Bendix

Aerospace Systems Division

Failure Mode, Effects & Criticality Analysis LSPE ALSEP Array E	NO. ATM 976	REV. NO.
	PAGE 1 OF 135	
	DATE 7-26-71	

This ATM documents the Failure Modes, Effects and Criticality Analysis on the Lunar Seismic Profiling Experiment for the Array E ALSEP System. The report reflects analysis on those parts which are presently planned to be used in the final flight configuration.

This document is prepared in accordance with the requirements of Section 5. 2 of The Reliability Program Plan for Array E, ALSEP-RA-08, Bendix document number BSR 3024, 11/30/70.

Reliability prediction data are also documented herein in accordance with Section 5. 5 of The Array E Reliability Program Plan.

Contained within this ATM are the following appendices:

Appendix A: Teledyne Geotech FMECA, Single Point Failure Summary, and prediction.

Appendix B. Bulova Watch Company FMECA and reliability analysis.

Appendix C: FMECA sheets for the Bendix built portion of the LSPE.

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8-14-71 JTS

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1.0 INTRODUCTION

The results of The Reliability Prediction and The Failure Mode, Effects, and Criticality Analysis for the ALSEP Array E LSPE are documented in this report.

The reliability prediction for this assembly is 0.98449 which exceeds the specified goal of 0.920. This is based upon a life of 200 hours.

2.0 CIRCUIT DESCRIPTION

Figure 1 is a block diagram of the assembly. This diagram is included to clarify the terms and descriptions given in the Failure Mode, Effects, and Criticality Analysis portion of this report (Table II).

The signal flow is as follows: a trigger pulse is generated in the Digital Processor. This trigger causes a CW signal to be generated in the Transmitter. This pulse burst is picked up by the Receiver, where it is filtered and detected. The detected pulse is counted in the Signal Processor. When a count of 3 is reached, a pulse is sent to the Firing Pulse Generator. This circuit then sends power to the explosives.

2.1 Digital Processor

The Digital Processor consists of circuitry required to perform interface functions between the input commands and the LSPE central electronics.

2.2 MUX-A/D Converter

For the detailed FMECA and prediction of the 16 channel multiplexer see ATM 912, dated 8/20/70.

2.3 SDS Amplifier

See Appendix A for the FMECA, prediction and SPFS as supplied by amplifier subcontractor, Teledyne Geotech.

2.4 DC-DC Converter

The DC-DC Converter converts input 29 volts DC to 28 volts DC, +12 volts DC, +5 volts DC, -12 volts DC and reference voltages used by the LSP temperature sensor and the A/D Converter.

The input 29 volts is regulated and applied to a free running oscillator circuit. The output of the oscillator is coupled through a transformer to rectifier and filter circuits to produce the output DC levels.

The output 12V DC is connected to a zener diode-voltage divider network which supplies reference voltages to the LSP temperature sensor and the analog to digital converter.

2.5 Transmitter

The Transmitter receives a trigger signal from the Digital Processor. This signal is used to modulate a CW signal. The CW is then amplified and fed to an antenna. A portion of the CW is rectified and filtered. This voltage is then fed into the Digital Processor for monitoring purposes.

2.6 Receiver

The receiver consists of an r-f amplifier, a filter, an output amplifier, and an AGC amplifier.

The filter is a two-pole, crystal filter. The narrow bandwidth of the filter reduces the possibility of noise getting through the receiver. The output amplifier is used to feed the Signal Processor with a signal of proper amplitude. The output also drives the AGC amplifier. The AGC amplifier provides a signal to AR1 and AR2 which will maintain the receiver output at a fairly constant level.

2.7 Signal Processor

The output of the Receiver is amplified and counted. When the proper count is reached, a pulse is sent to the Firing Pulse Generator. A gate signal is also transmitted to the Firing Pulse Generator when the Battery Timer turns on the battery.

2.8 Firing Pulse Generator

The Pulse Generator provides the power to the detonators after the Generator is armed and pulse appears at the input. The input stage is a buffer which drives the gate of a controlled rectifier. The load to the controlled rectifier is a detonator. The energy in the output pulse is insufficient to fire the detonators unless the Firing Gate appears at its proper input.

2.9 Thermal Battery Timer

See Appendix B for the FMECA and prediction as supplied by the timer subcontractor, Bulova Watch Company.

2.10 Safe Slide Timer

See Appendix B for the FMECA and prediction as supplied by the timer subcontractor, Bulova Watch Company.

2.11 Thermal Battery

Upon time-out of the thermal battery timer, the timer firing pin is released and impacts the thermal battery primer which activates the battery. The resultant output voltages power the receiver, signal processor, and the firing pulse generator.

3.0 CRITICALITY RANKING

The criticality ranking shown on the FMECA sheets is consistent with the rest of the ALSEP FMECA's in that the rank reflects the failure effect on experiment success:

Ranking	
I	Loss of ALSEP
II	Loss of System Control
III	Loss of One Experiment
IV	Loss of Housekeeping
V	Loss of a Redundant Element
VI	Degradation of a Redundant Element

4.0 SINGLE POINT FAILURE SUMMARY

From the Array E system standpoint there are no single point failures in the LSPE. A system SPF would be one which causes an ALSEP abort. There are also no experiment level single point failures in the Expolsive Package Assembly (EPA) as there are eight EPA's, each a separate, isolated unit.

The Failure Mode, Effect, and Criticality Analysis does show 40 modes of failure of the 367 EEE piece parts which perform approximately 770 functions within the Bendix disigned portion of the LSPE which could become experiment level single point failures. These are failures which could cause the loss of all science data.

As noted on page 2 of this ATM, the 16 channel mux - A/D converter FMECA is detailed in ATM 912. Page 6 of that ATM discusses the one single point failure in a second tier fet which if failed would cause the mux-A/D to totally fail.

Appendix A of this ATM is the subcontractor input for the SDS amplifier and Geophones. The FMECA, SPFS, and prediction worksheets were prepared by Teledyne Geotech and have established 9 SPF's for their equipment, none of these failures will propagate into the C/S E and cause failures of other equipment.

Appendix B of this ATM is the subcontractor input for the two mechanical timers used in each EPA. The FMECA and prediction work was prepared by the Bulova Watch Company, Systems and Instruments Division. The criticalities noted as 1, 2, or 3 on the FMECA worksheets are those which constitute single point failures for the timers.

The obvious solution to single point failures of adding redundant elements has been reviewed for the thermal batteries, timers, and electronics, but in all cases the envelope, weight, and power limitations have precluded redundancy. Additionally, all EEE parts are highly screened and quite adequately derated; the batteries and timers are undergoing an extensive acceptance and qualification test program to assure reliable operation.

5.0 RELIABILITY PREDICTION

The reliability prediction for the LSPE is calculated to 0.98449 This probability of success figure includes launch, deployment, and 200 hours of lunar operation. The overall reliability goal for the LSPE is established in AL 900131 as 0.920 for two years of lunar operation. However, it has been established in conversations with the Principle Investigator, Dr. Kovach, that approximately 200 hours is the total operational time the LSPE will be activated in either the active or passive listening modes. The 200 hour operatioanl life is also specified in the Exhibit B (AL900431) of subcontract SC-853 with Teledyne Geotech for the SDS Amplifier and Geophones.

Figure 2 defines the Reliability Block Diagram and mathmatical model for the LSPE. The failure probabilities ($Q's$) for each functional component are shown with each block and are presented in Table 1 as probabilities of success (P_s) for the central electronics and any one explosive package. To arrive at the LSPE total for P_s it is necessary to multiply the C/SE times the EPA to the eighth power as there are eight EPA's in the flight model LSPE.

For purposes of this prediction, total success is defined as all eight EPA's exploding and the C/SE receiving, formatting, and returning 200 hours of science data including the seismic waves generated by the exploding EPA's, as all functional elements are seriesed by reliability definition, the $P_s = e^{-\lambda t}$ formula has been used to compute the 0.98449 P_s figure where λt is the experiment total. The failure probabilities have been derived from the experiment Parts Application Analysis, ATM 975.

6.0 CONCLUSION

Based on the calculations in the report, the probability of successful operation of the LSP equipment is quite high.

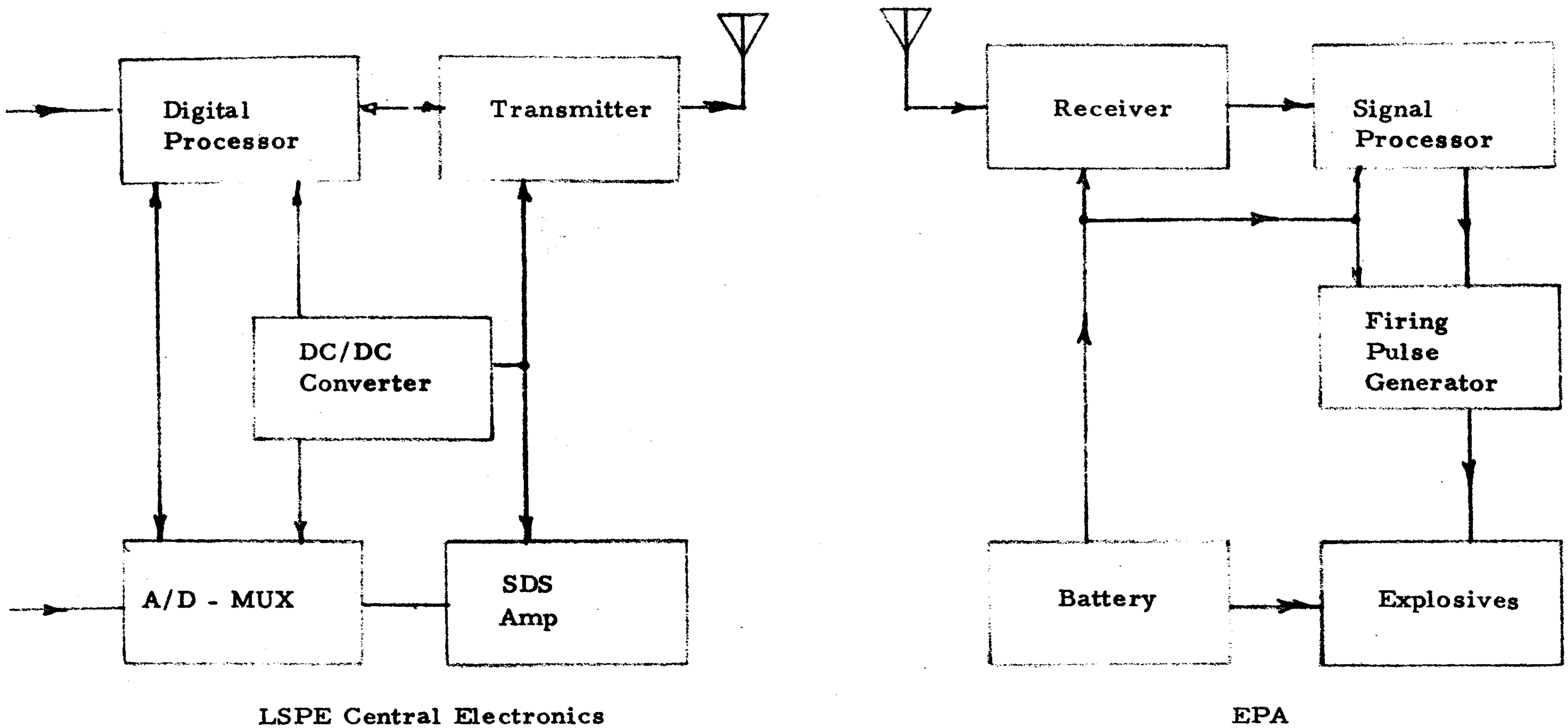
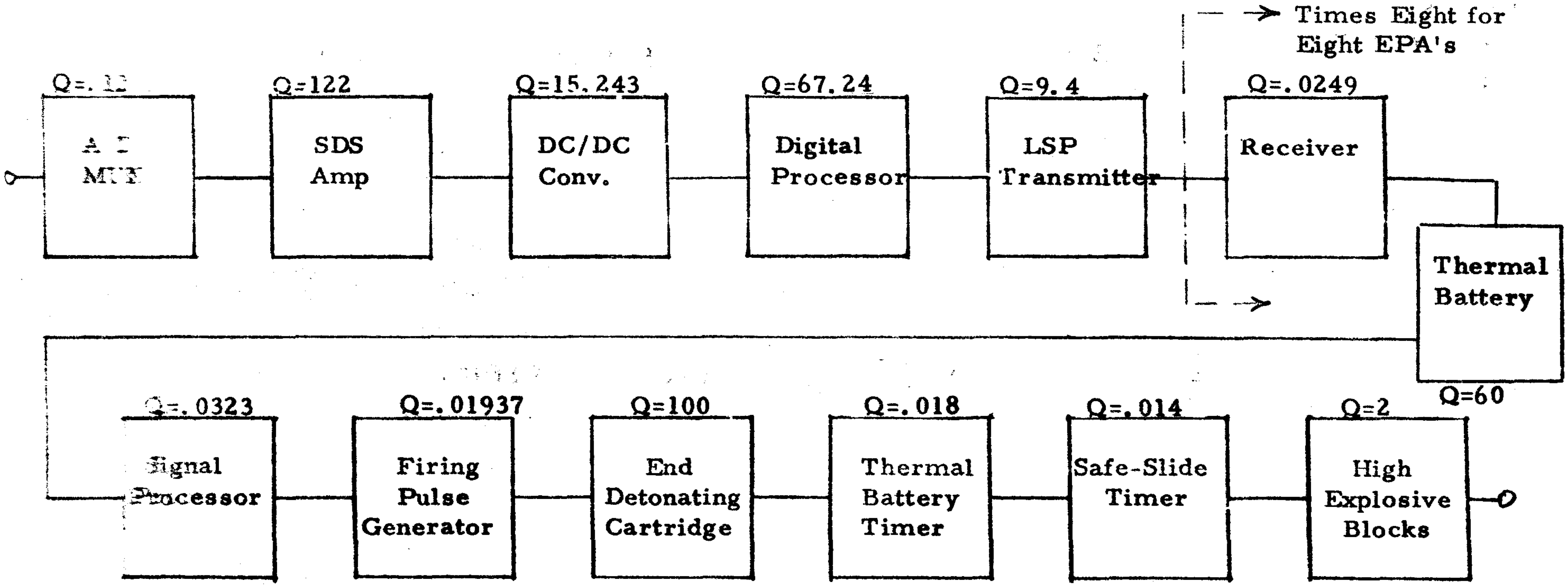


Figure 1 Assembly Block Diagram



All Q's x 10^{-5}

Figure 2 LSPE Reliability Block Diagram

TABLE 1

SUCCESS PROBABILITY SUMMARY

UNIT	λ	T	Q	P_s	Remarks
A/D-MUX	-	200 hrs	12×10^{-5}	.99988*	* See ATM 912
SDS Amp.	-	200	122×10^{-5}	.99878*	*See App. A ATM 976
DC/DC	$.0762 \times 10^{-5}$*	200	15.243×10^{-5}	.99984	*See ATM 975 Summary
Dig. Proc.	$.3362 \times 10^{-5}$*	200	67.24×10^{-5}	.99933	*ATM 975 Summary
Xmtr	$.047 \times 10^{-5}$*	200	9.4×10^{-5}	.99991	*ATM 975 Summary
Rcvr (1)	$.0249 \times 10^{-5}$*	< 1 hr.	Q=λ	.99999	*ATM 975 Summary
Th. Batt. (1)	60.0×10^{-5}*	< 1 hr.	Q=λ	.99940	*Estimate
Sig. Proc. (1)	$.0323 \times 10^{-5}$*	< 1 hr.	Q=λ	.99999	*ATM 975 Summary
F.P.G. (1)	$.01937 \times 10^{-5}$*	< 1 hr.	Q=λ	.99999	*ATM 975 Summary
E.D.C. (1)	-	< 1 hr.	$Q=100 \times 10^{-5}$	.99900*	*MSC Input
T.B. Timer (1)	$.018 \times 10^{-5}$*	90	$Q=1.6 \times 10^{-5}$	.99998	*Subcontractor Input

TABLE 1

SUCCESS PROBABILITY SUMMARY

UNIT	λ	T	Q	P_s	Remarks
S. S. Timer (1)	$.014 \times 10^{-5}$*	90	$Q=1.3 \times 10^{-5}$	.99999	*Subcontractor Input
H. E. Block (1)	-	< 1 hr.	$Q=2.0 \times 10^{-5}$	.99998*	*NOL input

$$\text{LSPE } P_{s(total)} = e^{-\lambda t} = e^{-(\lambda t_1 \cdot \lambda t_2 \cdot \lambda t_3 \cdot \ldots\ldots \lambda t_n)}$$

$$\text{or} = \text{C/S } EP_s \times \text{EPA } P_s^8$$

$$= .99774 \times .98672$$

$$= 0.98449$$

NOTE:(1) λ is for 1 EPA. All 8 EPA's must function therefore total EPA (P_s) is $(P_{s1})^8$.

APPENDIX A

SDS RELIABILITY PREDICTION

A reliability prediction has been completed for the Model 34100 Seismic Detection System. The prediction indicates the system to have a worst case probability for 100% mission success which exceeds 0.99877. Although the predicted reliability falls somewhat short of the system design goal of 0.9996, it nevertheless reflects strict adherence to reliability disciplines in the design of a complex system.

The assumptions and conditions which served as ground rules for this prediction are as follows:

1. The system configuration, for the purpose of this prediction, is assumed to be such that every assembly is in series with every other assembly. Likewise, every part within each assembly is assumed to be in series with every other part. Therefore, the failure of any single part is assumed sufficient to cause failure of the entire system.

2. The failure rate of each part is based on the thermal profile described in Bendix ATM605A with an additional 10°C temperature rise generated within the SDS Amplifier package.

3. All parts are assumed to have a 100% operating duty cycle with the exception of calibrator relays which are assumed to operate one time every 10 hours of system operation.

4. No consideration was given to parts failure mode apportionment (i.e., any part failure mode was considered sufficient to cause system failure).

5. Failure rate sources used for this prediction (in order of preference) were (a) ATM 605A, (b) MIL-HDBK-217A, and (c) other.

6. The reliability equation used for this prediction comes from ATM 605A and is

$$R = e^{-\lambda_{EQ}(t + F_B)}$$

where: R = probability of 100% mission success

e = base of natural log (i.e., 2.71828 ---)

λ_{EQ} = equivalent total parts failure rate defined by the equation $\lambda_{EQ} = .5\lambda_L + .5\lambda_H$

where: λ_L = parts failure rate at 0°C

λ_H = parts failure rate at 70°C

t = mission operating time interval of 200 hours

F_B = a term which equates pre-deployment stresses to units of operating time totaling 57.73 hours.

The assembly and part failure rates are given in the attached reliability prediction worksheets (Form 614) and are summarized in table 1.

