This ATM fulfills the Array D contractual requirements for an ALSEP system level Failure Mode Effects and Criticality Analysis (FMECA) in accordance with Item D-7 of the Array D, Flight System 5 Documentation Schedule.

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

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INTRODUCTION

This Failure Mode Effects and Criticality Analysis (FMECA) identifies those potential failure modes constituting single point failures or critical failures peculiar to ALSEP Flight System 5.

A single point failure mode summary is shown in Table I; it includes all single point failures existing in ALSEP Flight System 5. The "critical" failure modes in which command uplink is lost are summarized in Table II.

The major design changes that have been made to ALSEP since Array A have been made to the Central Station Electronics. Consequently, the FMECA found in Table III concentrates on the Central Station. The reader is referred to ATM 501B for the complete detailed FMECA for ALSEP.

The Reliability of the Central Station Data Subsystem has increased from 87% to more than 93% through redesign of some 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.

SYSTEM FMECA AND SPFS

All system single point failure modes are listed in Table I for easy identification. Due to redundancy, many assemblies contain no system single point failure modes. Assemblies which contain no such modes include the 90 Channel Multiplexer, and A/D Converter, and the Timer. Critical failure modes in the Receiver have been reduced to one. All are units which have been completely redesigned since Array A. See below for definition of a critical failure mode.

The probability of occurrence of a system single point failure is only 0.0072 and the probability of occurrence of a critical failure is only 0.0053.

Table III lists the most significant Failure Mode Effects and Criticality Analysis data for the Array D Central Station. The FMECA lists failure modes on a subsystem-black box level. More detailed FMECA information may be obtained by referring to the appropriate subsystem's individual FMECA. Appendix A lists the respective ATM numbers for each subsystem.

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 the 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 housekeeping data. (Criticality Rank = IV)

Failure modes with a criticality rank of "I" are termed "System Single Point Failure Modes." Those with a ranking of "II" are termed "Critical 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 5, it has been established by stringent qualification and acceptance testing of ALSEP systems that the design safety margins and redundancy utilized have achieved a reliable design and operation for one year 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 open.

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 Flight Handling Tool from the lunar surface and the possibility of the tool breaking is negligible.

TABLE I

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	46.00
	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	0.14
	2.	Mechanical damage to construction of either circulator	
Diplexer Filter	1.	Open in band pass filter coaxial elements	54.00
	2.	Mechanical damage to cavity elements - pick-offs and tuning stubs	
	3.	Connector or internal junction failures	
Command Decoder	1.	Shorted output decode gate causing premature Transmitter "off" command	1.05
PCU	1.	Defective cabling or connectors between PCU and RTG	613.35
	2.	Open RTG input filer choke	
	3.	Open primary on input current monitor transformers	
	4.	Shorted capacitor across astronaut start switch and ground	

TABLE I (CONT.)

Assembly		Failure Mode	Failure Probability $Q \times 10^{-5}$
PCU Cont.	5.	Shorted capacitor across input to DC-DC converter transformer and ground	
	6.	Shorted capacitor across Regulator #1 resistor feed line and ground	
	7.	Open contacts on regulator select relay	
	8.	Any component failure causing DC-DC converter #1 not to start	
	9.	Open in output filter chokes	
Power Dissipation Module	1.	Short in the dissipation module will cause the loss of +29 V line and the system	.14
PDU	1.	Spurious ground on either transmitter turn off line, due to possible wiring short, or shorted transistor in PDU.	3.40
	2.	Open input resistor on "Transmitter Off" relay driver	
	3.	Either transistor shorted in the "Transmitter Off" relay driver	
	4.	Reversed or shorted "flywheel" diode on "Transmitter On" relay coil	
	5.	Resistor short in either Power Dissipation Module or Transmitter heater causing loss of +29 volt line	
		TOTAL	718.08

Probability of single point failure = 0.0071808

TABLE II

CENTRAL STATION CRITICAL FAILURE MODE SUMMARY

Assembly	Failure Mode	$Q \times 10^{-5}$
Receiver	Open or short in RF Connector	1.31
Command Decoder	Failure of demodulator would cause the loss of uplink command capability	1.52
Data Processor	Loss of Frame Counter will impact real-time monitoring capability.	531.70
	TOTAL	534.53

Probability of occurrence of critical failure = 0.0053453

TABLE III

SYSTEM ALSEP	PREPARED BY R. Dallaire	NO. ATM 90-	REV.
END ITEM Central Station	DWG NO.	PAGE 7 of 12	
ASS'Y Downlink	DWG NO.	DATE 8-31-70	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

