This ATM fulfills the Array E contractual requirements for an ALSEP system level Failure Mode Effect and Criticality Analysis (FMECA) in accordance with Array E, Flight System 6 Documentation requirements.

Supporting and reference documents are listed to aid the reader in assessing the overall ALSEP system.

Prepared by J.G. Smith
J.G. Smith
ALSEP Reliability

Reviewed by R.C. Roukas
R.C. Roukas
Group Engineer
ALSEP Reliability

Approved by S.J. Ellison
S.J. Ellison
Manager
ALSEP Reliability

INTRODUCTION

This Failure Mode Effects and Criticality Analysis (FMECA) identifies those potential failure modes constituting single point failure modes and other failure modes peculiar to ALSEP Flight System 6.

A single point failure mode summary is shown in Table I; it includes all single point failures existing in ALSEP Flight System 6 Central Station.

Since Array E constitutes a major redesign of the Central Station Electronics, the FMECA found in Table II provides data for the Central Station. Experiment data are separately published by ATM's referenced herein.

The Reliability of the Central Station Data Subsystem for 2 years operation has increased from 93% for 1 year to 98.3% for 2 years through redesign of most critical assemblies. This has been achieved by the addition of redundancy and the use of integrated circuits which have a higher reliability than their equivalent discrete counterparts.

The reliability for mission success after two years of operation of each new experiment plus the Central Station is as follows:

Lunar Seismic Profiling Experiment (LSPE) + C.S.	R = TBD
Lunar Mass Spectrometer (LMS) + C.S.	R = .8663
Lunar Ejecta and Micrometeorite (LEAM) + C.S.	R = .8189
Lunar Seismic Gravimeter Experiment (LSGE) + C.S.	R = .8998
Heat Flow Experiment (HFE) + C.S.	R = .7972
*Passive Seismic Experiment + C.S.	R = .9195

*Back up for Lunar Seismic Gravimeter Experiment (LSGE).

The experiments do not have the redundancy that the Central Station possesses because of weight, power, and volume constraints. It is possible for each experiment to have particular failure modes which could cause degradation of the experiment or partial loss of scientific and engineering data; but for this report the reliability numbers shown represent the probability of total success for each experiment after two years of operation.

SYSTEM FMECA AND SPFS

Failure modes listed in the FMECA summary are limited only to modes which would:

1. Cause the loss of all scientific data (Criticality Rank = I)

2. Cause of loss of uplink or control of the system (Criticality Rank = II)

3. Cause the loss of some scientific data (Criticality Rank = III)

4. Cause the loss of some housekeeping data (Criticality Rank = IV)

Failure modes with a criticality rank of "I" and "II" are termed "System Single Point Failure Modes." Criticality ranks III &IV are less serious since scientific data is being returned. Failures in which functionality may be restored by switching to a redundant unit are of second order importance and are not included in the system FMECA.

Although each of the subassembly failure modes listed in Table I constitutes a potential shut-down of ALSEP Flight System 6, it has been established by stringent qualification and acceptance testing of ALSEP systems that the design safety margins and redundancy utilized have achieved a reliabile design and operation for two years on the lunar surface can be confidently expected.

The Diplexer Filter and Switch have never failed in their expected worst case modes of the switch failing shorted or the filter failing open or shorted. The Antenna assembly has also not failed.

The RTG has never failed to have an output; in fact after the APOLLO 12 deployment the RTG met and exceeded its required output.

The ACA cask has been subjected to qualification design limits testing without failure and performed its containment function during the APOLLO 13 return to earth.

Astronaut contingency operational procedures (as proven during deployment exercises) have been developed to preclude the astronaut not being able to recover the Fight Handling Tool from the lunar surface and the possibility of the tool breaking is negligible.

RELIABILITY PREDICTION

The reliability math model is shown in Figures (I) - (VIII). The reliability prediction for no failures in the Central Station data and power subsystem has increased from .93200 for 1 year to .98259 for 2 years due to increased redundancy over Array D.