Unit Description	Unit λ (per 10^8h)	Quan per System	λx Quan (per 10^8h)	Reliability	Ref. Worksheet Pages
Seismic Det. System	474.070	1	474.070	0.998778	1
SDS Amplifier	436.750	1	436.750	0.998874	2
Geophone-Cable Assy.	37.320	1	37.320	0.999904	3
Dual Regulator	33.234	1	33.234	0.999914	4,5
Cal, Amp, Filter, Log Comp.	100.879	4	403.516	0.998960	6-11

Table 1. Reliability Prediction Summary

REVISION A

SDS SINGLE FAILURE POINT SUMMARY

February 19, 1971

The SDS single failure points (SFP's) are summarized in table 1. Data inputs to this summary and the data sources are as follows:

1. Critical Parts. Critical parts are defined as those which could (a) render the entire SDS inoperative, (b) result in a personnel hazard, or (c) propagate to external equipment. The SDS contains no parts having failure modes which could result in a hazard to personnel. The source of critical parts is the FMECA.

2. Mode. This is the failure mode which causes the part to be defined as critical.

3. Part Failure Rates. The part failure rates listed are taken from the SDS reliability prediction and are stated in failures per 10^8 hours.

4. Probability of Occurrence. The probability of failure mode occurrences are given in ATM605A.

5. Product. The product of the failure rate and probability of occurrence.

Specific revisions made to this issue are the removals of six previously reported critical failure modes. One removal was due to a design change and the remaining five were removed because ATM605A gives a zero probability of occurrence for those modes. The list of critical failure modes is now shortened from 21 to 15.

The remaining critical failure modes are inherent in the design due to the use of a common voltage regulator for all four channels. There are no practical means to eliminate these failure modes and redundancy is not feasible.

Table 1. Single Failure Point Summary

Rank	Ref. Design	Mode	Failure Rate	Probability	Product
1	Q502	B-E short	6.580	.125	.8225
2	CR504	Short	2.425	.30	.7275
3	R509	Open	1.525	.20	.305
4	Q501	B-E open	2.300	.125	.2875
5	CR504	Open	2.425	.10	.2425
6	CR502	Open	.885	.20	.177
7	R510	Short	1.525	.10	.1525
8	C508	Short	.050	.90	.045
9	R501	Open	.177	.10	.0177
10	R504	Open	.177	.10	.0177
11	R513	Open	.177	.10	.0177
12	C502	Short	.0107	.20	.0021
13	C503	Short	.0107	.20	.0021
14	C509	Short	.0107	.20	.0021
15	C510	Short	.0107	.20	.0021

FINAL ASSEMBLY Seismic Det. System DRAWING NO. 34100-01-01 REV. PREPARED BY R. P. Cheatham

SUBASSEMBLY Final Assembly DRAWING NO. 34100-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g	K	λ_f (/10^8h)
	Geophone Cable Assy.	Geotech	34120-01-01	Page 3	-73 & 127	NA			37.320
	SDS Amplifier Assy.	Geotech	34110-01-01	Page 2	0 & 70				436.750

FORM 514

SUBTOTAL 474.07/10^8h

FINAL ASSEMBLY SDS Amplifier DRAWING NO. 34110-01-01 REV. PREPARED BY R.P. Cheatham

SUBASSEMBLY Final Assembly DRAWING NO. 34110-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g	K	λ_f (/10⁸h)
	Dual Regulator	Geotech	34686-01-01	pp. 4-5	0 & 70	NA			33.2342
	C.A.F./Log Compressor	Geotech	34687-01-01	pp. 6-11	"	"			100.879
	C.A.F./Log Compressor	Geotech	34687-01-01	pp. 6-11	"	"			100.879
	C.A.F./Log Compressor	Geotech	34687-01-01	pp. 6-11	"	"			100.879
	C.A.F./Log Compressor	Geotech	34687-01-01	pp. 6-11	"	"			100.879

FORM 614

SUBTOTAL 436.7502/10

FINAL ASSEMBLY Seismic Det. System DRAWING NO. 34100-01-01 REV. PREPARED BY R.P.Cheatham

SUBASSEMBLY Geophone Cable Assy. DRAWING NO. 34120-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g	K	λ_f (/10^8h)
	Geophone Cable Assy.	Geotech	34120-01-01	MIL-217A	-73 & 127	NA			37.320

SUBTOTAL 37.320/10^8h

FORM 514

FINAL ASSEMBLY [illegible]DS Amplifier DRAWING NO. 34110-01-01 REV. ____ PREPARED BY R. P. Cheatham

SUBASSEMBLY [illegible]al Regulator DRAWING NO. 34686-01-01 REV. ____ PREDICTION DATE 1/18/71 REV. ____

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g Per 10^8h	K	λ_f ($1/10^8$h)
R501	Resistor, Met film,100Ω	MIL-R-55182	RNR50-H-1000FS	ATM-605A	0 & 70	0.1	.177		.177
R502	" " " ,1.8K	"	RNR50-H-1801Fs	"	"	"	.177		.177
R503	" " " ,2K	"	RNR50-H-2001FS	"	"	"	.177		.177
R504	" " " ,28K	"	RNR50-H-2802FS	"	"	"	.177		.177
R505	" WW	34734-01-00	34734-Selected	"	"	0.1	1.375		1.375
R506	" Met film	MIL-R-55182	RNR-Selected-FS	"	"	"	.177		.177
R507	" WW	MIL-R-39007	RWR-Selected-FS	"	"	"	.064		.064
R508	" " 6.63K	34734-01-00	34734-01-06	"	"	"	1.375		1.375
R509	" " ,10K	"	34734-01-07	"	"	0.2	1.525		1.525
R510	" 10K	34734-01-00	34734-01-07	"	"	0.2	1.525		1.525
R511	" Met film, 2K	MIL-R-55182	RNR50-H-2001FS	"	"	0.1	.177		.177
R512	" " " ,1.8K	"	RNR50-H-1801FS	"	"	0.1	.177		.177
R513	" " " ,100Ω	"	RNR50-H-1000FS	"	"	0.1	.177		.177
C501	Capacitor, Sol Tan, 4.7µF	MIL-C-39003	CSR136-475KS	"	"	0.2	.0107		.0107
C502	" Sol Tan 4.7µF	"	CSR13G-475KS	"	"	0.2	.0107		.0107
C503	" " 4.7µF	MIL-C-39003	CSR13G-475KS	"	"	0.2	.0107		.0107
C504	" " 4.7µF	MIL-C-39003	CSR13G-475KS	"	"	0.2	.0107		.0107
C505	" Ceramic 100pF	34661-01-00	34661-01-04	"	"	0.1	.05		.050
C506	" " 100pF	34661-01-00	34661-01-04	"	"	0.1	.05		.050
C507	" " 100pF	34661-01-00	34661-01-04	"	"	0.1	.05		.050
C508	" " 100pF	34661-01-00	34661-01-04	"	"	0.1	.05		.050
C509	" Sol Tan 4.7µF	MIL-C-39003	CSR13G-475KS	"	"	0.2	.0107		.0107
C510	" " 4.7µF	MIL-C-39003	CSR13G-475KS	"	"	0.2	.0107		.0107

SUBTOTAL $7.5442/10^8$h

FINAL ASSEMBLY SMS Amplifier DRAWING NO. 34110-01-01 REV. PREPARED BY R.P. Cheatham

SUBASSEMBLY Dual Regulator DRAWING NO. 34686-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	T_n STRESS RATIO	λ_{B} (/10^8h)	K	λ_f (/10^8h)
Q501	Transistor, Si NPN	85M02699	S2N2219A	ATM605A	0 & 70	0.0/0.45	2.300		2.300
Q502	" " PNP	MIL-S-19500	JANTX2N2905A	"	"	.05/.45	6.580		6.580
CR501	Diode, Zener, Si	MIL-S-19500	JANTX1N752A	"	"	0.0/0.4	3.200		3.200
CR502	Diode, Gen Purp, Si	50M60197	SM1N914A	"	"	0.0/0.3	.885		.885
CR503	Diode, Zener, Si	MIL-S-19500	JANTX1N752A	"	"	0.0/0.4	3.200		3.200
CR504	" , Ref, Si	PC1-104	FCT-1121	"	"	0.0/0.3	2.425		2.425
Z501	Op Amp., IC	34651-01-00	LM108A	"	"		3.550		3.550
Z502	" " , IC	34651-01-00	LM108A	"	"		3.550		3.550

FORM 614

SUBTOTAL 25.690/10^8h

RELIABILIT EDICTION

FINAL ASSEMBLY ... Amplifier DRAWING NO. 34110-01-01 REV. PREPARED BY R. P. Cheatham

SUBASSEMBLY ... Log Compressor DRAWING NO. 34687-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g ($/10^8$h)	K	λ_f ($/10^8$h)
R1	Resistor, Met Film, 150K	MIL-R-55182	RNR60-H-1503FS	ATM605A	0 & 70	0.1	.177		.177
R2	Resistor, Met Film, 28K	"	RNR50-H-2802FS	"	"	0.1	.177		.177
R3	Resistor, " " 249Ω	"	RNR50-H-2490FS	"	"	0.1	.177		.177
R4	" " " 28K	"	RNR50-H-2802FS	"	"	0.1	.177		.177
R5	" " " 150K	"	RNR60-H-1503FS	"	"	0.1	.177		.177
R6	" " " 95.3K	"	RNR50-H-9532FS	"	"	0.1	.177		.177
R7	" " " 13K	"	RNR50-H-1302FS	"	"	0.1	.177		.177
R8	" " " 13K	"	RNR50-H-1302FS	"	"	0.1	.177		.177
R9		Deleted							
R10	" " " 60.4K	MIL-R-55182	RNR50-H-6042FS	"	"	0.1	.177		.177
R11	" " " 59K	"	RNR50-H-5902FS	"	"	0.1	.177		.177
R12	" " " 150K	"	RNR60-H-1503FS	"	"	0.1	.177		.177
R13	" " " 2K	"	RNR50-H-2001FS	"	"	0.1	.177		.177
R14	" " " 15K	"	RNR50-H-1502FS	"	"	0.1	.177		.177
R15	" " " 3.01K	"	RNR50-H-3011FS	"	"	0.1	.177		.177
R16	" " " 422Ω	"	RNR50-H-4220FS	"	"	0.1	.177		.177
R17	" " " 1.0M	"	RNR65-H-1004FS	"	"	0.1	.177		.177
R18	" " " 1.0M	"	RNR65-H-1004FS	"	"	0.1	.177		.177
R19	" " " 499K	"	RNR60-H-4993FS	"	"	0.1	.177		.177
R20	" " " 178K	"	RNR60-H-1783FS	"	"	0.1	.177		.177
R21	" " " 309K	"	RNR60-H-3093FS	"	"	0.1	.177		.177
R22	" " " 1.0M	"	RNR65-H-1004FS	"	"	0.1	.177		.177
R23	" " " 68.1K	"	RNR50-H-6812FS	"	"	0.1	.177		.177
R24	" " " 10K	"	RNR50-H-1002FS	"	"	0.1	.177		.177
R25	" " " 137K	"	RNR60-H-1373FS	"	"	0.1	.177		.177

SUBTOTAL $4.248/10^8$

FINAL ASSEMBLY SDS Amplifier DRAWING NO. 34110 REV. PREPARED BY R. P. Cheatham

SUBASSEMBLY C.A.F./Log Compressor DRAWING NO. 34637-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g $(/10^8h$	K	λ_f $(/10^8h$
R26	Resistor, Met Film 137K	MIL-R-55182	RNR60-H-1373FS	ATM605A	0 & 70	0.1	.177		.177
R27	" " " 137K	"	RNR60-H-1373FS	ATM605A	0 & 70	0.1	.177		.177
R28	" " " 1.0M	"	RNR65-H-1004FS	"	"	0.1	.177		.177
R29	" " " 732K	"	RNR65-H-7323FS	"	"	0.1	.177		.177
R30	" " " 137K	"	RNR60-H-1373FS	"	"	0.1	.177		.177
R31	" " " 137K	"	RNR60-H-1373FS	"	"	0.1	.177		.177
R32	" " " 137K	"	RNR60-H-1373FS	"	"	0.1	.177		.177
R33	" " " 1.0M	"	RNR65-H-1004FS	"	"	0.1	.177		.177
R34	" " " 732K	"	RNR65-H-7323FS	"	"	0.1	.177		.177
R35	" " " 49.9K	"	RNR50-H-4992FS	"	"	0.1	.177		.177
R36	" " " 49.9K	"	RNR50-H-4992FS	"	"	0.1	.177		.177
R37	" " " 49.9K	"	RNR50-H-4992FS	"	"	0.1	.177		.177
R38	" " " 8.06K	"	RNR50-H-8061FS	"	"	0.1	.177		.177
R39	" " " 4.75K	"	RNR50-H-4751FS	"	"	0.1	.177		.177
R40	" " " 4.75K	"	RNR50-H-4751FS	"	"	0.1	.177		.177
R41	" WW 10K	34734-01-00	34734-01-07	"	"	0.1	1.375		1.375
R42	" " 10K	"	34734-01-07	"	"	0.1	1.375		1.375
R43	" " 10K	"	34734-01-07	"	"	0.1	1.375		1.375
R44	" Met film	MIL-R-55182	RNR-Selected-FS	"	"	0.1	.177		.177
R45	" " "	"	RNR-Selected-FS	"	"	0.1	.177		.177
R46	" WW	34734-01-00	34734 Selected	"	"	0.1	1.375		1.375
R47	" WW 10.25K	34734-01-00	34734-01-08	"	"	0.1	1.375		1.375
R48	" Met film	MIL-R-55182	RNR-Selected-FS	"	"	0.1	.177		.177
R49	" WW	MIL-R-39007	RWR-Selected-FS	"	"	0.1	.064		.064
R50	" WW 10.25K	34734-01-00	34734-01-08	"	"	0.1	1.375		1.375

SUBTOTAL 11.500/10

RELIABILITY PREDICTION

FINAL ASSEMBLY SDS Amplifier DRAWING NO. 34110-01-01 REV. PREPARED BY R. P. Cheatham

SUBASSEMBLY [illegible].F./log Compressor DRAWING NO. 34687-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g $(/10^8h)$	K	λ_f $(/10^8h)$
R51	Resistor, Met film	MIL-R-55182	RNR-Selected-FS	ATM605A	0 & 70	0.1	.177		.177
R52	' WW	MIL-R-39007	RWR-Selected-FS	"	"	0.1	.064		.064
R53	' WW	34734-01-00	34734-Selected	"	"	0.1	1.375		1.375
R54	' Met film	MIL-R-55182	RNR-Selected-FS	"	"	0.1	.177		.177
R55	' "	"	RNR-Selected-FS	"	"	0.1	.177		.177
R56	' WW 4K	34734-01-00	34734-01-05	"	"	0.1	1.375		1.375
R57	' " 4K	"	34734-01-05	"	"	0.1	1.375		1.375
R58	' " 15.2K	"	34734-01-09	"	"	0.1	1.375		1.375
R59	" Met film 1.22K	MIL-R-55182	RNR50-H-1221FS	"	"	0.1	.177		.177
R60	' WW 4K	34734-01-00	34734-01-05	"	"	0.1	1.375		1.375
R61	' Met film 220Ω	MIL-R-55182	RNR50-H-2200FS	"	"	0.1	.177		.177
R62	" "	"	RNR-Selected-FS	"	"	0.1	.177		.177
R63	" "	"	RNR-Selected-FS	"	"	0.1	.177		.177
R64	" " 60.4K	"	RNR50-H-6042FS	"	"	0.1	.177		.177
R65	" " 28K	"	RNR50-H-2802FS	"	"	0.1	.177		.177
R66	" " 1K	"	RNR50-H-1001FS	"	"	0.1	.177		.177
RT1	Thermistor, WW, 1.0K	34689-01-01	34689	MIL-217A	"	0.1	3.000		3.000
RT2	" " "	"	"	"	"	0.1	3.000		3.000
RT3	" " "	"	"	"	"	0.1	3.000		3.000
RT4	" " "	"	"	"	"	0.1	3.000		3.000
K1	Relay, DPDT, Sealed	34655-01-01	432-7094	"	"	--	1.00		1.00

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SUBTOTAL 21.645 /10^8

RELIABILITY PREDICTION

FINAL ASSEMBLY SOS Amplifier DRAWING NO. 34110-01-01 REV. ___ PREPARED BY R. P. Cheatham

SUBASSEMBLY C.A.F./Log Compressor DRAWING NO. 34687-01-01 REV. ___ PREDICTION DATE 1/18/71 REV. ___

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_{g} $(/10^8 h)$	K	λ_{fs} $(/10^8 h)$
C1	Capacitor, Deleted								
C2	Capacitor, Ceramic, 33 pf	34661-01-00	34661-01-03	ATM-605A	0 & 70	0.1	.050		.050
C3	" " 100 pF	"	34661-01-04	"	"	0.1	.050		.050
C4	" " .12μF	"	34661-01-08	"	"	0.1	.050		.050
C5	" " .068μF	"	34661-01-07	"	"	0.1	.050		.050
C6	" " 33pF	"	34661-01-03	"	"	0.1	.050		.050
C7	" " .068μF	"	34661-01-07	"	"	0.1	.050		.050
C8	" " .039μF	"	34661-01-06	"	"	0.1	.050		.050
C9	" " .022μF	"	34661-01-05	"	"	0.1	.050		.050
C10	" " 33pF	"	34661-01-03	"	"	0.1	.050		.050
C11	" " .068μF	"	34661-01-07	"	"	0.1	.050		.050
C12	" " .039μF	"	34661-01-06	"	"	0.1	.050		.050
C13	" " .022μF	"	34661-01-05	"	"	0.1	.050		.050
C14	" " 33pF	"	34661-01-03	"	"	0.1	.050		.050
C15	", Solid Tan 15μF	MIL-C-39003	CSR13-E-156KS	"	"	0.1	.008		.008
C16	" " 15μF	"	CSR13-E-156KS	"	"	0.1	.008		.008
C17	" Ceramic 10pF	34661-01-00	34661-01-01	"	"	0.1	.050		.050
C18	" 22pF	"	34661-01-02	"	"	0.1	.050		.050
C19	" " 100pF	"	34661-01-04	"	"	0.1	.050		.050
C20	" " 100pF	"	34661-01-04	"	"	0.1	.050		.050
C21	" " 22pF	"	34661-01-02	"	"	0.1	.050		.050
C22	" " 100pF	"	34661-01-04	"	"	0.1	.050		.050
C23	" " 100pF	"	34661-01-04	"	"	0.1	.050		.050
C24	" " 22pF	"	34661-01-02	"	"	0.1	.050		.050
C25	" " 100pF	"	34661-01-04	"	"	0.1	.050		.050

SUBTOTAL $1.166/10^8$

FINAL ASSEMBLY SDS Amplifier DRAWING NO. 34110-01-01 REV. PREPARED BY R.P. Cheatham

SUBASSEMBLY C.A.F./Log Compressor DRAWING NO. 34687-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g (/10⁸h)	K	λ_f (/10⁸h)
C26	Capacitor, Ceramic, 10 pF	34661-01-00	34661-01-01	ATM605A	0 & 70	0.1	.050		.050
C27	" " 10 pF	34661-01-00	34661-01-01	"	"	0.1	.050		.050
C28	" " 10 pF	34661-01-00	"	"	"	0.1	.050		.050
C29	" " 22 pF	"	34661-01-02	"	"	0.1	.050		.050
C30	" " 10 pF	"	34661-01-01	"	"	0.1	.050		.050
C31	" " 22 pF	"	34661-01-02	"	"	0.1	.050		.050
C32	" " 100 pF	"	34661-01-04	"	"	0.1	.050		.050
						T_n ↓			
Q1	Transistor Si, NPN	85M02699	SM2N2222A	"	"	0.0/0.3	1.775		1.775
Q2	" N-Chan, FET	34664-01-01	2N4445	"	"	0.0/0.25	3.800		3.800
Q3	" P-Chan, FET	MIL-S-19500	JAN2N2609	"	"	0.0/0.3	1.775		1.775
Q4	" Dual NPN	MIL-S-19500	JANTX2N2920	"	"	0.0/0.3	1.775		1.775
Q5	" Dual PNP	MIL-S-19500	JAN2N3811	"	"	0.0/0.25	3.800		3.800
Q6	" Si, PNP	50M60198	SM2N2907A	"	"	0.0/0.25	3.800		3.800
CR1	Diode, Gen Purpose, Si	50M60197	SM1N914A	"	"	0.0/0.3	.885		.885
CR2	" " "	"	SM1N914A	"	"	0.0/0.3	.885		.885
CR3	" " "	"	SM1N914A	"	"	0.0/0.3	.885		.885
CR4	" " "	"	SM1N914A	"	"	0.0/0.3	.885		.885
CR5	" " "	"	SM1N914A	"	"	0.0/0.3	.885		.885
CR6	" " "	"	SM1N914A	"	"	0.0/0.3	.885		.885
CR7	" " "	"	SM1N914A	"	"	0.0/0.3	.885		.885

SUBTOTAL 23.270/10⁸

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RELIABILITY PREDICTION

FINAL ASSEMBLY SDS Amplifier DRAWING NO. 34110-01-01 REV. PREPARED BY R. P. Cheatham

SUBASSEMBLY C.A.F./Log Compressor DRAWING NO. 34687-01-01 REV. PREDICTION DATE 1/18/71 REV.