CIRCUIT OR FUNCTION	ASSUMED FAILURE MODE	CAUSE OF FAILURE	EFFECT OF FAILURE: END ITEM	EFFECT OF FAILURE: SYSTEM	Source	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1. Antenna	No Signal	A. Mechanical Open or Short B. Loss of Aiming Ability	Loss of Transmitted Data	Loss of All Data	B	46.00	I
2. Diplexer Filter	No Signal	A. Open or Short B. Mechanical Failure C. Connector & Resonator Failure	Loss of Transmitted Data	Loss of All Data	B	59.00	I
3. Diplexer-Circulator Switch	No Signal	A. Open or Short	Loss of Transmitted Data	Loss of All Data	B	.1416	I
4. Transmitter	Failure such as to also cause to fail the Redundant Unit	A. None	None	None	B	-	-
5. Data Processor	Failure such as to also cause to fail the Redundant Unit	A. Frame Counter Failure	Loss of Frame Mark	Ground Station Data Processing Required to Restore Data	B	25.432	III
6. 90 Ch. Mux	Failure such as to also cause to fail the Redundant Unit	A. None, removed since Array C	None	None	H	-	-
7. A/D Converter	Failure such as to also cause to fail the Redundant Unit	A. None, removed since Array A2	None	None	J	-	-
				Total		130.57	

SYSTEM ALSEP	PREPARED BY R. Dallaire	NO. ATM 90[illegible]	REV.
END ITEM Central Station	DWG NO.	PAGE 8 of 12	
ASS'Y Uplink	DWG NO.	DATE 8-31-70	

TABLE III

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	Source		
1. Receiver	Loss of Signal Through Failure of RF Connector	A. Short to Ground B. Open Both Sides	Loss of Received Commands	Unable to Modify Automatic Delayed Command Sequencer of Timer	B	1.314	II
2. Demodulator	Loss of Command Data	A. Loss of Output B. Loss of Threshold Gate C. Loss of Clock Pulses	Loss of Received Commands	Unable to Modify Delayed Command Sequence of Timer	B	531.70	II
3. Command Decoder	Loss of Both Sides	A. Loss of Memory Address Inhibit	Loss of Both Command Decoders	Unable to Modify Delayed Command Sequence	B	1.515	II
4. Command Decoding Gates & Drivers	Loss of a Command Function	A. Open or Short Digital Logic	Loss of a Command Function	Possible Loss of An Experiment or Command	B	1202.71	III
5. RSST	Early Time Out	A. Electronic Failure	Temporary Loss of Transmitter, may be regained by Ground Command	None	L	-	-
				Total		1737.24	

TABLE III

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	R. Dallaire	ATM [illegible]	
END ITEM: Central Station	DWG NO.	PAGE 9 of 12	
ASS'Y: Power System	DWG NO.	DATE 8-31-70	

CIRCUIT OR FUNCTION	ASSUMED FAILURE MODE	CAUSE OF FAILURE	EFFECT OF FAILURE: END ITEM	EFFECT OF FAILURE: SYSTEM	Source	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1. PCU	A. Loss of + 5V, + 29V	A. Electrical Failure	A. Loss of Transmitter or Data Processor	A. Loss of All Data	B	613.35	I
	B. Loss of Other Supplies	B. Electrical Failure	B. Loss of Some Experiments and Uplink	B. Loss of Major Portion of Data or Uplink	B	613.35	II
2. PDU	Loss of Supply to Receiver, Either transistor Q2(A) or Q5(A) Shorts	A. Electrical Failure	Loss of Receiver	Loss of Uplink	B	.659	II
				Total		1227.54	

RELIABILITY PREDICTION

The reliability math model is shown in Figure 1. The functional block diagram is drawn in such a manner that redundant subsystems having circuits in common are drawn with the common function's block is in series rather than parallel. This includes switching.

The reliability prediction for the Central Station data and power subsystems may be found in Table IV, the Reliability Comparison Table. Reliability for the data subsystem has increased from 0.86921 to 0.93185 due to design improvements such as including redundancy and the use of integrated circuits in the redesigned assemblies. The redesigned assemblies are denoted by asterisks in Table IV.

RELIABILITY COMPARISON

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

CONCLUSION

Design improvements of ALSEP hardware since Array A has increased the reliability of the overall ALSEP System. It is therefore concluded that ALSEP Flight System 5 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.

