF	1CD	
		L	1CD	1CD	

Digital Data Processor

FMECA - ATM 950
PAA - ATM 955

ATM 950 - changes

Page	Part	Mode	Was	Is	Comments
20	U70A	H	LSPE	None	Deleted,
		L	1DP	None	Removed ASE Capability
20	U70B	H	1DP	None	
		L	1DP	None	
20	U70C	H	1DP	None	
		L	1DP	None	
27	U83A	H	LHDR	None	
		L	LHDR	None	
27	U84A	H	LHDR	None	
		L	LHDR	None	
43	R18	O	LSPE	None	Deleted
	C18	O	None	None	Deleted
		S	LSPE	None	

90 Channel Multiplexer - No Change *

FMECA - ATM 863
PAA - ATM 860

A/D Converter - No Changes *

FMECA - ATM 905
PAA - ATM 904

* Documents were updated for Array in BxA memorandum 9721-2293, dated 28 May 1971.

Power Distribution Unit

FMECA - ATM 951
PAA - ATM 956

ATM 951 - changes

Page	Part	Mode	Was	Is	Comments
	R1	O	---	LDF	Added +5V Delay Module
	R2	O	---	RDM	
	C1, C2	O		PNL	
		S		None	
	CR1, CR2	O		PNL	
		S		None	
	U1	H		LDF	
		L		RDM	
	Q1	O		RDM	
		S		LDF	

Power Conditioning Unit

FMECA - ATM 952
PAA - ATM 957

ATM 952A - changes

Page	Part	Mode	Was	Is	Comments
--	CR1	O	---	None	Added +5V
		S	---	None	Sluggine Circuit
--	R1	O	---	None	
		S	---	None	
--	C1 thru	O	---	None	
--	C18	S	---	None	