REF. DESIG.	PART DESCRIPTION	MIL-SPEC. OR VENDOR	MIL DESIGNATION OR VENDOR PART NO.	λ SOURCE	TEMP. °C	STRESS RATIO	λ_g (/10⁸h)	K	λ_f (/10⁸h)
Z1	Op-Amp, IC	34651-01-00	LM108A	ATM605A	0 & 70	0.1	3.550		3.550
Z2	" "	"	LM108A	"	"	0.1	3.550		3.550
Z3	" "	"	LM108A	"	"	0.1	3.550		3.550
Z4	" "	"	LM108A	"	"	0.1	3.550		3.550
Z5	" "	"	LM108A	"	"	0.1	3.550		3.550
Z6	" "	"	LM108A	"	"	0.1	3.550		3.550
Z7	" "	"	LM108A	"	"	0.1	3.550		3.550
Z8	" "	"	LM108A	"	"	0.1	3.550		3.550
Z9	" "	"	LM108A	"	"	0.1	3.550		3.550
Z10	" "	"	LM108A	"	"	0.1	3.550		3.550
Z11	" "	34659-01-01	LM108A	"	"	0.1	3.550		3.550

SUBTOTAL 39.05 /10⁸ h

FORM 514

REVISION A

SDS SINGLE FAILURE POINT SUMMARY

February 19, 1971

The SDS single failure points (SFP's) are summarized in table 1. Data inputs to this summary and the data sources are as follows:

1. Critical Parts. Critical parts are defined as those which could (a) render the entire SDS inoperative, (b) result in a personnel hazard, or (c) propagate to external equipment. The SDS contains no parts having failure modes which could result in a hazard to personnel. The source of critical parts is the FMECA.

2. Mode. This is the failure mode which causes the part to be defined as critical.

3. Part Failure Rates. The part failure rates listed are taken from the SDS reliability prediction and are stated in failures per 10^8 hours.

4. Probability of Occurrence. The probability of failure mode occurrences are given in ATM605A.

5. Product. The product of the failure rate and probability of occurrence.

Specific revisions made to this issue are the removals of six previously reported critical failure modes. One removal was due to a design change and the remaining five were removed because ATM605A gives a zero probability of occurrence for those modes. The list of critical failure modes is now shortened from 21 to 15.

The remaining critical failure modes are inherent in the design due to the use of a common voltage regulator for all four channels. There are no practical means to eliminate these failure modes and redundancy is not feasible.

Table 1. Single Failure Point Summary

Rank	Ref. Design	Mode	Failure Rate	Probability	Product
1	Q502	B-E short	6.580	.125	.8225
2	CR504	Short	2.425	.30	.7275
3	R509	Open	1.525	.20	.305
4	Q501	B-E open	2.300	.125	.2875
5	CR504	Open	2.425	.10	.2425
6	CR502	Open	.885	.20	.177
7	R510	Short	1.525	.10	.1525
8	C508	Short	.050	.90	.045
9	R501	Open	.177	.10	.0177
10	R504	Open	.177	.10	.0177
11	R513	Open	.177	.10	.0177
12	C502	Short	.0107	.20	.0021
13	C503	Short	.0107	.20	.0021
14	C509	Short	.0107	.20	.0021
15	C510	Short	.0107	.20	.0021

REVISION A

SDS FMECA

22 January 1971

The Failure Mode Effects and Criticality Analysis has been revised to include the parts added during a recent design change and to eliminate some typographical errors found in the original issue.

As described in TR 70-33, SDS Reliability Program Plan, the criticality ranges from 0 to 1.0 such that the degree of criticality increases with the degree of performance degradation. A failure mode which renders the system inoperative is considered to be a critical failure and would have a an entry in the criticality column of 1.0. Likewise, an entry of zero would relate to a part failure mode having a negligible effect on system performance.

All critical part failure modes are also listed in a separate Single Failure Point (SFP) summary.

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 1-22-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2-16-71
PAGE 1 OF 31

NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R1	Calibration signal voltage divider	Open	No cal function	.05	No effect on normal operation or other data channels
		Drift	Cal signal error	.01	Error proportional to drift
Resistor, R2	Q1, Input resistance	Open	No cal function	.05	See remarks R1 open
		Drift	No effect	0	
Resistor, R3	Cal. voltage divider	Open	Cal. abnormally high	.05	Calibration useless, normal operation not affected
		Drift	Cal. signal error	.01	Error proportional to drift
Resistor, R4	Q1, Collector res.	Open	Cal. relay held on	.1	Gain reduced (÷10)
		Drift	No effect	0	
Resistor, R5	Cal. current res.	Open	No cal. function	.05	See remarks R1 open
		Drift	Varies Z1 offset during cal	.01	See remarks R1 drift
Resistor, R6	Cal. current res.	Open	No cal. function	.05	See remarks R1 open
		Drift	Varies Z1 offset during cal	.01	See remarks R1 drift

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2-16-71
PAGE 2 OF 31

NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R7	Z1 input res.	Open	Renders one channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R8	Z1 input res.	Open	Renders one channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R9	Deleted				
Resistor, R10	Z1 offset coefficient shunt	Open	Increase dc offset coefficient	.1	Reduces dynamic range
		Drift	Varies dc offset coefficient	0	Negligible effect
Resistor, R11	Z1 feedback resistor	Open	Renders one channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R12	Q3, Drain resistor	Open	Stays in low gain mode	.1	Channel gain, reduced by 20 dB
		Drift	None	0	
Resistor, R13	Z1 feedback resistor	Open	Z1 gain reduced	.1	
		Drift	Δ gain with drift	.02	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2-16-71
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R14	Feedback resistor	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R15	Feedback resistor	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R16	Gain change isolation resistor	Open	Stays in low gain mode	.1	
		Drift	Gain change error	.01	Cal will give true channel gain
Resistor, R17	Z2 input res.	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R18	Z2 feedback res.	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R19	Z2 input resistor	Open	Large drop in channel gain	.2	Large signals will still feed through
		Drift	Δ gain with drift	.02	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME: SDS Amplifier
ASSEMBLY NAME: Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY: 4
ASSY. DWG. NO.: 34687-01-01
SCHEMATIC REF. NO.: 90-34687-21-01

DATE: 22 January 1971
PREPARED BY: R. F. McMurray
APPROVED BY: R. P. Cheatham
FMECA REV. NO.: A, 2-16-71
PAGE 4 OF 31

NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R10	Filter resistor	Open	Changes bass boost	.05	
		Drift	Varies bass boost	0	Little noticeable effect
Resistor, R11	Filter resistor	Open	Changes bass boost	.05	
		Drift	Varies bass boost	0	Little noticeable effect
Resistor, R12	Z2 input resistor	Open	Severe data degradation	.2	
		Drift	Varies CMR of Z2	0	Little noticeable effect
Resistor, R13	Z2 feedback res.	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R14	Z2 feedback res.	Open	Approx. 20 dB loss of gain	.1	
		Drift	Δ gain with drift	.02	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2-16-71
PAGE 5 OF 31

NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R25	Z3 input res.	Open	One channel inoperative	.25	
		Drift	Δ frequency response with drift	.05	
Resistor, R26	Z3 input res.	Open	One channel inoperative	.25	
		Drift	Δ frequency response with drift	.05	
Resistor, R27	Z3 input res.	Open	One channel inoperative	.25	
		Drift	Δ frequency response with drift	.05	
Resistor, R28	Z3 input res.	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R29	Z3 feedback res.	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	

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TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2-16-71
PAGE 6 OF 31

NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R30	Z4 input resistor	Open	One channel inoperative	.25	
		Drift	Δ frequency response with drift	.05	Little noticeable effect
Resistor, R31	Z4 input resistor	Open	One channel inoperative	.25	
		Drift	Δ frequency response with drift	.05	Little noticeable effect
Resistor, R32	Z4 input resistor	Open	One channel inoperative	.25	
		Drift	Δ frequency response with drift	.05	Little noticeable effect
Resistor, R33	Z4 input	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R34	Z4 feedback	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2-16-71
PAGE 7 OF 31

NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R35	Input resistor for Z5	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R36	Input resistor for - reference log Amplifier Z6	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R37	Input resistor for + reference log Amplifier Z7	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	
Resistor, R38	Main log amplifier frequency compensation resistor	Open	One channel inoperative	.25	
		Drift	No significant effect	0	
Resistor, R39	- Reference log amplifier frequency compensation resistor	Open	One channel inoperative	.25	
		Drift	No significant effect	0	
Resistor, R40	+ Reference log amplifier frequency compensation resistor	Open	Loss of + signals	.2	Partial output still useful
		Drift	No significant effect	0	
Resistor, R41	Signal splitter amp (Z8) input resistor	Open	One channel inoperative	.25	
		Drift	Δ gain with drift	.02	

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FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

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QUANTITY OF ASSY. 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY S. F. Correll
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R42	+ Feedback resistor on splitter amplifier	Open	Loss of + signals	.2	Partial output still useful
		Drift	Δ + amplitude with drift	.02	
Resistor, R43	- Feedback resistor on splitter amplifier (Z8)	Open	Loss of - signals	.2	Partial output still useful
		Drift	Δ Amplitude with drift	.02	
Resistor, R44	Bias resistor + signal compensation amplifier	Open	Dc shift in output which would possibly cause loss of one channel	.25	
		Drift	Dc level shift in output proportional to drift	.01	Slight degradation of dynamic range
Resistor, R45	Bias resistor + signal compensation amplifier	Open	Dc shift in output which would possibly cause loss of one channel	.25	
		Drift	Dc level shift in output proportional to drift	.02	Slight degradation of dynamic range

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Resistor, R46	Bias resistor + signal compensation amplifier	Open	Dc shift in output which would possibly cause loss of one channel	.25	
		Drift	Dc level shift in output proportional to drift	.1	Considerable loss of dynamic range
Resistor, R47	Feedback resistor + signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	+ Signal amplitude will change proportional to drift	.02	
Resistor, R48	Feedback resistor + signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	+ Signal amplitude will change proportional to drift	.02	
Resistor, R49	Feedback resistor + signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	+ Signal amplitude will change proportional to drift	.02	
Resistor, R50	Feedback resistor - signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	- Signal amplitude will change proportional to drift	.02	

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Resistor, R51	Feedback resistor - signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	- Signal amplitude will change proportional to drift	.02	
Resistor, R52	Feedback resistor - signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	- Signal amplitude will change proportional to drift	.02	
Resistor, R53	Bias resistor - signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	Dc shift in output proportional to drift	.1	Considerable loss of dynamic range
Resistor, R54	Bias resistor - signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	Dc shift in output proportional to drift	.02	Slight loss of dynamic range
Resistor, R55	Bias resistor - signal compensation amplifier	Open	One channel inoperative	.25	
		Drift	Dc shift in output proportional to drift	.01	Slight loss of dynamic range

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R56	Input summing resistor, output amplifier	Open	Lose + signal from one channel	.2	Partial output still useful
		Drift	Error in + signal amplitude proportional to drift	.02	
Resistor, R57	Input summing resistor, output amplifier	Open	One channel inoperative	.25	
		Drift	Error in - signal amplitude proportional to drift	.02	
Resistor, R58	Output amplifier dc offset level set	Open	Output dc level will shift from 2.5 V to zero	.15	~ 6 dB reduction in one channel dynamic range
		Drift	Dc level shift proportional to drift	.02	
Resistor, R59	Output amplifier bias resistor	Open	One channel inoperative	.25	
		Drift	No effect	0	
Resistor, R60	Output amplifier feedback resistor	Open	One channel inoperative	.25	
		Drift	Amplitude change proportional to drift	.02	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R61	Output amplifier frequency compensation resistor	Open	One channel inoperative	.25	
		Drift	No effect	0	
Resistor, R62	Cal current resistor	Open	No cal function	.05	No effect on normal operation
		Drift	Cal error	.03	No effect on normal operation
Resistor, R63	Cal current resistor	Open	No cal function	.05	No effect on normal operation
		Drift	Cal error	.03	No effect on normal operation
Resistor, R64	Q1 Collector Resistor	Open	Unable to calibrate	.05	No effect on normal operation
		Drift	No effect	0	
Resistor, R65	Biases Q1 with R66	Open	May cause cal relay to be held on	.1	Gain reduced (÷10)
		Drift	No effect	0	

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Resistor, R66	Biases Q1 with R65	Open	Unable to operate cal relay	.05	Normal operation not effected
		Drift	No effect	0	
Resistor, R67	Part of voltage divider with R71	Open	Degrades log compressor accuracy	.01	< 2% degradation
		Drift	Negligible effect	0	
Resistor R68	Part of current limiter with R69 and R70	Open	Degrades log compressor accuracy	.02	< 4% degradation
		Drift	Negligible effect	0	
Resistor, R69	Part of current limiter with R68 and R70	Open	Degrades log compressor accuracy	.02	< 4% degradation
		Drift	Negligible effect	0	
Resistor, R70	Part of current limiter with R68 and R69	Open	Degrades log compressor accuracy	.02	< 4% degradation
		Drift	Negligible effect	0	
Resistor, R71	Part of voltage divider with R67	Open	Causes large offset at log compressor output	.25	One channel inoperative
		Drift	Negligible effect	0	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Thermistor, RT1	Temperature compensator	Short	Degrades log compressor accuracy	.1	
		Open	Opens + signal path	.2	Causes severe data degradation
		Drift	Compressor error proportional to drift	.1	
Thermistor, RT2	Temperature compensator	Short	Degrades log compressor accuracy	.1	
		Open	Opens + signal path	.2	Causes severe data degradation
		Drift	Compressor error proportional to drift	.1	
Thermistor RT3	Temperature compensator	Short	Degrades log compressor accuracy	.1	
		Open	Opens + signal path	.2	Causes severe data degradation
		Drift	Compressor error proportional to drift	.1	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Thermistor, RT4	Temperature compensator	Short	Degrades log compressor accuracy	.1	
		Open	Opens + signal path	.2	Causes severe data degradation
		Drift	Compressor error proportional to drift	.1	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C1	DELETED				
Capacitor, C2	Z1 compensation	Short	Z1 INOP, output → + 9.5 V	.25	One channel inoperative
		Drift	Varies compensation	0	Negligible effect
Capacitor, C3	Z1 compensation	Short	Z1 INOP, out → 0 V	.25	One channel inoperative
		Drift	None	0	
Capacitor, C4	Z2 filter cap	Short	Reduces LF boost	.05	Affects freuqency response
		Drift	Δ Frequency response with drift	0	Affects frequency response
Capacitor, C5	Z2 filter cap	Short	Reduces LF boost	.05	Affects frequency response
		Drift	Δ Frequency response with drift	0	Affects frequency response
Capacitor, C6	Z2 compensation	Short	Z2 INOP, output → + 9.5 V	.25	One channel inoperative
		Drift	Varies compensation	0	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C7	Z3 filter cap	Short	Shorts signal path	.25	One channel inoperative
		Drift	Varies HF attenuation	0	Negligible effect
Capacitor, C8	Z3 filter cap	Short	Shorts signal path	.25	One channel inoperative
		Drift	Varies HF attenuation	0	Negligible effect
Capacitor, C9	Z3 filter cap	Short	Shorts signal patch	.25	One channel inoperative
		Drift	Varies HF attenuation	0	Negligible effect
Capacitor, C10	Z3 compensation	Short	Z3 INOP, output → + 9.5 V	.25	One channel inoperative
		Drift	Varies compensation	0	Negligible effect
Capacitor, C11	Z4 filter cap	Short	Shorts signal path	.25	One channel inoperative
		Drift	Varies HF attenuation	0	
Capacitor, C12	Z4 filter cap	Short	Shorts signal path	.25	One channel inoperative
		Drift	Varies HF attenuation	0	
Capacitor, C13	Z4 filter cap	Short	Shorts signal path	.25	One channel inoperative
		Drift	Varies HF attenuation	0	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C14	Z4 compensation	Short	Z4 INOP, output →+9.5 V	.25	Channel inoperative
		Drift	Varies compensation	0	
Capacitor, C15	Input coupling - high pass filter capacitor	Short	Dc offset at output proportional to offset of Z4	0 to .15	Degradation proportional to Z4 output offset
		Drift	No effect	0	
Capacitor, C16	Input coupling - high pass filter capacitor	Short	Dc offset at output proportional to off-set	0 to .15	Degradation proportional to Z4 output offset
		Drift	No effect	0	
Capacitor, C17	High frequency roll-off capacitor on Z5 (input amplifier)	Short	One channel inoperative	.25	
		Drift	No effect	0	
Capacitor, C18	Frequency compensa-tion on Z5 (input amplifier)	Short	Output goes to + supply	.25	One channel inoperative
		Drift	No effect		