The probability of full success for each experiment (including the Central Station) is shown in the Reliability Block Diagrams, Figures IV through VIII. The reliability of the Central Station is calculated to be .98663 for the ability to command, supply power, and process the data for one experiment for 2 years with no loss of data.

Further information about the experiment and Central Station can be found in the documents listed in Table III and Table IV.

The Digital Data Processor has filter capacitor on each data demand line and data line and these critical failure modes are included in the reliability prediction for each experiment.

RELIABILITY COMPARISON

The design of the Array E Central Station has improved over Array D. The probability and quantity of single point failures has been reduced significantly. Table (V) lists some reliability comparisons between Array D and Array E. It is to be remembered that Array A and Array C are operating reliably on the moon. Any improvement in reliability is an improvement on a unit of demonstrated reliability.

TABLE 1

CENTRAL STATION SINGLE POINT FAILURE SUMMARY

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

TABLE II

SYSTEM ALSEP (Array E)	PREPARED BY J. G. Smith	NO. ATM 953	REV.
END ITEM Central Station	DWG NO.	PAGE 6 of 16	
ASS'Y Downlink	DWG NO.	DATE 4/29/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

CIRCUIT OR FUNCTION	ASSUMED FAILURE MODE	CAUSE OF FAILURE	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
			END ITEM	SYSTEM		
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.

SYSTEM	PREPARED BY	NO.	REV.
ALSEP (Array E)	J. G. Smith	ATM 953	
END ITEM: Central Station	DWG NO.	PAGE 7 of 16	
ASS'Y: Up Link	DWG NO.	DATE 4/29/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

CIRCUIT OR FUNCTION	ASSUMED FAILURE MODE	CAUSE OF FAILURE	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
			END ITEM	SYSTEM		
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.