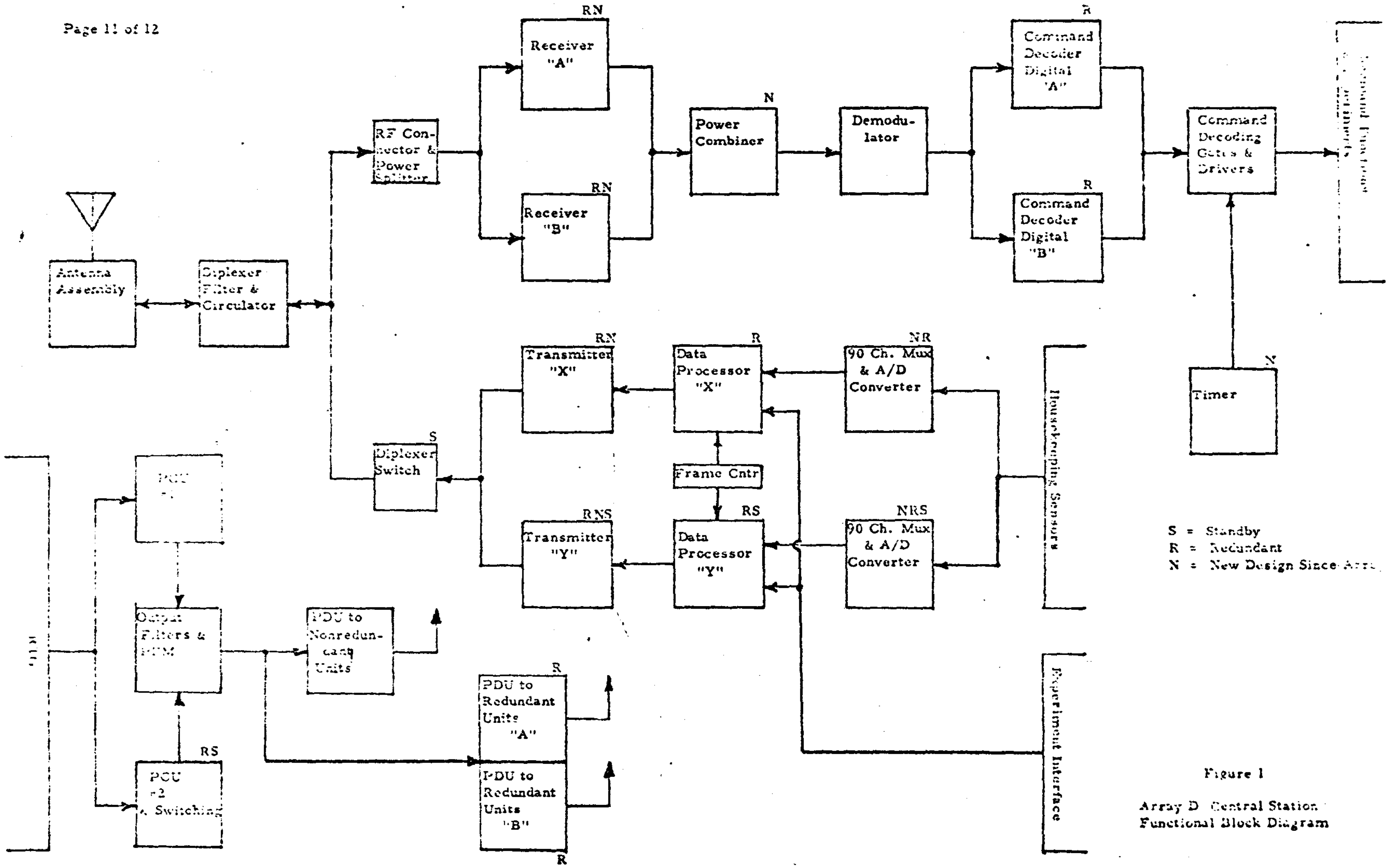

Figure 1

Array D Central Station Functional Block Diagram

TABLE IV

CENTRAL STATION SUBSYSTEMS
RELIABILITY PREDICTION AND COMPARISON

System	Array D R	Array A R	Differences ΔR
Power	.93315	.93315	———
PDU	.98773	.98773	———
PCU	.94484	.94484	———
PDM	.99990	.99990	———
Data	.93185	.86921	+0.06264
Antenna Assy.	.99746	.99746	———
D. P. Filter	.99898	.99898	———
Receiver*	.99925	.98882	+0.01043
Transmitter*	.99988	.99923	+0.00065
Comm. Decoder	.98304	.98304	———
Timer*	.99450	.99028	+0.00422
MUX & A/D*	.99872	.94608	+0.05246
Data Processor	.95863	.95863	———
TOTAL R	.86956	.81110	+0.05846

*Redesigned units since Array A.

APPENDIX A

References

Below is a list of references the reader is referred to for the purpose of more detailed information. Note that ATM 501B and ATM 274G contain the Failure Mode Effects and Criticality Analysis and System Prediction Analysis, respectively, for the entire system except where circuit modifications or redesigns have necessitated the issuance of new ATM's. The letter to the left corresponds to the source letter referenced in the system FMECA included in this ATM.

A	ATM 501B	ALSEP Failure Mode Effects and Criticality Analysis
B	ATM 274G	ALSEP Reliability Math Model, Prediction, and Assessment
C	ATM 262	Evaluation Data Subsystem Failure Modes
D	ATM 841A	Transmitter PAA
E	ATM 852	Fuel Handling Tool, Fuel Capsule/Cask Assembly Interface FMECA
F	ATM 854	Transmitter FMECA
G	ATM 860A	90 CH. Multiplexer PAA
H	ATM 863	90 CH. Multiplexer FMECA
I	ATM 904	A/D Converter PAA
J	ATM 905	A/D Converter FMECA
K	ATM 878	RSST (Timer) FMECA
L	ATM 879	RSST PAA
M	Motorola 3875/035	Receiver FMECA
N	ATM 894	Structural/Thermal Subsystem