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C19	Power supply rejection capacitor on Z5 (input amplifier)	Short	Output goes to zero	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C20	- Reference amplifier (Z6) high frequency rolloff capacitor	Short	Output of reference amplifier would go to 0 volts	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C21	- Reference amplifier (Z6) frequency compensation	Short	Output of Z6 goes to + supply	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C22	Power supply rejection capacitor - reference amplifier (Z6)	Short	Output of Z6 will go to zero	.25	One channel inoperative
		Drift	No effect	0	

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NAME & REF DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C23	High frequency roll-off capacitor + reference amplifier (Z7)	Short	Output of Z7 will go to zero	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C24	Frequency compensation + reference amplifier (Z7)	Short	Output of Z7 will go to + supply voltage	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C25	Power supply rejection capacitor + reference amplifier (Z7)	Short	Output of Z7 will go to 0 V	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C26	Frequency compensation splitter amplifier (Z8)	Short	Output of Z8 will go to + supply	.25	One channel inoperative
		Drift	No effect	0	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C27	Power supply rejection capacitor, splitter amplifier (Z8)	Short	Output of Z8 will go to 0 V	.25	One channel inoperative
		Drift	No effect	0	
Capacitor C28	Frequency compensation + compensation amplifier (Z9)	Short	Output of Z9 will go to + supply	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C29	Power supply rejection capacitor + compensation amplifier (Z9)	Short	Output of Z9 will go to 0 V	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C30	Frequency compensation - compensation amplifier (Z10)	Short	Output of Z10 will go to + supply	.25	One channel inoperative
		Drift	No effect	0	

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NAME & REF DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C31	Power supply rejection capacitor - compensation amplifier (Z10)	Short	Output of Z10 will go to 0 V	.25	One channel inoperative
		Drift	No effect	0	
Capacitor, C32	High frequency cut-off on output amplifier (Z11)	Short	Causes large offset in output	.25	One channel inoperative
		Drift	No effect	0	

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Transistor, Q1 2N2222	Relay Amplifier	h_{FE} Drift	May not calibrate	.05	Normal operation not affected
		C-B Short	Cal relay always closed	.1	Reduces gain 20 dB
		C-B Open	Cal relay inoperative	.05	No cal function
		B-E Short	Cal relay inoperative	.05	No cal function
		B-E Open	Cal relay inoperative	.05	No cal function
Transistor, Q2 2N4445	Analog Switch	Drift, D-S Res.	Small Δ gain with drift	.02	
		D-G Short	Would cause large dc offset	.25	Channel inoperative
		D-G Open	Switch open (low gain mode)	.1	No gain change function
		G-S Short	Switch on (high gain mode)	.05	No gain change function
		G-S Open	Switch open (LG mode)	.1	No gain change function

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Transistor, Q3 2N2609	Analog Switch	Drift, Pinch Off	Switch on (HG mode)	.05	No gain change function
		D-G Short	Switch on (HG mode)	.05	No gain change function
		D-G Open	Switch off (LG mode)	.1	No gain change function
		G-S Short	Short gain change command switch on (HG mode)	.2	Unable to change gain of any channel. All stay in HG mode.
		G-S Open	Switch off (LG mode)	.1	No gain change function
Transistor, Q4A	Positive signal log function feedback transistor	C-B Short	Short signal path to ground	.25	One channel inoperative
		C-B Open	Large loss of dynamic range	.2	Output may still be useful
		B-E Short	Shorts signal path to ground	.25	One channel inoperative
		B-E Open	Large loss of dynamic range	.2	Output may still be useful

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NAME & REF DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Transistor, Q4B	Positive reference signal feedback transistors	C-B Short	Lose + log compensation	.2	Causes severe data degradation
		C-B Open	Lose + log compensation	.2	Causes severe data degradation
		B-E Short	Lose + log compensation	.2	Causes severe data degradation
		B-E Open	Lose + log compensation	.2	Causes severe data degradation
Transistor, Q5A	Negative signal log function feedback transistor	C-B Short	Short signal path to ground	.25	One channel inoperative
		C-B Open	Large loss of dynamic range	.2	Output may still be useful
		B-E Short	Short signal path to ground	.25	One channel inoperative
		B-E Open	Large loss of dynamic range	.2	Output may still be useful

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Transistor, Q5A	Negative reference signal feedback transistor	C-B short	Lose-log compensation	.2	Causes severe data degradation
		C-B open	Lose-log compensation	.2	Causes severe data degradation
		B-E short	Lose-log compensation	.2	Causes severe data degradation
		B-E open	Lose-log compensation	.2	Causes severe data degradation

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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Transistor, Q6 2N2907	Relay Driver	h_{FE} Drift	May not calibrate	.05	Normal operation not affected
		C-B Short	Cal relay always closed	.1	Reduces gain 20 dB
		C-B Open	Cal relay inoperative	.05	Normal operation not affected
		B-E Short	Cal relay inoperative	.05	Normal operation not affected
		B-E Open	Cal relay inoperative	.05	Normal operation not affected
Diode, CR1 1N914	Transient protection	Short	No cal function	.05	No effect on normal operation
		Open	May damage Q6	.05	No effect on normal operation

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FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME: SDS Amplifier
ASSEMBLY NAME: Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY.: 4
ASSY. DWG. NO.: 34687-01-01
SCHEMATIC REF. NO.: 90-34687-21-01

DATE: 22 January 1971
PREPARED BY: S. F. Correll
APPROVED BY: R. P. Cheatham
FMECA REV. NO.: A, 2-16-71
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Diode, CR2 1N914	Positive signal splitter	Short	Would cause severe signal distortion	.2	Output may still be useful
		Open	Would reduce dynamic range and cause distortion	.2	Output may still be useful
Diode, CR3 1N914	Negative signal splitter	Short	Would cause severe signal distortion	.2	Output may still be useful
		Open	Would reduce dynamic range and cause distortion	.2	Output may still be useful
Diode, CR4 1N914	Reverse zeroing diode for Z9	Short	Cause loss of + signals	.2	Output may still be useful
		Open	Effect could range from slight offset to channel inoperative	.05 to .25	
Diode, CR5 1N914	Reverse zeroing diode for Z10	Short	Cause loss of -signals	.2	
		Open	Same as CR4 open	.05 to .25	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS Amplifier
ASSEMBLY NAME Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY 4
ASSY. DWG. NO. 34687-01-01
SCHEMATIC REF. NO. 90-34687-21-01

DATE 22 January 1971
PREPARED BY S. F. Correll
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Diode, CR6 1N914	+ threshold limiting diode	Short	Cause output ambiguity	.15	
		Open	Channel inoperative	.25	
Diode, CR7 1N914	-threshold limiting diode	Short	Cause output ambiguity	.15	
		Open	Channel inoperative	.25	
Relay, K1	Cal relay	Coil open	No cal function	.05	No effect on normal operation
		Contacts stuck closed	Signal attenuated and geophone undamped	.1	Output still useful
OP Amp, Z1 LM108A	Signal preamplifier	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	
OP Amp, Z2 LM108A	LF boost, filter	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME: SDS Amplifier
ASSEMBLY NAME: Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY.: 4
ASSY. DWG. NO.: 34687-01-01
SCHEMATIC REF. NO.: 90-34687-21-01

DATE: 22 January 1971
PREPARED BY: R. F. McMurray
APPROVED BY: R. P. Cheatham
FMECA REV. NO.: A, 2-16-71
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
OP Amp, Z3 LM108A	Low pass filter	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	
OP Amp, Z4 LM108A	Low pass filter	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	
OP Amp, Z5 LM108A	Main log amplifier	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	
OP Amp, Z6 LM108A	-Reference amplifier	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	
Op Amp, Z7 LM108A	+ Reference amplifier	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

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ASSEMBLY NAME: Cal-Amp-Fil/Log Compressor
QUANTITY OF ASSY: 4
ASSY. DWG. NO.: 34687-01-01
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NAME & REF DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
OP Amp, [illegible] LM108A	Signal splitter	Output inoperative	Channel inoperative	.25	
		Offset drift	Decrease dynamic range	.1	
OP Amp, [illegible] LM108A	+ Summation amplifier	Output inoperative	+ signals would be lost	.15	Output still useful
		Offset drift	Decrease dynamic range	.1	
OP Amp, [illegible] LM108A	- Summation amplifier	Output inoperative	- signals would be lost	.15	Output still useful
		Offset drift	Decrease dynamic range	.1	
OP Amp, [illegible] LM741	Output amplifier	Output inoperative	Channel inoperative	.25	
		Offset drift	Slight decrease in dynamic range	.02	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Dual Regulator
QUANTITY OF ASSY. 1
ASSY. DWG. NO. 34686-01-01
SCHEMATIC REF. NO. 90-34686-21-01

DATE 1-21-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
FMECA REV. NO. A, 2/16/71
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R501, Met Film	Filter/Q501 Base Bias Resistor	Open	+12 lost to Z501	1.0	Regulator output goes to zero
		Drift	None	0	
Resistor, R502 Met film	Q501 Base Bias	Open	+ bias on Q501 lost	.4	Regulator output → ±8.5V, data accuracy lost
		Drift	None	0	
Resistor, R503 Met film	Coupling resistor	Open	Regulation lost ±9.5V → ±11V	.4	Data accuracy lost
		Drift	None	0	
Resistor, R504 Met film	Reference Bias Resistor	Open	±9.5V goes to zero	1.0	Complete power loss
		Drift	Slight variation in output voltage	0	
Resistor, R505 Wirewound	Voltage Divider, Error Signal	Short	Output reduced to ±7V	.4	Data accuracy lost
		Open	Output increased to ±11V, regulation lost	.4	Data accuracy lost
		Drift	±outputs vary with drift	0	
Resistor, R506 Met film	Error Sig. Trim Res.	Open	Output → ±11V, regulation lost	.4	Data accuracy lost
		Drift	None	0	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
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QUANTITY OF ASSY. 1
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R507 Wirewound	Error Sig.Trim Res.	Short	Slight change in ±9.5V	0	
		Open	Output → 11V, regulation lost	.4	Data accuracy lost
		Drift	None	0	
Resistor, R508	Error Sig. Voltage Divider	Short	Output → ±11V, Regulation lost	.4	Data accuracy lost
		Open	Output → ±7V	.4	Data accuracy lost
		Drift	None	0	Negligible error
Resistor, R509 Wirewound	Error Sig. Voltage divider (neg.)	Short	-9.5V output → -11V regulation lost	.4	Data accuracy lost
		Open	-9.5V output → 0	1.0	Complete data loss
		Drift	-9.5V varies with drift	0	Negligible error
Resistor, R510 Wirewound	Error Sig. Voltage Divider (Neg.)	Short	-9.5V output → 0	1.0	Complete data loss
		Open	-9.5V output → -11V regulation lost	.4	Data accuracy lost
		Drift	-9.5V varies with drift	0	Negligible error
Resistor, R511 Met Film	Coupling Resistor	Open	-9.5V → -11V	.4	Data accuracy lost
		Drift	None	0	Negligible error

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Dual Regulator
QUANTITY OF ASSY 1
ASSY. DWG. NO. 34686-01-01
SCHEMATIC REF. NO. 90-34686-21-01

DATE 1-21-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Resistor, R512 Met Film	Q502 Base Bias	Open	-9.5V → -8.5V	.4	Data accuracy lost
		Drift	None	0	Negligible error
Resistor, R513 Met Film	Filter/Q502 Base Bias resistor	Open	-9.5V → 0V	1.0	Complete data loss
		Drift	None	0	
Resistor, R514	Isolates gain change command logic	Open	All channels always in low gain mode	.4	Gain ÷ 10
		Drift	No effect	0	
Resistor, R515	Sets bias of Q503 with R517	Open	Would cause an error in log accuracy of all channels	.15	Most noticeable for very small signals
		Drift	No effect	0	
Resistor, R516	Collector load for Q503	Open	Would cause small error in log accuracy of all channels	.1	<3% error
		Drift	Negligible effect	0	
Resistor, R517	Sets bias of Q503 with R515	Open	Would cause an error in log accuracy of all channels	.15	Most noticeable for very small signals
		Drift	No effect	0	

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FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Dual Regulator
QUANTITY OF ASSY. 1
ASSY. DWG. NO. 34686-01-01
SCHEMATIC REF. NO. 90-34686-21-01

DATE 1-21-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C501	H.F. Boost, and Reg.	Short	±9.5V decreases	.4	Data accuracy lost
		Drift	None	0	
Capacitor, C502	Ripple filter	Short	±9.5V → 0V, R501 fuzes	1.0	Complete data loss
		Drift	None	0	
Capacitor, C503	Ripple filter	Short	-9.5V → 0V, R503 fuzes	1.0	Complete data loss
		Drift	None	0	
Capacitor, C504	H.F. Boost, - Reg.	Short	-9.5V → Low, Temp. dependent	.4	Data accuracy lost
		Drift	None	0	
Capacitor, C505	Z501 Compensation	Short	±9.5V → ±11V	.4	Data accuracy lost
		Drift	None	0	
Capacitor C506	Z501 Compensation	Short	±9.5V → ±5V, regulation lost	.4	Data accuracy lost
		Drift	None	0	Negligible effect
Capacitor, C507	Z502 Compensation	Short	-9.5V → -5V	.4	Data accuracy lost
		Drift	None	0	
Capacitor, C508	Z502 Compensation	Short	-9.5V → 0V	1.0	Complete data loss
		Drift	None	0	

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Dual Regulator
QUANTITY OF ASSY. 1
ASSY. DWG. NO. 34686-01-01
SCHEMATIC REF. NO. 90-34686-21-01

DATE 1-21-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Capacitor, C509	Output Filter	Short	-9.5V → 0V	1.0	Complete data loss
		Drift	None	0	
Capacitor, C510	Output Filter	Short	±9.5V → 0V	1.0	Complete data loss
		Drift	None	0	
Transistor, Q501	Series Regulator	h_{FE} Drift	Regulation lost at low temp.	.4	Data accuracy lost
		C-B short	±9.5V → ±11.4V	.4	Data accuracy lost
		C-B open	±9.5V → ±1V	1.0	Complete data loss
		B-E short	±9.5V → ±1V	1.0	Complete data loss
		B-E open	±9.5V → ±0V	1.0	Complete data loss
Transistor, Q502	Series Regulator	h_{FE} Drift	Regulation lost at low temp -9.5 only	.4	Data accuracy lost
		C-B short	-9.5V → -11.4V	.4	Data accuracy lost
		C-B open	-9.5V → -1V	1.0	Complete data loss
		B-E short	-9.5V → -1V	1.0	Complete data loss
		B-E open	-9.5V → 0V	1.0	Complete data loss

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Dual Regulator
QUANTITY OF ASSY. 1
ASSY. DWG. NO. 34686-01-01
SCHEMATIC REF. NO. 90-34686-21-01

DATE 1-21-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Transistor, Q503	Compensates for log compressor op-amp input bias current	h_{FE} Drift	Would reduce small signal log accuracy	.1	Would effect all channels
		C-B Short	Impairs log accuracy	.15	
		C-B Open	Impairs log accuracy	.15	
		E-B Short	Impairs log accuracy	.15	
		E-B Open	Impairs log accuracy	.15	
Diode, CR501 Zener	Coupling	Drift	None	0	
		Open	±9.5V → ±11.4V	.4	Data accuracy lost
		Short	None	0	
Diode, CR502, General Purpose	Anti-Negative Lockup	Open	Possible Neg. Lockup	1.0	Complete data loss
		Short	±9.5V → ±5V	.4	Data accuracy lost
Diode, CR503, Zener	Coupling	Drift	None	0	
		Open	-9V → -11.4V	.4	Data accuracy lost
		Short	None	0	
Diode, CR504 Zener	Reference	Drift	±9.5V varies with drift	.1	Some accuracy loss
		Open	Regulators oscillate	1.0	Complete data loss
		Short	±9.5V → 0V	1.0	Complete data loss

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Dual Regulator
QUANTITY OF ASSY. 1
ASSY. DWG. NO. 34686-01-01
SCHEMATIC REF. NO. 90-34686-21-01

DATE 1-21-71
PREPARED BY R. F. McMurray
APPROVED BY R. P. Cheatham
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Op-Amp, Z501, LM108A	Error Sig. Amplifier	Output Open	±9.5V → ±11V	.4	Data accuracy lost
		Parameter drift	None	0	
Op-Amp, Z502 LM108A	Error Sig. Amplifier	Output open	-9.5V → -11V	.4	Data accuracy lost
		Parameter drift	None	0	

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TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

EM NAME: IES
MBLY NAME: ...ophone - Cable Assembly
ITITY OF ASS'Y: -
DWG. NO.: ...120-01-01
MATIC REF. NO.: ...120-21-01

DATE: 25 January 1971
PREPARED BY: Unruh
APPROVED BY: Cheatham
FMECA REV. NO.:
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AME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
.l Assembly	Generates a voltage proportional to the relative velocity between the coil and magnet assemblies	Open	Would render the geophone inoperative	.25	One channel inoperative
		Short	Would degrade the generator constant and damping characteristics	.01 to .25	The degree of degradation would depend on the number of turns shorted
pension Spring	Controls mass position and free period of the geophone	Broken spring	Geophone inoperative	.25	One channel inoperative
		Bent spring	Would change the free period and damping of the geophone	.01 to .25	The degree of degradation would depend on the amount of spring deformity
ulator Gasket	Electrically isolates and pressure seals the magnet shells (case)	Short	Geophone inoperative	.25	One channel inoperative
		Pressure leak	Epoxy parts may outgas in lunar environment	.0	Negligable effect
net Assembly	Maintains constant magnetic field in the vicinity of the coil	Change in magnet charge	Would change the generator constant and damping characteristics	.01	The degree of degradation would depend on the amount of change in the state of charge. Handling and storage methods are sufficient. Thermally induced changes are minor.
ail	Forms a redundant electrical connection spring and coil and spring and magnet assembly	Open	No effect	0	Pigtails have double and triple redundancy and are across spring terminations which are also conductive

TELEDYNE GEOTECH

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS

SYSTEM NAME SDS
ASSEMBLY NAME Geophone - Cable Assembly
QUANTITY OF ASSY. 1
ASSY. DWG. NO. 34120-01-01
SCHEMATIC REF. NO. 34120-21-01

DATE 25 January 1971
PREPARED BY Unruh
APPROVED BY Cheatham
FMECA REV. NO.
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NAME & REF. DESIG.	FUNCTION	ASSUMED MODE	FAILURE EFFECT	CRIT.	REMARKS
Cables	Connects geophones to electronics package and determines relative distances between each unit	Open in any one of the 8 signal conductors	One channel inoperative	.25	No effect on other channels
		Short between any twisted pair	One channel inoperative	.25	No effect on other channels
		Short between any conductor and a shield	Could cause slight increase in crosstalk but this is doubtful	0	This assumes that shield "ground" is isolated from "common" line of the calibration source voltage. See note below
		Open shield	Probably not be noticed	0	
		Failure to lay in a uniform straight line when deployed	Would reduce accuracy of travel time correlation	.01 to .05	This failure mode may not exist if the cable spool is designed to pay out cable without twisting it (i.e., a casting reel versus a spinning reel)
					NOTE: If the shield ground point and the common line of the calibration voltage source are not isolated, the calibration signal for the affected channel would be lost. Normal operation would probably not be affected enough to notice

APPENDIX B

Bulova Watch Company, Inc.
Systems and Instruments Division
Valley Stream, New York

Failure Mode, Effect & Criticality Analysis for LSPE Mechanical Timer

Prepared by: Louis N. Allen
Reliability Engineer

Concurrence by: R. Caruso
Program Manager

Approved by: M. J. Striano
Q. C. and Reliability Mgr.