Figure I DATA SUBSYSTEM RELIABILITY BLOCK DIAGRAM

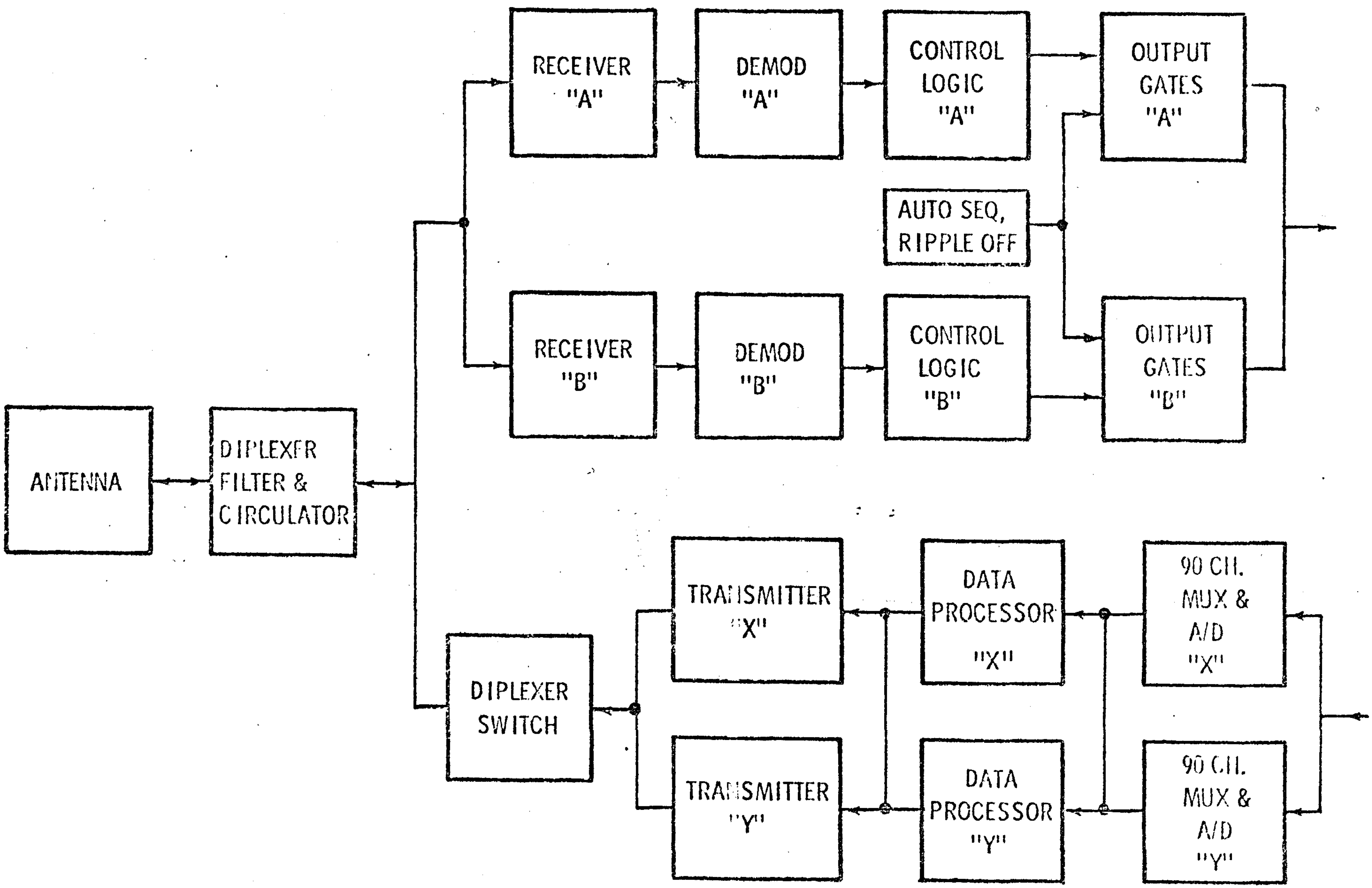
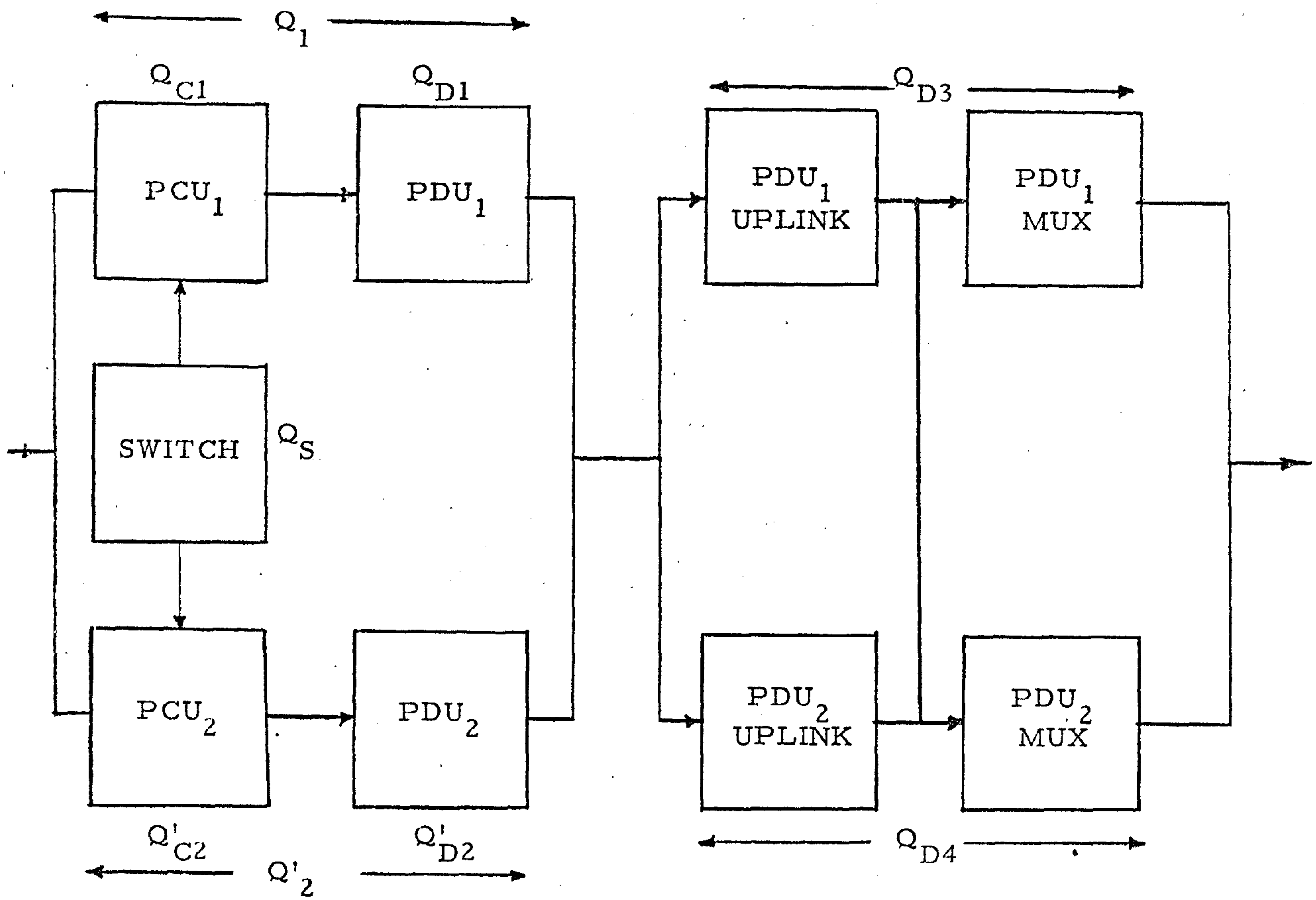