B. Garfinkel
Q. A. Manager

NASA Contract No. NAS9-5829
Bendix Sub Contract No. SC-881

Revision	A	B
Date	5/17/71	8/6/71

TABLE OF CONTENTS

1. RELIABILITY

The Mechanical Timers are herein treated as two basic sections; the control or hack watch section, and the timer or all other components, and fall under the category of Non-Time Dependent Reliability.

1.1 The Watch Section

Failure of the watch can be caused by several factors; overstress on parts, possible under severe shock or vibration conditions, or excessive pivot or bearing friction resulting from gumming, oxidation or solidification of the lubricant at low temperatures.

The specification stress levels to which the watch will be exposed under the shock and vibration on the subject program are well within the capability of the chosen hack watch, which will be confirmed by the results of impending prequalification and qualification tests.

The watch oil, Moebius-Synta-Visco-Lube, has been chosen based upon Bulova experience with it for approximately 15 years. It is a synthetic oil noted for its low oxidation and gumming rate, and for its thick viscosity for high temperature operation.

Neither of the above failure mechanisms (part stress or lubrication) is cycle sensitive. The failures are stress or time sensitive. The watch oil in particular depends mainly on the time since cleaning and oiling, unless stored at -40°F.

1.2 Parts External to the Watch

The parts external to the watch do not undergo a large number of cycles, so fatigue is not a problem with these parts. The failure modes involve the actual stress in a part exceeding some critical value and not cycles of operation.

1.3 Cycle Dependent Reliability

The only cycle sensitive component in the timer by definition is the switch, in that it falls under the category of possibly being susceptible to random openings. The failure rate for these switches is taken as 1×10^{-4} each.

The failure rate that can be calculated from various sources is approximately $.25 \times 10^{-6}$, but these failure rates do not apply to the space environment actually seen in use. The above failure rate is estimated.

1.4 Non-Cycle Dependent Reliability

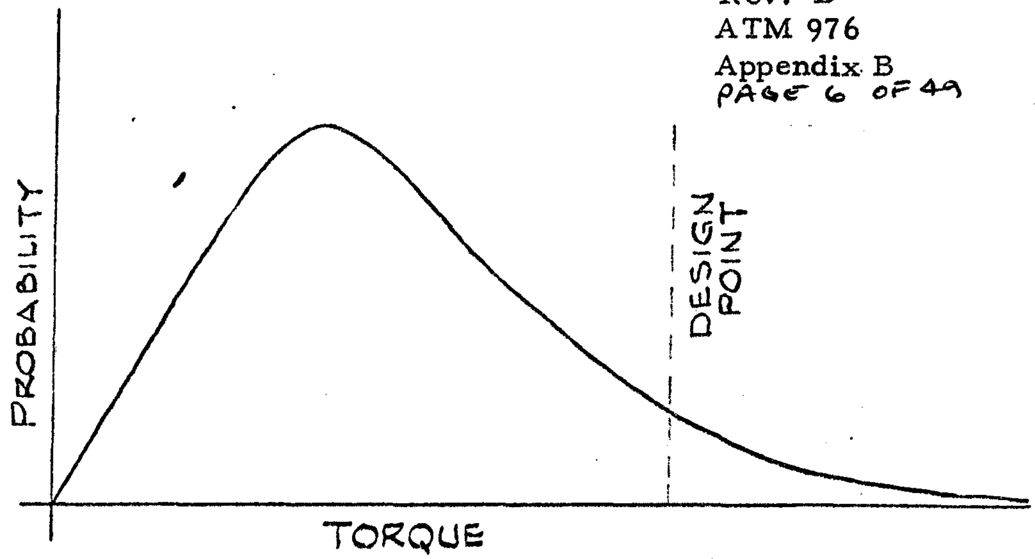
All failure rates used were considered non-cycle dependent.

There were several considerations in selecting failure rates, i.e. friction, safety factor (design factor), AQL, variation in strength of material, and tolerance "build-up". These effects were considered to be non-time dependent, although they are environment sensitive. The analytical methods of A. Bulfinch were used, as described in Laboratory Methods for determining Non-Time Dependent Reliability. Friction effects, safety factor, and tolerance "build-up" are considered separately. See Appendix C for Reliability Block Diagrams.

1.4.1 System Friction Effects

The system friction effects failure rate takes into account the overall frictional losses of the system. This frictional loss represents the torque as seen by the watch or mainsprings.

The frictional torque can be represented by a one sided probability distribution, i.e. friction can only be a loss and cannot supply energy to a system.



In the above figure probability is plotted vs torque. This figure would apply for any one point in the alignment of the gears and other parts which make up the mechanism. The figure would change gradually as the alignment of the various parts change during the operation of the timer.

The design point is that point at which the system is designed to operate. The torque can,however, be at any point on the curve within the probabilities outlined on the curve. Those points to the right of the design point have a high chance of failure, i.e. the frictional torque might be sufficient to stop the watch. The peak on the curve represents the most probably value the frictional torque might have.

Although the actual torque probability curve is unknown, frictional torques usually exhibit large variations. The distance of the design point from the most probable value for the frictional torque is also unknown. Due to the large variation which is exhibited by frictional torque the probability of the watch being stopped by this torque is estimated at .13%.

1.4.2 Inspection Effects

If parts are inspected on a sampling basis, there is always some probability of parts being out of tolerance. This being out of tolerance can have several effects (increased friction, less cross section area to support a given force or torque, or misaligned parts). If the parts are sufficiently out of tolerance they cannot be assembled and are, therefore, no problem reliability wise although they may be a serious assembly problem. The following analyses were performed in order to determine the magnitude of the out of tolerance situation, using Mil-Std-105 as a basis.

<u>1.0% AQL (Safety Factor of 1.15)</u>

Using code letter E, 16% of the pieces will exhibit the characteristic out of the tolerance interval within 90% confidence limit. If the distribution is centered, the worst condition would be a lot with 8% under the low limit and 8% over the high limit. The upper and lower tolernace limits for this condition and assuming a normal distribution would be at $\pm$ 1.41 sigma.

<u>2.5% AQL (Safety Factor of 1.15)</u>

Using code letter F, 18% of the pieces will exhibit the characteristic out of tolerance interval within a 90% confidence limit. If the distribution is centered, the worst condition would be a lot with 9% under the low limit and 9% over the high limit. The upper and lower tolerance limits for this condition and assuming a normal distribution would be at $\pm$ 1.34 sigma.

1.4.2.1 Increased Friction

Due to the large variation in frictional torques as explained in section 1.4.1, it is estimated that the inspection AQL effect can be included in the .13% failure rate.

1.4.2.2 Less Cross Sectional Area

The variation in cross sectional area in a lot of material which was inspected and accepted is calculated as shown below.

Use AQL of 2.5% for worst case conditions.

Per section 1.4.2 above, the upper and lower tolerance limits would be at $\pm$ 1.34 sigma.

If the tolerance interval is 5% of a dimension, the sigma would be 1.9%.

$5\% = 2.68\sigma$

Therefore, $\sigma = 1.9\%$.

In order to have a sigma based upon area instead of a linear dimension, the above sigma was doubled. Therefore, sigma based on area is 3.8%. It was not known if the variation of a dimension on a piece part is independent or dependent upon another dimension of the same piece part. The sigma was simply doubled in order to consider the worse possible case.

This variation in cross sectional area would have the same effect as variation in the maximum stress which a piece part is capable of without breakage. A sigma of 20% for the material is indicated based on a study for Hughes Aircraft Company. Being as both sigmas are unitless quantities they may be added in the same fashion as any root mean square quantity.

$$\text{resultant} = \sqrt{\sigma_{area}^2 + \sigma_{stress}^2}$$

$$\text{resultant} = \sqrt{3.8^2 + 20^2}$$

$$\text{resultant} = 20.4\%$$

This sigma is used in section 1.4.3 and the failure rate is given there.

1.4.2.3 Misaligned Parts

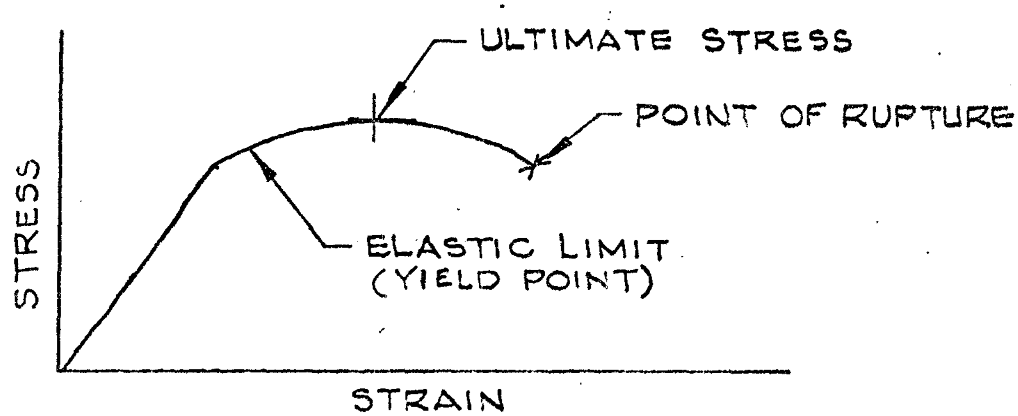
Having piece parts with dimensions outside the tolerance range specified on a drawing would mean that it would be possible to have a problem due to the "stacking up" of out of tolerance dimensions. The layout draftsman in the Design Engineering Department has checked to be sure that there is no problem with piece part dimensions in tolerance. If the parts are sufficiently out of tolerance, the parts will not be capable of being assembled. The case under consideration reduces to the case of those out of tolerance dimensions accepted by inspection due to a sampling plan being used. From section 1.4.2, 9% of the piece parts would exhibit dimensions out of tolerance on the upper tolerance limit, and 9% on the lower tolerance limit. If there are seven dimension additives to obtain an unacceptable condition and all dimensions are statistically independent the probability would be 4.8×10^{-8} for this condition.

$$(.09)^7 = 4.8 \times 10^{-8} \text{ (one way build-up)}$$

The failure rate for tolerance build up conditions was taken as less than 1×10^{-7}.

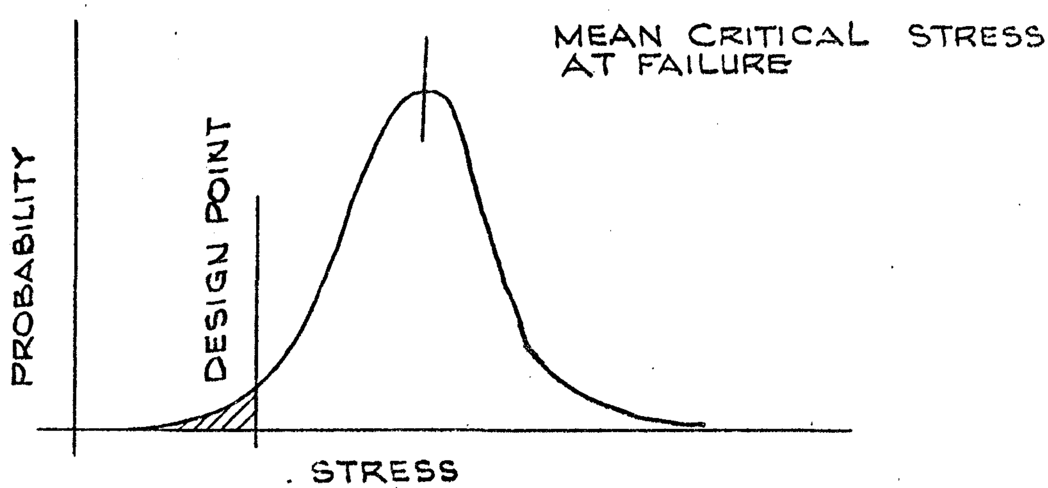
1.4.3 Stress Effects

If a stressin a part exceeds some critical value the part becomes a failure. The ratio of this critical value to the design stress in a part is greater than 2/1. A typical stress strain curve is shown below.



Upon exceeding the elastic limit and with the removal of stress the curve does not return to the origin but has some residual strain. Design safety factors based on this point would ensure that the piece part would operate in a manor that would eliminate permanent distortion. Safety factors based on the ultimate are greater than those based on yield due to the greater stress at the ultimate point, however, if the ultimate stress is exceeded the part will fail.

The stress strain curve is not constant throughout the piece part due to several factors such as heat treating, cold working and the previous history not being uniformly the same for every grain of material in the part. The sigma representing this variation has been determined for similar parts on another program for Hughes Aircraft Co. and it is estimated that the same sigma can be used here as modified in paragraph 4.2.2. The following is a normal curve representing this variation.



The area under the normal curve below the design point represent failures. The sigma from paragraph 4.2.2 is 20.4%. The ratio of themean critical stress at failure to the design point is greater than 2 to 1. The area under the normal curve represents a failure rate of less than 10^{-6} because the design point is 4.9 sigmas away from the mean critical stress at failure.

1.4.4 "O" Rings

Data for determination of failure rates for the "O" rings was obtained from the Igniter Program for Thiokol. Every lot of 110 units has 10 units withdrawn from the lot by DCASR for destructive testing. Over sixty such destructive tests have been performed without a leak failure. The testing consists of sealing the unit and leak testing, followed by various functional acceptance tests including vibration. The data obtained is variable in nature i.e. the actual leak rate obtained is recorded. Upon examination of the last two lots, the actual increase and variation was found to be small. The leak rate used for final acceptance was similar to that specified for the Mechanical Timers.

Using 600 units without a failure and a 90 percent confidence, the failure rate calculated would be .4 percent. Using the variation obtained and the much larger factors of safety for the Mechanical Timers the failure rate obtained is extremely small much less than 1×10^{-7}. The failure rate was set at 1×10^{-6} for each "O" ring used. In addition, each unit, as part of the acceptance test procedure, is checked for a leak rate of 10^{-6} Std. cc/sec.

1.5 Hack Watch Movement

The test was performed to determine, grossly, the breaking point of the Hack Watch. An overload was applied to the watch stem. First the mainspring was wound up tight, then the overload was applied to the stem until the stem broke. The mainspring is capable of delivering approximately 75 gm-cm.; the stem broke at approximately 1600 gm-cm., a better than 20:1 safety factor from actual test results. The watch is designed to withstand a shock of greater than one foot onto a hard wood surface. The failure rate for the Hack Watch movement was estimated at 48×10^{-7}.

1.6 Overbanking

Overbanking will be controlled by several factors. A hermetic seal which will maintain the interval pressure in the control or watch housing to within 5 or 6 pounds differential throughout the life of the timers will eliminate a major portion of the overbanking causes. High temperature and 1/6 g can only be compensated for by decreasing the balance wheel amplitude on earth to approximately 1 turn so that it will not exceed 1 3/4 turns on the moon.

However, preliminary indications of the overbanking tests which have been conducted, are that under the worst conditions of increased amplitude or overbanking on the moon, the timer actuation time may be decreased approximately 5 or 6 hours.

Factors on the lunar surface which affect the watch amplitude are:

Low gravity	-	increases amplitude 1/4 turn
High vacuum	-	increases amplitude 3/8 turn
High temperature	-	increases amplitude 1/8 turn

In order to provide safe operation on earth during outdoor testing with possible low temperatures at no less than 1/2 turn amplitude, the nominal balance wheel amplitude at the watch will be set at one turn. This will provide operating amplitude of 1 3/8 turns nominal on the moon, when the vacuum affect is eliminated by sealing the watch unit in dry Nitrogen at atmospheric pressure.

1.7 Fail Safe

The timers have been designed so that in the event of inadvertant failure, a "dud" will result rather than a premature. The timer pull pins have been arranged so that if the timer has advanced from its safe or zero position, a hangup will occur which will prevent removal of the pull pin. A shear wire has been incorporated into each pull pin assembly to shear at approximately 18 lbs.

The firing pin pull pin is similarly designed. If the firing pin has been released, the pull pin cannot be removed and the firing pin is hung up.

The design has eliminated the possibility of physical harm or injury from the hazardous effects of sharp edges and corners, or the discharge of energy stored in springs. A shipping or handling plate has been incorporated on the output end of the Thermal Battery Timer, as a precaution in the unlikely event the spring loaded firing pin fails in shear.

1.8 Conclusions

The S/A Slider Timer and the Thermal Battery Timer are capable of performing with an overall reliability of 0.996 each.

1.9 Failure Rates

The failure rate for each piece part is included in Appendix A. The total failure rate for each timer was obtained by adding the piece part failure rates.

Most piece part failure rates are obtained from paragraphs 1.4.3, 1.4.2.2 and 1.4.2.3. The failure rate for these piece parts is 1×10^{-6}. The frictional failure rate is identified as a separate item. The remaining failure rates were estimated.

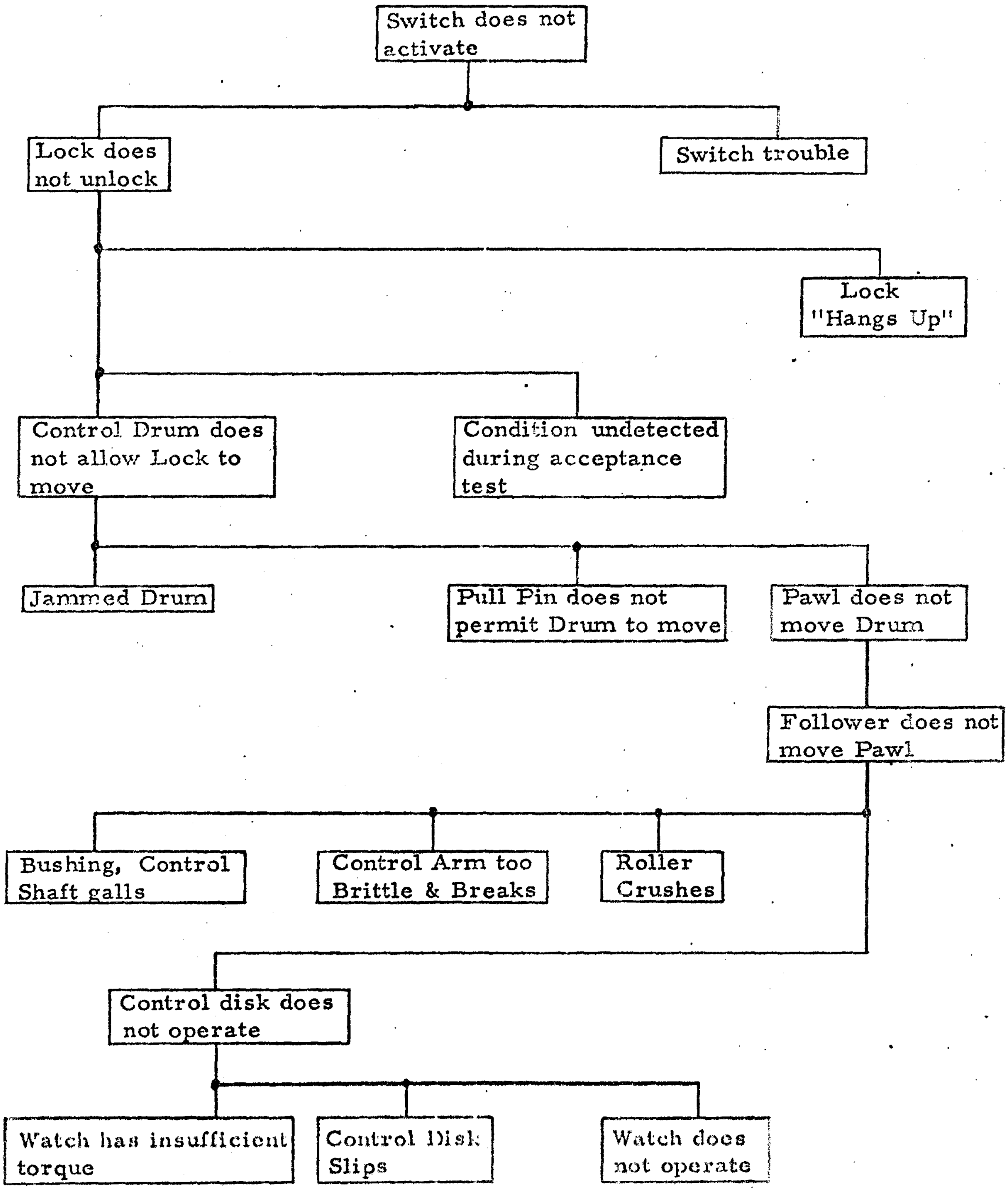
1.10 Failure Modes

A summary of failure modes is included in the Failure Mode, Effect and Criticality Analysis Worksheets included in Appendix B.

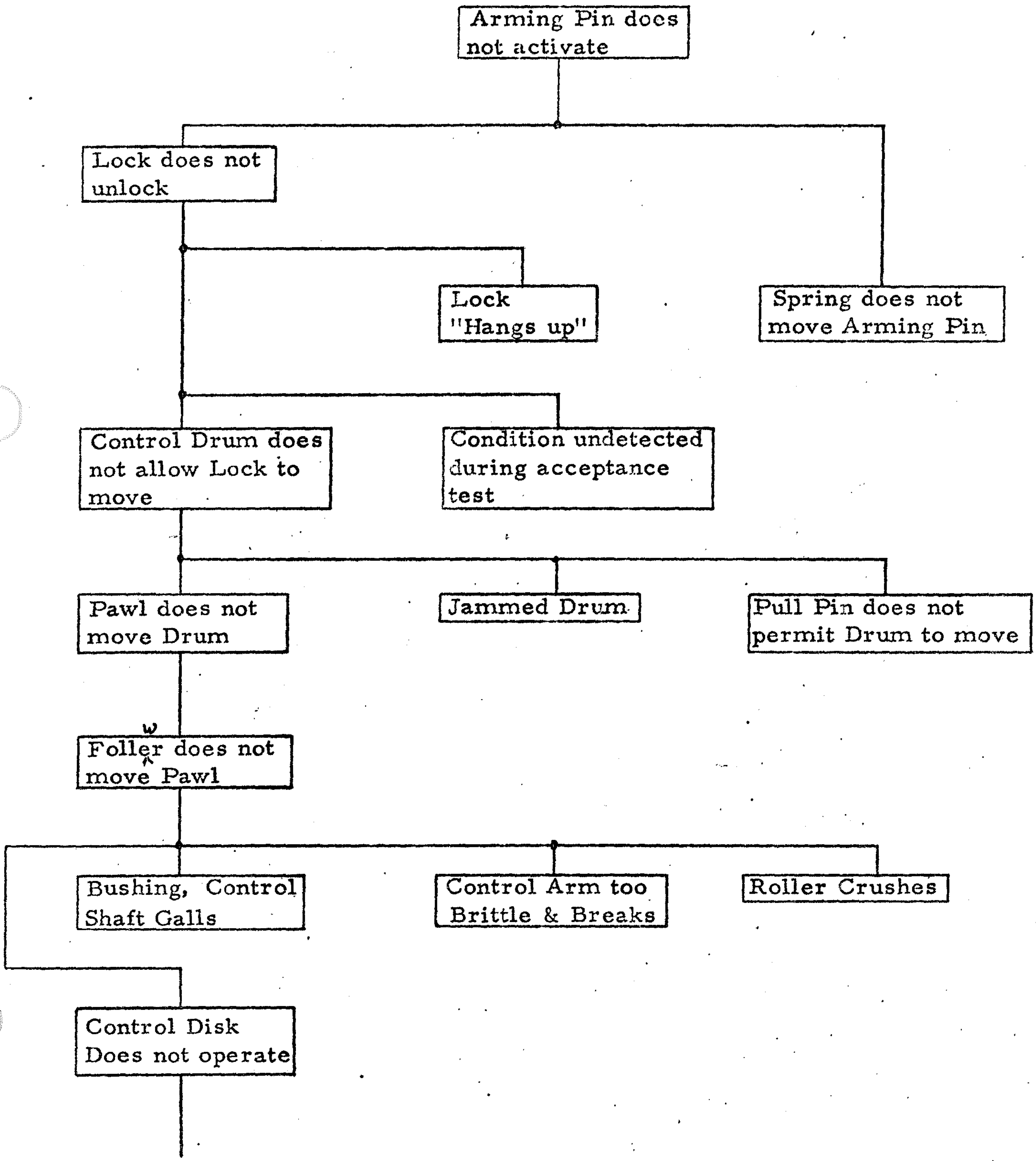
1.11 Criticality

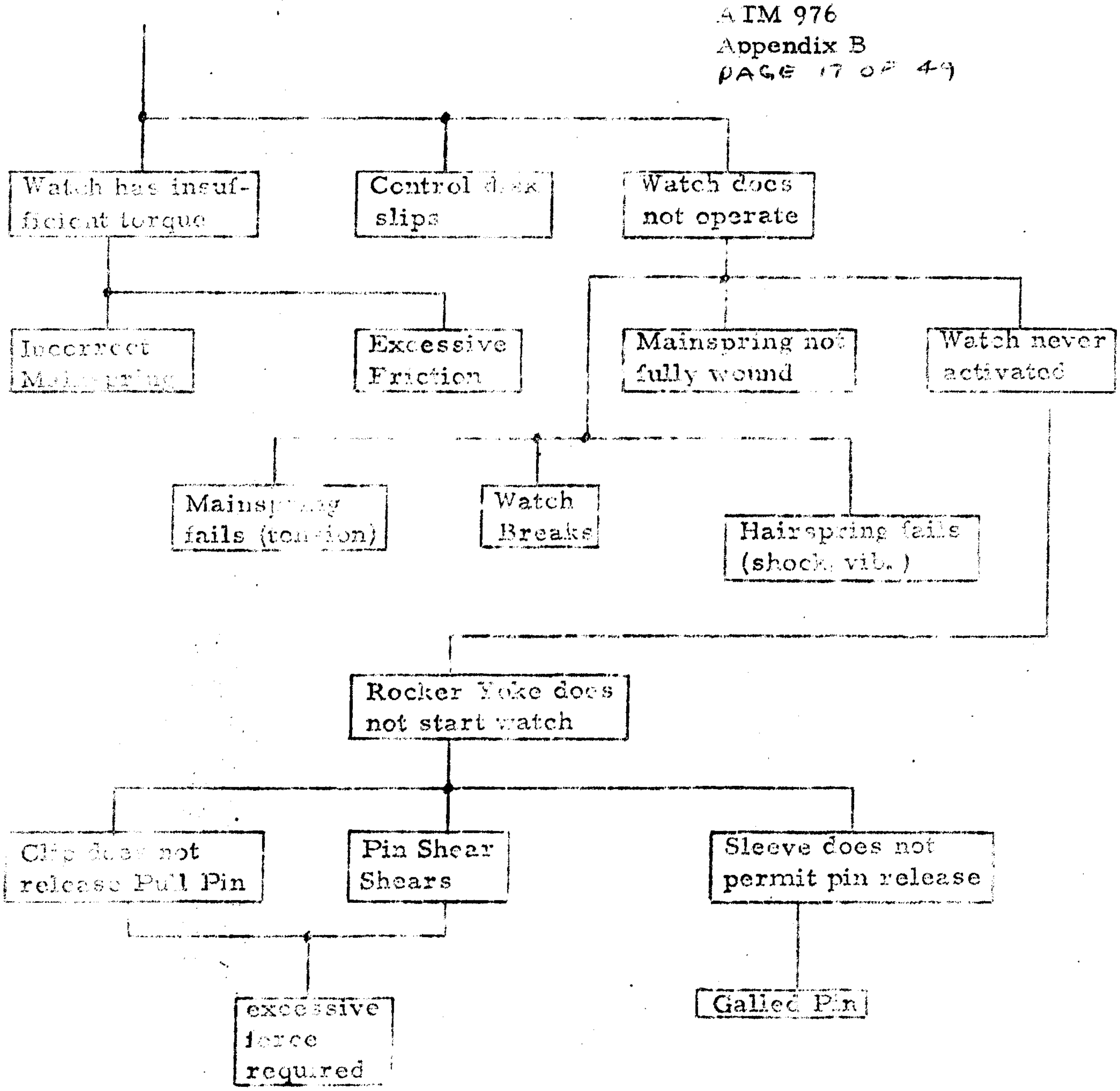
The criticality of the various failure modes was arranged in accordance with the effect that the failure has. The number one (1) mode is the most critical followed by number two (2), etc. The criticality is listed on the Failure Mode, Effect and Criticality Worksheets in Appendix B.