Figure II ALSEP ARRAY E POWER SUBSYSTEM RELIABILITY BLOCK DIAGRAM



$$Q_T = \frac{(Q_{C1} + Q_{D1})^2}{2} + R'_2\, Q_1\, Q_S + \frac{(Q'_{C2} + Q'_{D2})^2}{2} + Q_{D3} Q_{D4}$$

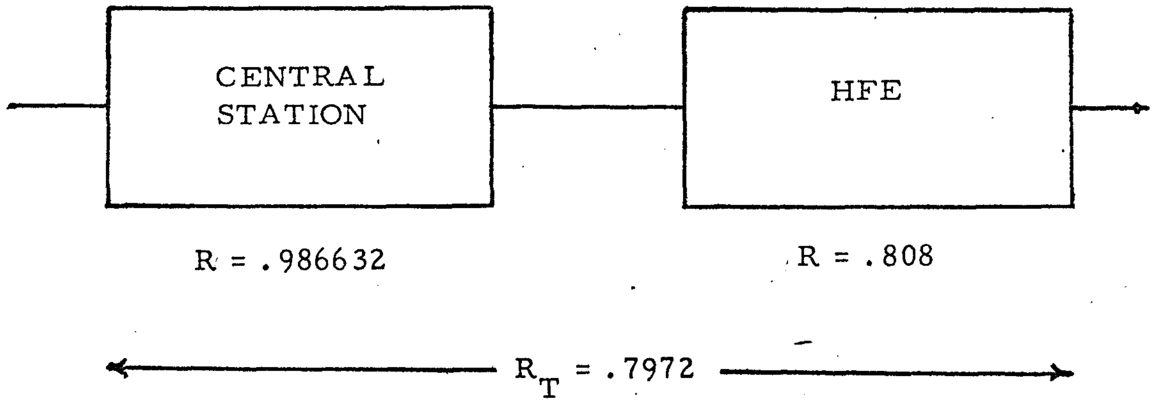


FIGURE III CENTRAL STATION + HFE RELIABILITY BLOCK DIAGRAM

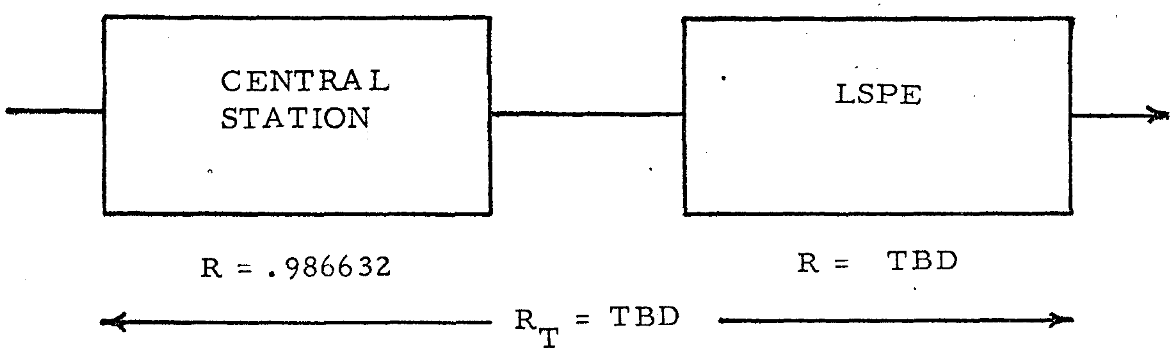


FIGURE IV CENTRAL STATION + LSPE RELIABILITY BLOCK DIAGRAM

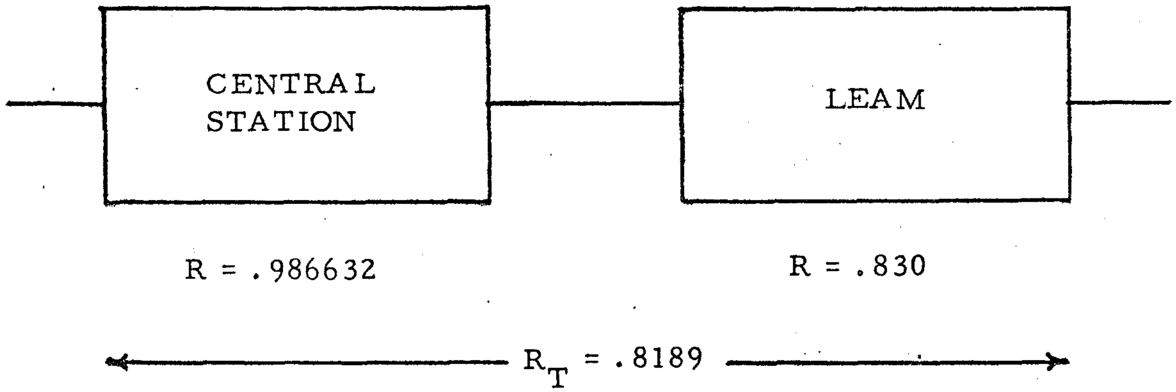


FIGURE V CENTRAL STATION + LEAM RELIABILITY BLOCK DIAGRAM

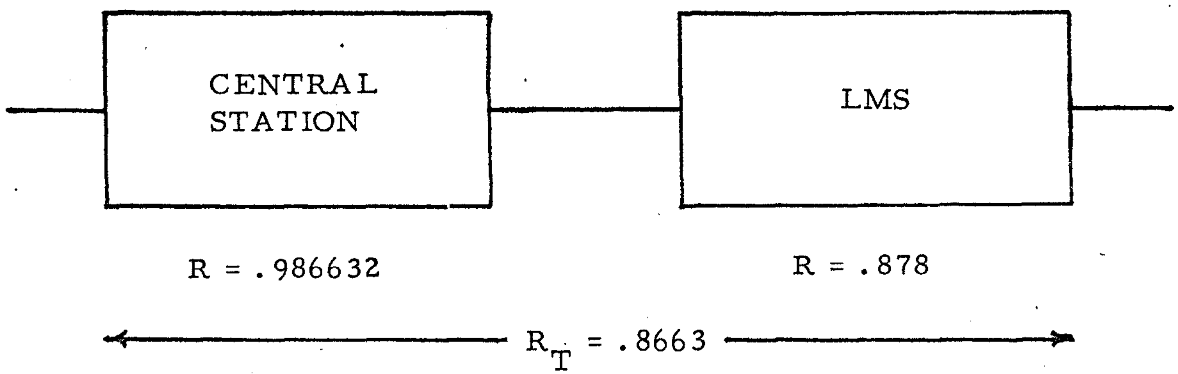


FIGURE VI CENTRAL STATION + LMS RELIABILITY BLOCK DIAGRAM

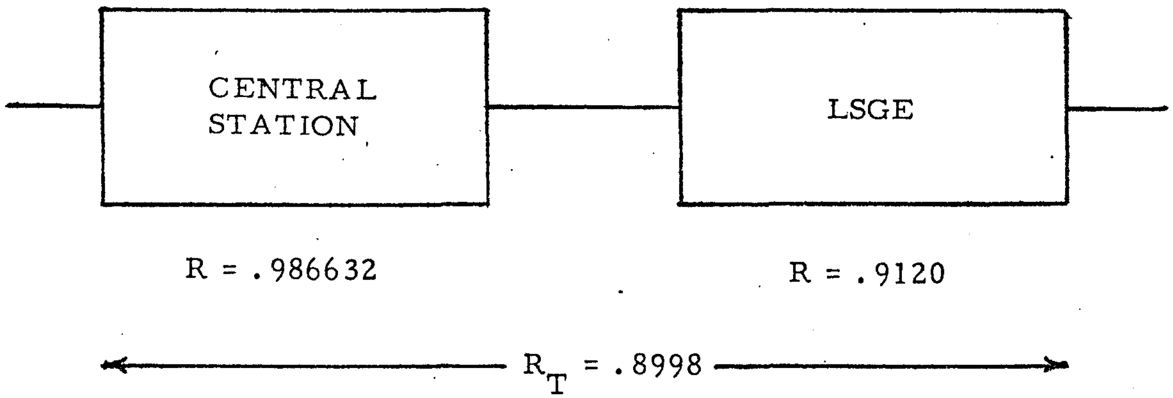


FIGURE VII CENTRAL STATION + LSGE RELIABILITY BLOCK DIAGRAM

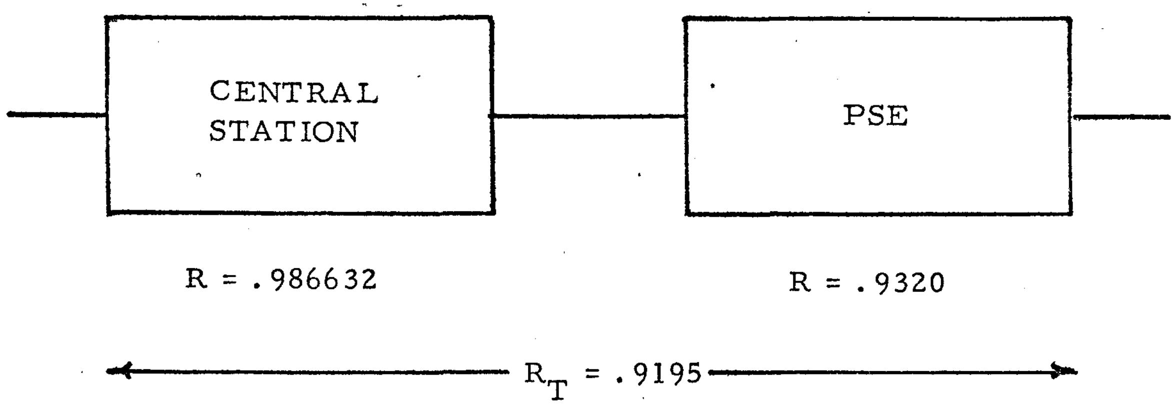


FIGURE VIII CENTRAL STATION + PSE RELIABILITY BLOCK DIAGRAM

TABLE III

LIST OF PAA AND FMECA DOCUMENTS FOR ARRAY E CENTRAL STATION

ATM 984	Receiver	FMECA
ATM 983	Receiver	PAA
ATM-949	Command Decoder	FMECA
ATM-954	Command Decoder	PAA
ATM-951	Power Distribution Unit	FMECA
ATM-956	Power Distribution Unit	PAA
ATM-952	Power Conditioning Unit	FMECA
ATM-957	Power Conditioning Unit	PAA
ATM-950	Digital Data Processor	FMECA
ATM-955	Digital Data Processor	PAA
ATM-863	90 CH Multiplexer	FMECA
ATM-860	90 CH Multiplexer	PAA
ATM-1005	PSK Transmitter	FMECA
ATM-1006	PSK Transmitter	PAA
ATM-905	A/D Converter	FMECA
ATM-904	A/D Converter	PAA
BxA Letter No. 9721-2293 5/28/71	90 CH MUX + A/D Update For Array-E	

TABLE IV

LIST OF PAA AND FMECA DOCUMENTS FOR ARRAY E EXPERIMENTS

A) - (HFE)		
ATM - 274	Heat Flow Experiment	FMECA
See Note 1	Heat Flow Experiment	PAA
B) - (LSPE)		
ATM - 976	Lunar Seismic Profiling Expt.	FMECA
ATM - 975	Lunar Seismic Profiling Expt.	PAA
C) - (LEAM)		
ATM - 1013	Lunar Ejecta & Micrometeorite	FMECA
ATM - 1014	Lunar Ejecta & Micrometeorite	PAA
D) - (LSGE)		
ATM - 1008	Lunar Seismic Gravimeter Expt.	FMECA
ATM - 1009	Lunar Seismic Gravimeter Expt.	PAA
E) - (LMS)		
ATM - 970	Lunar Mass Spectrometer	FMECA
ATM - 966	Lunar Mass Spectrometer	PAA
F) - (PSE)		
Letter No.	Passive Seismic Expt.	FMECA
97001-105-1	Passive Seismic Expt.	PAA
2 Oct. 67		

Note 1: Gulton Industries document dated 5/6/68, "Parts Application Analysis, Heat Flow Electronics, Model SN02 and Later.

TABLE V

RELIABILITY