Thermal Battery Timer

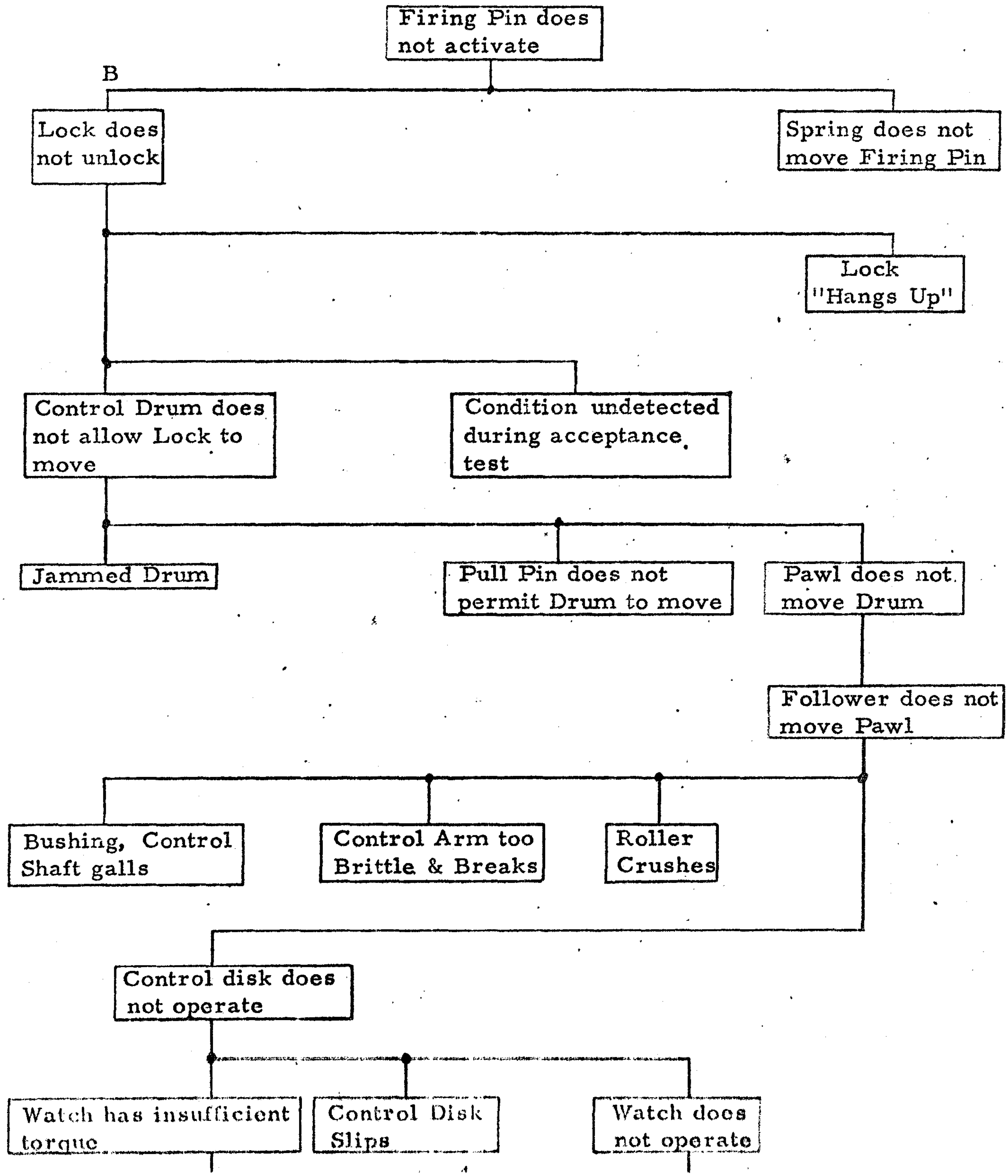


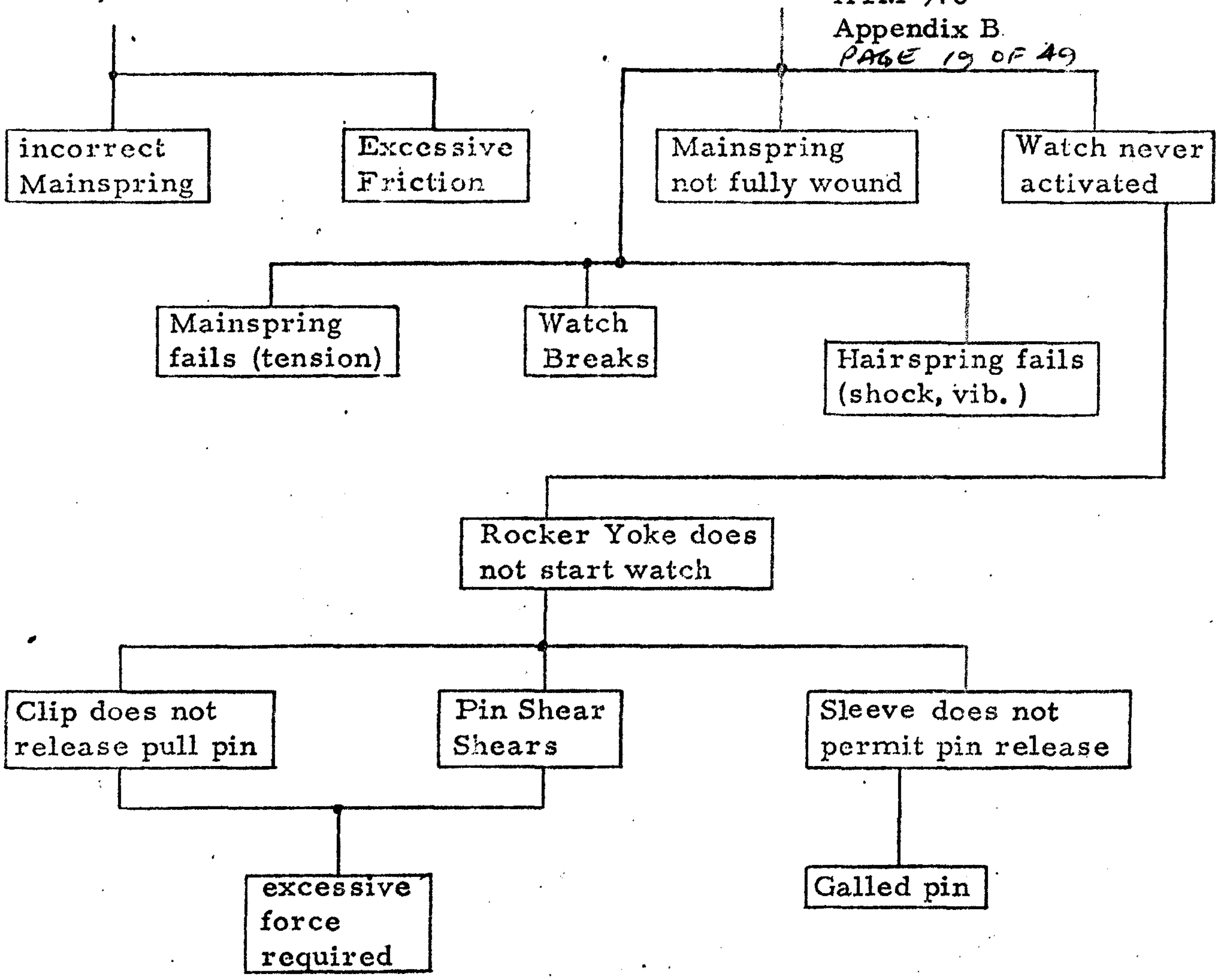
S/A Timer

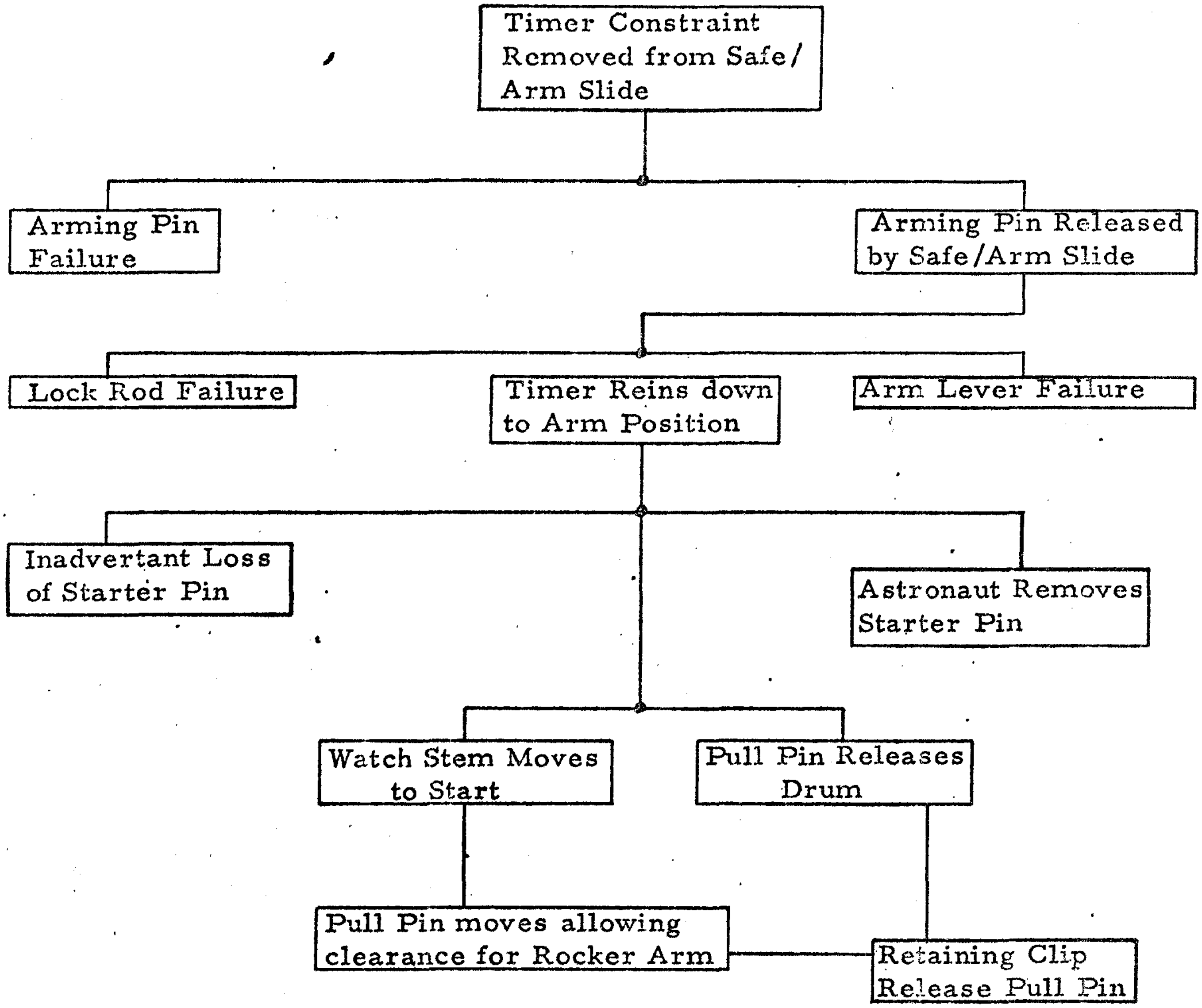

Arming Pin does not activate
Lock does not unlock
Lock "Hangs up"
Spring does not move Arming Pin
Control Drum does not allow Lock to move
Condition undetected during acceptance test
Pawl does not move Drum
Jammed Drum
Pull Pin does not permit Drum to move
Foller does not move Pawl
Bushing, Control Shaft Galls
Control Arm too Brittle & Breaks
Roller Crushes
Control Disk Does not operate

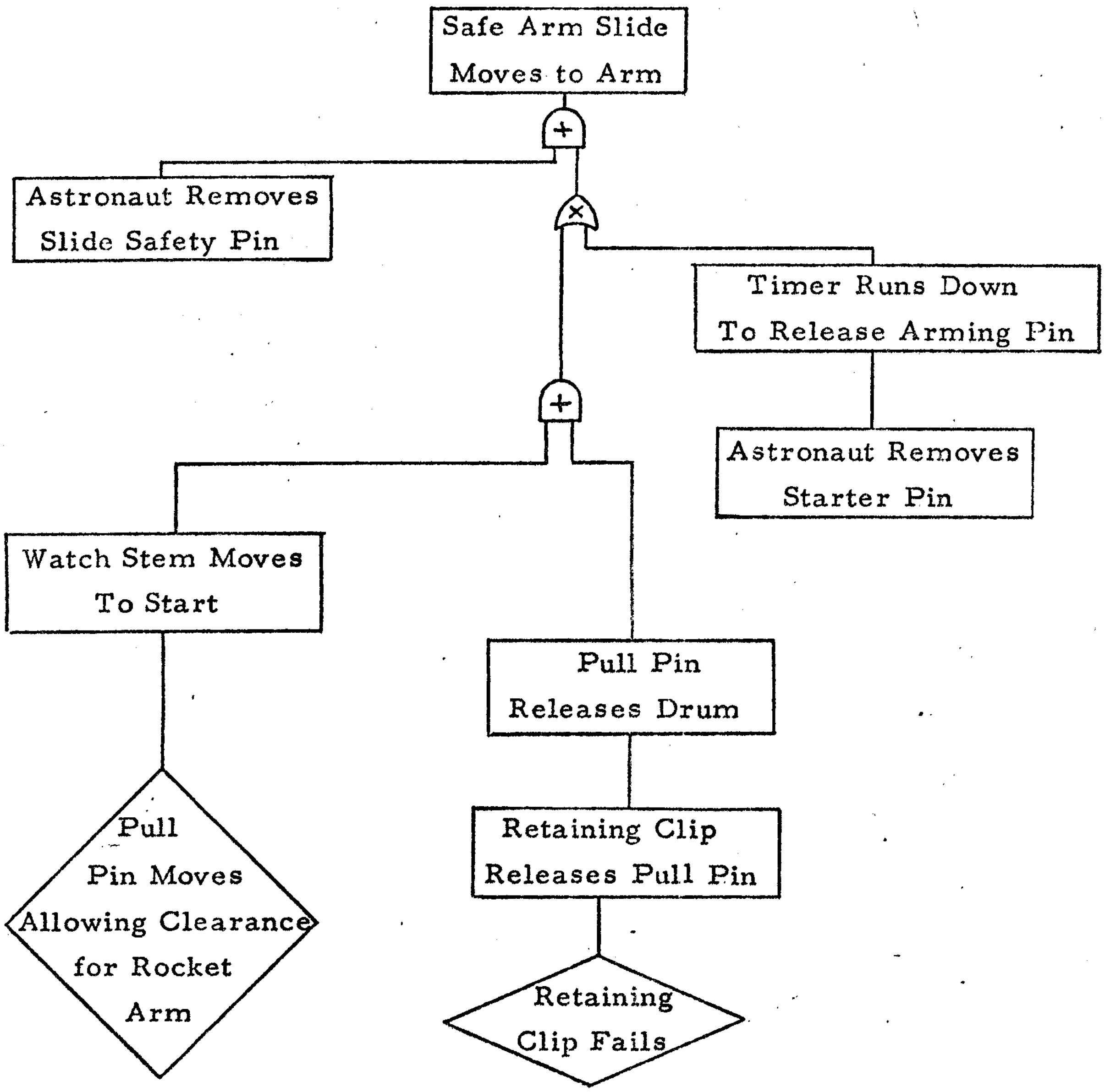

Watch has insuf-
ficient torque
Control disk
slips
Watch does
not operate
Incorrect
Mainspring
Excessive
Friction
Mainspring not
fully wound
Watch never
activated
Mainspring
fails (torsion)
Watch
Breaks
Hairspring fails
(shock, vib.)
Rocker Yoke does
not start watch
Clip does not
release Pull Pin
Pin Shear
Shears
Sleeve does not
permit pin release
excessive
force
required
Galled Pin

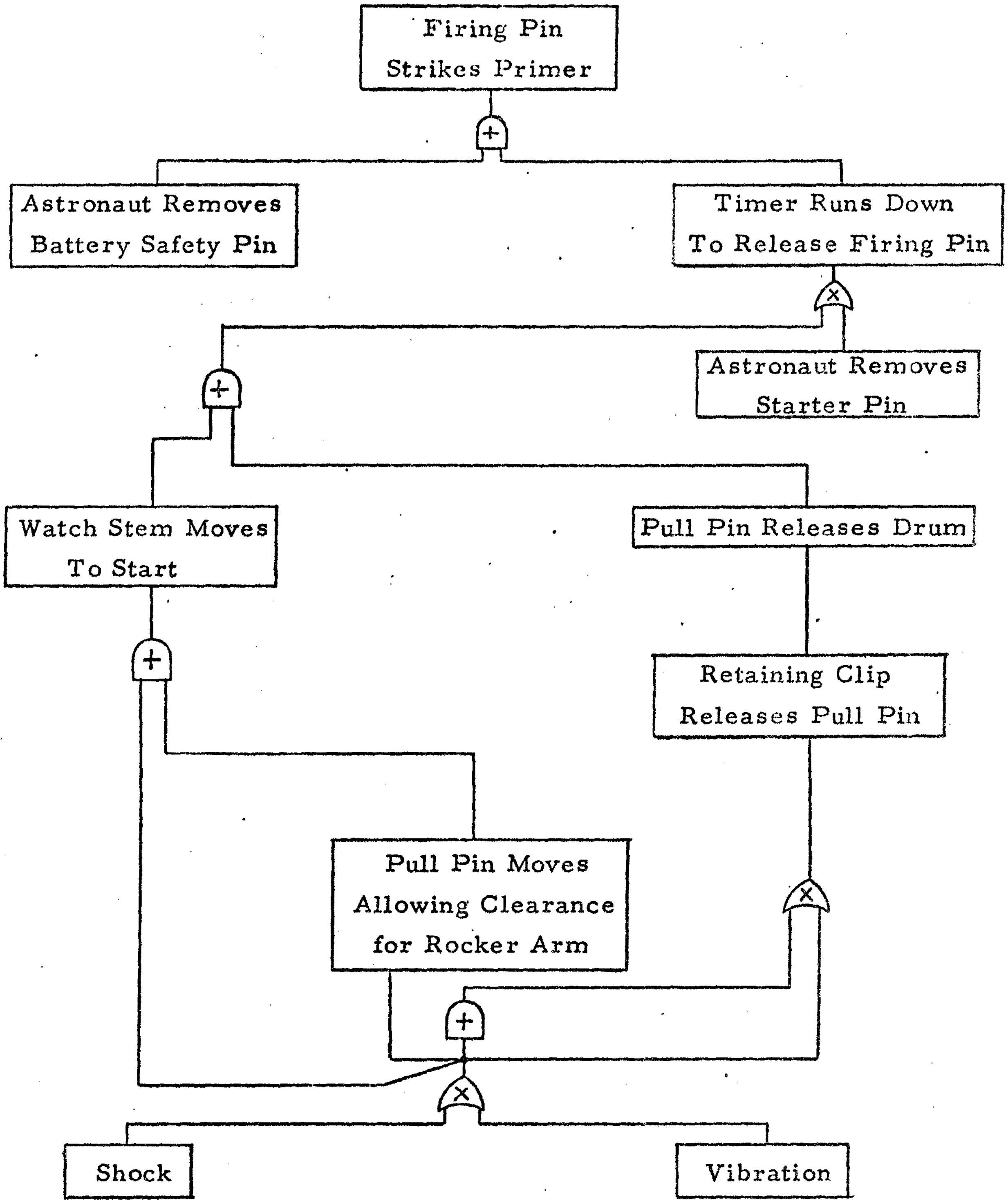
Thermal Battery Timer

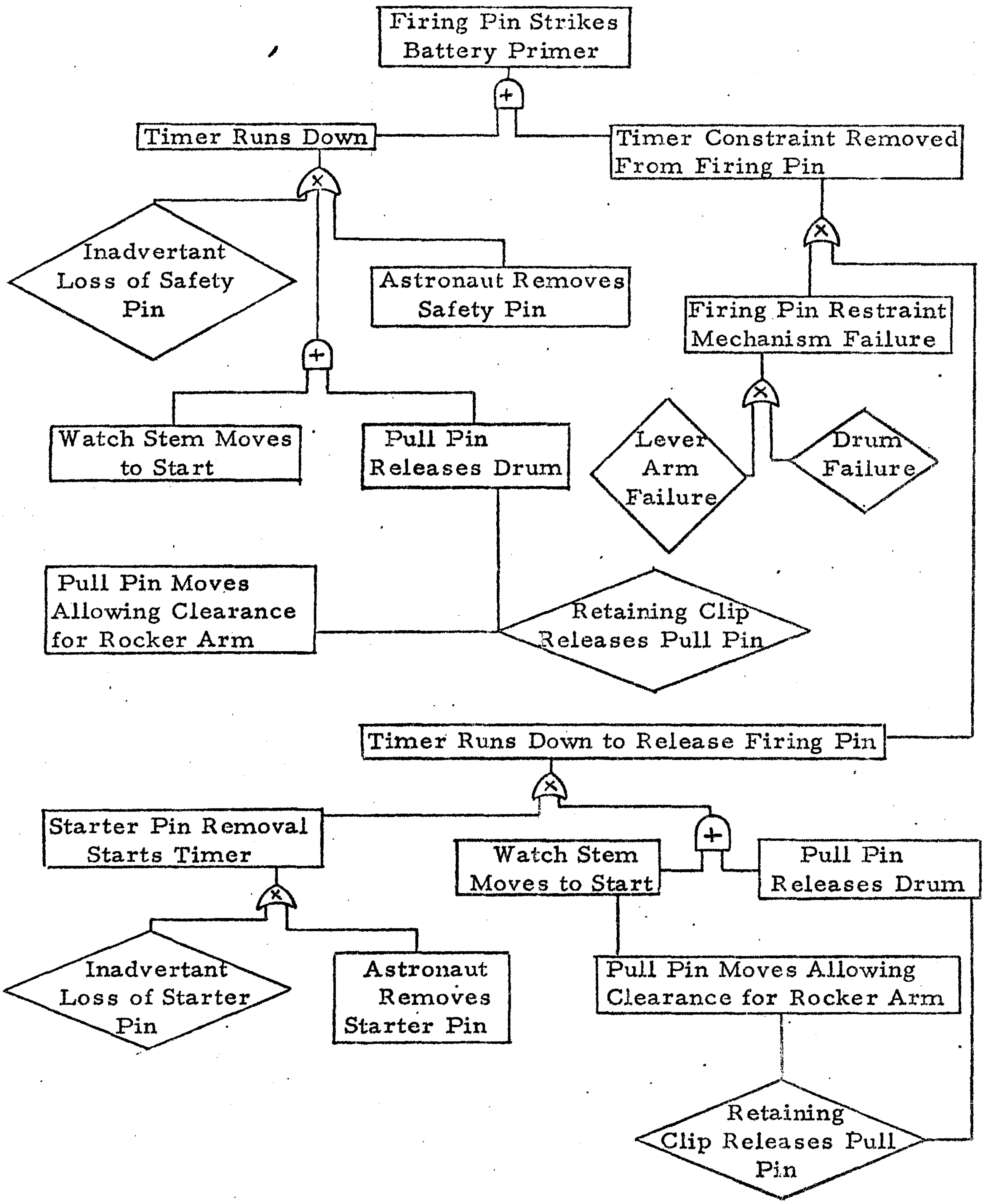


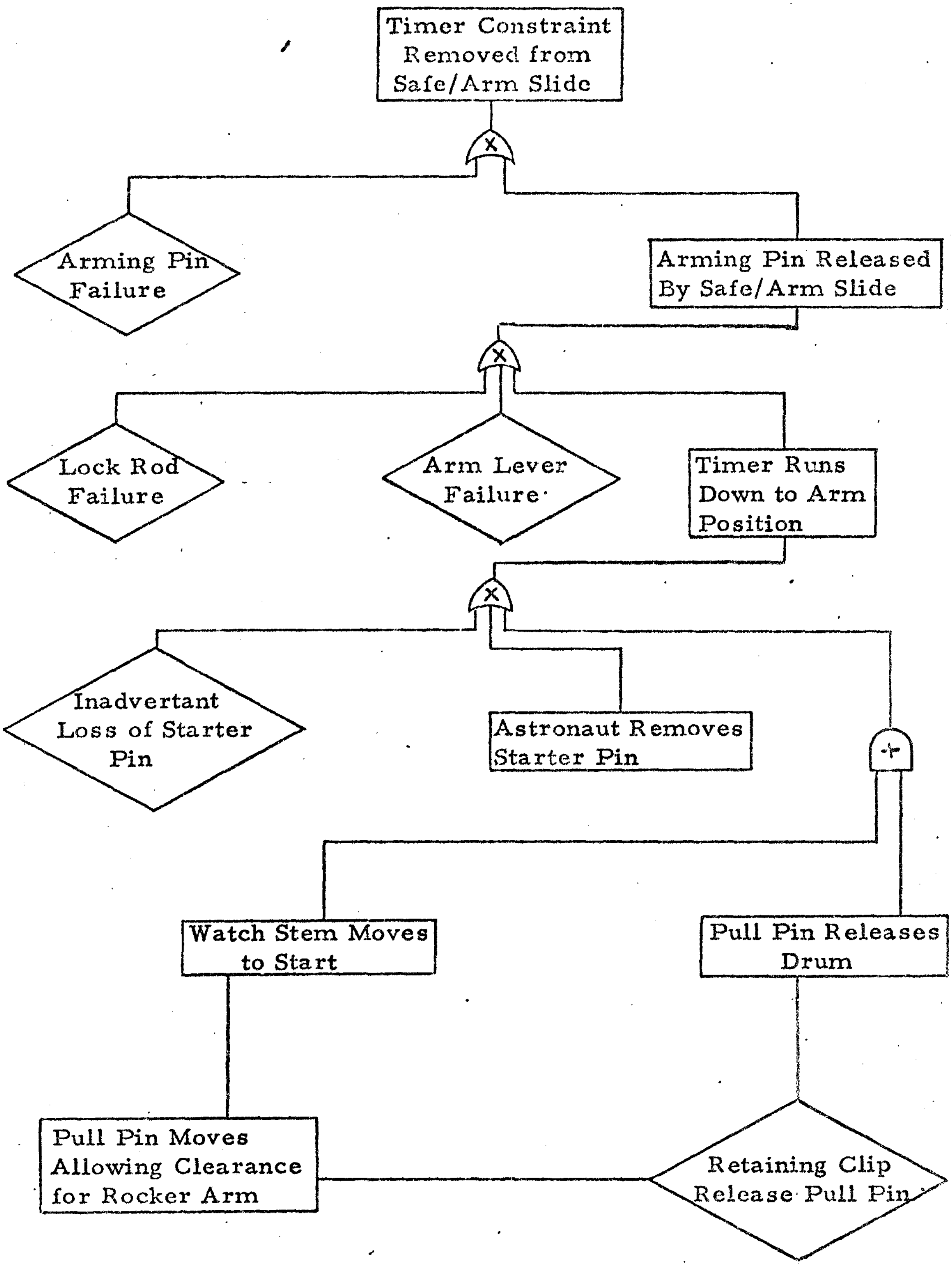

incorrect Mainspring
Excessive Friction
Mainspring not fully wound
Watch never activated
Mainspring fails (tension)
Watch Breaks
Hairspring fails (shock, vib.)
Rocker Yoke does not start watch
Clip does not release pull pin
Pin Shear Shears
Sleeve does not permit pin release
excessive force required
Galled pin