COMPARISON OF ARRAY E AND ARRAY D-2 YEAR RELIABILITY

	ARRAY D (FMECA)	ARRAY E (FMECA)	FAILURE PROBABILITY IMPROVEMENT FACTOR
CENTRAL STATION	.76328	.98259	13.6
UPLINK	.94129	.99915	69.07
DOWNLINK	.99322	.99534	1.45
POWER	.82235	.99520	37.0
PCU	.86512	.999834	812.53
PDU	.95056	.99613	12.77
CD	.94454	.99930	79.2
MUX + A/D	.99536	.99616	1.21
DDP	.99846	.999540	3.35
TRANSMITTER	.99940	*.999642	1.68

UNCHANGED COMPONENTS (BASED ON FMECA)

RECEIVER	.99637 (NON REDUNDANT)
ANTENNA	.99482
FILTER	.99796

*TELEDYNE DESIGN TRANSMITTER: TTC=.999642 (INCLUDES DIPLEX SWITCH)

CONCLUSION

Design improvements of ALSEP hardware since Array D has increased the reliability of the overall ALSEP System. It is therefore concluded that ALSEP Flight System 6 will satisfactorily perform its intended function after lunar deployment with higher probability of full system success and reduced risk of single point failure occurrence than any previous Array.

The ALSEP Array E Central Station satisfies the specified reliability requirements. The individual experiment reliability conclusions are separately discussed in the Experiment FMECA ATM's listed on page 14, Table IV.