Timer Constraint Removed from Safe/ Arm Slide
Arming Pin Failure
Arming Pin Released by Safe/Arm Slide
Lock Rod Failure
Timer Reins down to Arm Position
Arm Lever Failure
Inadvertant Loss of Starter Pin
Astronaut Removes Starter Pin
Watch Stem Moves to Start
Pull Pin Releases Drum
Pull Pin moves allowing clearance for Rocker Arm
Retaining Clip Release Pull Pin


Safe Arm Slide Moves to Arm
Astronaut Removes Slide Safety Pin
Timer Runs Down To Release Arming Pin
Astronaut Removes Starter Pin
Watch Stem Moves To Start
Pull Pin Releases Drum
Retaining Clip Releases Pull Pin
Pull Pin Moves Allowing Clearance for Rocket Arm
Retaining Clip Fails


Firing Pin Strikes Primer
Astronaut Removes Battery Safety Pin
Timer Runs Down To Release Firing Pin
Astronaut Removes Starter Pin
Watch Stem Moves To Start
Pull Pin Releases Drum
Retaining Clip Releases Pull Pin
Pull Pin Moves Allowing Clearance for Rocker Arm
Shock
Vibration


Firing Pin Strikes Battery Primer
Timer Runs Down
Timer Constraint Removed From Firing Pin
Inadvertant Loss of Safety Pin
Astronaut Removes Safety Pin
Firing Pin Restraint Mechanism Failure
Watch Stem Moves to Start
Pull Pin Releases Drum
Lever Arm Failure
Drum Failure
Pull Pin Moves Allowing Clearance for Rocker Arm
Retaining Clip Releases Pull Pin
Timer Runs Down to Release Firing Pin
Starter Pin Removal Starts Timer
Watch Stem Moves to Start
Pull Pin Releases Drum
Inadvertant Loss of Starter Pin
Astronaut Removes Starter Pin
Pull Pin Moves Allowing Clearance for Rocker Arm
Retaining Clip Releases Pull Pin


Timer Constraint Removed from Safe/Arm Slide
Arming Pin Failure
Arming Pin Released By Safe/Arm Slide
Lock Rod Failure
Arm Lever Failure
Timer Runs Down to Arm Position
Inadvertant Loss of Starter Pin
Astronaut Removes Starter Pin
Watch Stem Moves to Start
Pull Pin Releases Drum
Pull Pin Moves Allowing Clearance for Rocker Arm
Retaining Clip Release Pull Pin

SET ___ OF ___

PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
D87207	Base Mounting Assy	1	4.2×10^{-4}
F87203	Control Assy	1	5.3×10^{-5}
D87205	Timer Assy	1	3.3×10^{-5}
MS51959-13	Screw-Flat Head (#4-40 x 1/4 lg., CRES)	4	4×10^{-6}
MS51959-12	Screw-Flat Head (#4-40 x 3/16 lg., CRES)	2	2×10^{-6}
MS35275-13	Screw-Filister Head (#4-40 x 1/4 lg., CRES)	1	1×10^{-6}
B87146-02	Pull Pin Assy	1	2×10^{-6}
B87146-03	Pull Pin Assy	1	2×10^{-6}
Loctite "C"	Sealing Compound	A/R	Zero
B87230	Shim-Winding Hub	A/R	Zero
B87256	Spacer, Shaft	1	1×10^{-6}
A87187	Low Friction Plating	1	Zero
--	System Friction	-	1.3×10^{-3}
	TOTAL Failure Rate	-	1.8×10^{-3}

TITLE

TIMER, THERMAL BATTERY, LSPE ASSEMBLY

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NX F87200

PART NO.	NOMENCLATURE — DESC[illegible]ION	QTY. PER UNIT	Failure Rate
D87175	Base Mounting	1	Zero
B87171	Body-Firing Pin	1	1×10^{-6}
B87172	Tip-Firing Pin	1	1×10^{-6}
D87174	Lock-Firing Pin	1	1×10^{-6}
Esna 79-022-099-0187	Pin-Roll	1	1×10^{-6}
A87186	Switch (SCD)	2	2×10^{-4}
B87219	Screw, Modif.	4	4×10^{-6}
Loctite "C"	Sealing Compound	A/R	Zero
B87201	Spring	1	2×10^{-4}
B87241	Bushing-Firing Pin	1	1×10^{-6}
B87231	Latch	1	1×10^{-6}
	Pin Dowel 3/32 Dia. x 5/16 lg.	1	1×10^{-6}
B87255	Tip, Actuator	1	1×10^{-6}
1/32 Dia. x 3/16	Spirol Pin (Stainless Steel Type 302)	1	1×10^{-6}
C87259-01	Actuator, Switch	1	1×10^{-6}
C87259-02	Actuator, Switch	1	1×10^{-6}
1/16 Dia. x 1/2 lg.	Spirol Pin (Stainl. Stl. Type 302)	1	1×10^{-6}
	TOTAL 87207	-	4.2×10^{-4}

TITLE

TIMER, THERMAL BATTERY LSPE ASSEMBLY

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NX F87200

PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
MS35650-314	Nut-Hex (#0-80)	1	1 ~~2~~ x 10^{-6}
D87204	Watch Movement Assy	1	1.13 x 10^{-5}
B87157	Cover-Housing	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
MS51959-13	Screw-Flat Head, 82° (#4-40 x 1/4 lg., CRES)	4	4 ~~8~~ x ~~10^{-7}~~ 10^{-6}
F87158	Housing-Control	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
C87143	Pawl	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87140	Cover-Control Arm	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
MS51959-2	Screw-Flat Head, 82° (#0-80 x 1/8 lg., CRES)	2	1 ~~4~~ x ~~10^{-7}~~ 10^{-6}
B87141	Cap-Housing-Seal	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87131	Bushing-Control	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87148	Spacer-Control Shaft	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87132	Shaft-Control	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87133	Arm-Control	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
	Dowel Pin (.062 x 3/8 CRES)	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87136	Ring-Movement Retaining	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87138	Adapter-Stem Seal	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
A87190-01	"O" Ring (SCD)	1	1 x 10^{-6}
B87182	Stem-Control	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87142	Retainer-Pull Pin	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87137	Adapter, Locating	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}
B87258	Wave Washer	1	1 ~~4~~ x ~~10^{-7}~~ 10^{-6}
MS 51023-1	Screw, Set, Cup Pt. (#0-80 x 1.8 lg., CRES)	1	1 ~~2~~ x ~~10^{-7}~~ 10^{-6}

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TIMER, THERMAL BATTERY LSPE ASSEMBLY

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NX F87200

PART NO.	NOMENCLATURE — DESCRIPTION		QTY. PER UNIT	Failure Rate
MS51038-2	Set Screw Cone Pt (#2-56 x 3/16 lg., CRES)		1	1×10^{-6}
A87190-02	"O" Ring	(SCD)	2	2×10^{-6}
MS51023-1	Set Screw, Cup Pt. (#0-80 x 1/8 lg., CRES)		1	1×10^{-6}
A87190-03	"O" Ring	(SCD)	1	1×10^{-6}
A87189-02	Ball Bearing	(SCD)	1	1×10^{-6}
B87191	Nut (Adapter)		1	1×10^{-6}
B87212	Window		1	1×10^{-6}
Loctite "C"	Sealant		A/R	Zero
A87262	Epoxy (Stycast 2741)	(SCD)	A/R	Zero
B87223	Coupling Drive		1	1×10^{-6}
B87222	Pin Drive		1	1×10^{-6}
B87224	Sleeve Spring		1	1×10^{-6}
B87225	Bushing		1	1×10^{-6}
C87226	Link		1	1×10^{-6}
	Grease, High Vacuum (Krytox, DuPont)			
B87221	Bushing, Drive		1	1×10^{-6}
B87248	Actuator, Clock		1	1×10^{-6}
B87252	Release Pull Pin		1	1×10^{-6}
B87260	Housing, Detent	(Replace 87142)		1×10^{-6}
B87263	Detent Spring	(Replace 87142)		1×10^{-6}
		TOTAL	-	53×10^{-5}

TITLE

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NX F87200

PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
C87218	Control Drum	1	1×10^{-6}
C87123	Gear-Timing	1	1×10^{-6}
C87135	Mainspring-Timer	1	1×10^{-6}
B87109	Pin-Spring Retaining	1	1×10^{-6}
D87156	Frame-Support	1	1×10^{-6}
B87150	Bushing	1	1×10^{-6}
B87183	Screw-Modified	4	8×10^{-8}
B87243	Pin-Spring Anchor	1	1×10^{-6}
B87247	Washer	1	1×10^{-6}
MS35233-1	Screw, Pan Hd. (#2-56 x 1/8 lg., CRES)	3	3×10^{-6}
B87215	Flange Mounting	1	1×10^{-6}
	Screw (#0-80 x 1/8 lg.) Pan Head	3	3×10^{-6}
B87230	Shim-Spring Winding (Hub)	3	3×10^{-6}
B87214	Mainspring Winding Shaft	1	1×10^{-6}
B87237	Bushing (Fir. Pin Pull Pin)	1	1×10^{-6}
B87216	Bearing Plate	1	1×10^{-6}
B87254	Bearing Flanged (SCD)	2	2×10^{-6}
B87239	Plate, Drum Locating	1	1×10^{-6}
B87245	Clip, Spring	1	1×10^{-6}
B87256	Shaft, Spacer	1	1×10^{-6}
B87257	Shaft, Spacer	1	1×10^{-6}
	Screw, Pan Hd. (#0-80 x 3/32 lg., CRES)	2	2×10^{-6}
	Screw, Flat Hd., 100° (#2-56 x 3/16 lg., CRES)	1	1×10^{-6}
B87264	Spacer, Shaft	1	1×10^{-6}
A87261	Flanged Bearing	2	2×10^{-6}
	TOTAL 87205	-	3.3×10^{-5}

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NX F87200

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PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
B87151	Pin-Pull	1	1×10^{-6}
B87153	Sleeve-Pull Pin	1	1×10^{-6}
	#24 Awg. Buss Wire Per QQ-W-343 1/2" lg.	A/R	2×10^{-6}
	TOTAL 87146-02		4×10^{-6}

TITLE

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NX F87200

PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
B87152	Pin-Pull (Firing Pin)	1	1×10^{-6}
B87153	Sleeve-Pull Pin	1	1×10^{-6}
	#24 Awg. Buss Wire Per QQ-W-343 1/2" lg.	A/R	2×10^{-6}
	TOTAL 87146-03		4×10^{-6}

TITLE

TIMER, THERMAL BATTERY, LSPE ASSEMBLY

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NX F07200

PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
F87208	Base Mounting Assy	1	1.8×10^{-5}
D87185	Control Assy	1	5.3×10^{-5}
D87199	Timer Assy	1	3.3×10^{-5}
B87146-01	Pull Pin Assy	1	4×10^{-6}
MS35275-13	Screw-Fil. Hd. (#4-40 x 1/4 lg. CRES)	1	1×10^{-6}
MS51957-12	Screw-Pan Hd. (#4-40 x 3/16 lg. CRES)	2	1×10^{-6}
Loctite "C"	Sealant	A/R	Zero
	Screw, Pan Hd. (2-56 x 3/16, CRES)	4	4×10^{-6}
B87235	Post	1	1×10^{-6}
B87236	Post	1	1×10^{-6}
	Dowel Pin (1/16 Dia. x 3/32 lg., CRES)	2	2×10^{-6}
B87230	Shim-Winding Hub	A/R	Zero
B87256	Shaft, Spacer	1	1×10^{-6}
MS-35275-11	Screw, Fil. Hd. (#4-40 x 1/8 lg., CRES)	1	1×10^{-6}
MS-35233-13	Screw, Pan Hd. (#4-40 x 1/4 lg., CRES)	1	1×10^{-6}
A87187	Low Friction Plating	A/R	Zero
A87267	Block Jack (Slider Reset)	1	1×10^{-6}
B87266	Screw Jack (Slider Reset)	1	1×10^{-6}
——	System Friction	-	1.3×10^{-3}
	TOTAL Failure Rate	-	1.4×10^{-3}

TITLE

S/A SLIDER TIMER ASSEMBLY

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NX F87100

PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
F87154	Base-Mounting	1	Zero
B87161	Shaft-Lock	1	1×10^{-6}
B87164	Retainer	1	1×10^{-6}
MS51959-3	Screw-Flat Head, 82°, (#2-56 x 1/4 lg., CRES)	1	1×10^{-6}
B87166	Spacer	1	1×10^{-6}
B87165	Spacer	1	1×10^{-6}
B87163	Pin-Arming & Safing	2	2×10^{-6}
A87127	Spring-Compression	2	2×10^{-6}
C87167	Lock-Arming Pin	1	1×10^{-6}
C87168	Lock-Safing Pin	1	1×10^{-6}
C87169	Lever-Arm Lock	1	1×10^{-6}
MS51923-112	Pin-Spring (1/32 Dia. x 3/16 lg., CRES)	2	2×10^{-6}
Loctite "C"	Sealing Compound	A/R	Zero
B87249	Latch	2	2×10^{-6}
MS 51056-2	Screw, Set (#2-56 x 3/16 lg., CRES)	2	2×10^{-6}
	TOTAL 87208		1.8×10^{-5}

TITLE

S/A SLIDER TIMER ASSEMBLY

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NX F87100

PART NO.	NOMENCLATURE — DESC ON	QTY. PER UNIT	Failure Rate
MS35650-314	Nut-Hex (# 0 - 80)	1	1×10^{-6}
D87204	Watch Movement Assy	1	1.13×10^{-5}
B87130	Cover-Housing	1	1×10^{-6}
MS51959-13	Screw-Flat Head, 82° (#4-40 x 1/4 lg., CRES)	4	4×10^{-6}
F87129	Housing-Control	1	1×10^{-6}
C87143	Pawl	1	1×10^{-6}
B87140	Cover-Control Arm	1	1×10^{-6}
MS51959-2	Screw-Flat Head, 82° (#0-80 x 1/8 lg., CRES)	4	4×10^{-6}
B87141	Cap-Housing Seal	1	1×10^{-6}
B87131	Bushing-Control	1	1×10^{-6}
B87148	Spacer-Control Shaft	1	1×10^{-6}
B87132	Shaft-Control	1	1×10^{-6}
B87133	Arm-Control	1	1×10^{-6}
	Dowel Pin (.062 Dia. x 1/2 lg., CRES)	1	1×10^{-6}
B87136	Ring-Movement Retaining	1	1×10^{-6}
B87138	Adapter-Stem Seal	1	1×10^{-6}
A87190-01	"O" Ring (SCD)	1	1×10^{-6}
B87181	Stem-Control	1	1×10^{-6}
B87142	Retainer-Pull Pin (Spring Clip)	1	1×10^{-6}
B87137	Adapter, Locating	1	1×10^{-6}
B87258	Wave Washer	1	1×10^{-6}
MS 51023-1	Screw, Set, Cup Pt. (#0-80 x 1/8 lg., CRES)	1	1×10^{-6}

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PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
MS51038-2	Set Screw Cone Pt. (#2-56 x 3/16 lg., CRES)	1	1×10^{-6}
A87190-03	"O" Ring (SCD)	1	1×10^{-6}
	Set Screw, Cup Pt. (#0-80 x 1/8 lg., CRES)	1	1×10^{-6}
A87190-02	"O" Ring (SCD)	2	1×10^{-6}
A87189-02	Ball-Bearing (SCD)	1	1×10^{-6}
B87191	Nut (Adapter)	1	1×10^{-6}
B87212	Window	1	1×10^{-6}
Loctite "C"	Sealant	A/R	Zero
A87262	Sealant-Epoxy (Stycast 2741) SCD	A/R	Zero
B87223	Coupling Drive	1	1×10^{-6}
B87222	Pin Drive	1	1×10^{-6}
B87224	Sleeve-Spring	1	1×10^{-6}
B87225	Bushing	1	1×10^{-6}
C87226	Link	1	1×10^{-6}
	Grease, High Vacuum (Krytox, DuPont)	A/R	Zero
B87221	Bushing, Drive	1	1×10^{-6}
B87248	Actuator, Clock	1	1×10^{-6}
B87252	Release, Pull Pin	1	1×10^{-6}
C87260	Housing, Detent (Replace 87263)	1	1×10^{-6}
B87263	Detent Spring (Replace 87263)	1	1×10^{-6}
	TOTAL 87185	-	5.3×10^{-5}

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PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
C87217	Control Drum	1	1×10^{-6}
C87123	Gear-Timing	1	1×10^{-6}
C87188	Mainspring-Timer	1	1×10^{-6}
B87109	Pin-Spring Retaining	1	1×10^{-6}
D87121	Frame-Support	1	1×10^{-6}
B87125	Bushing	1	1×10^{-6}
B87183	Screw-Modified	4	4×10^{-6}
B87239	Plate, Drum Locating	1	1×10^{-6}
B87247	Washer	3	3×10^{-6}
	Screw, Pan Hd. (#0-80 x 3/32 lg., CRES)	2	2×10^{-6}
Loctite "C"	Sealing Compound	A/R	Zero
B87215	Flange Mounting	1	1×10^{-6}
	Screw (#0-80 x 1/8 lg.) Pan Head	3	3×10^{-6}
B87230	Shim-Spring Winding-Hub	3	3×10^{-6}
B87214	Mainspring Winding Shaft	1	1×10^{-6}
B87243	Pin-Spring Anchor	1	1×10^{-6}
B87216	Bearing-Plate	1	1×10^{-6}
B87254	Bearing, Flanged (SCD)	2	2×10^{-6}
B87256	Spacer, Shaft	1	1×10^{-6}
B87257	Spacer, Shaft	1	1×10^{-6}
B87264	Spacer, Shaft	1	1×10^{-6}
A87261	Flanged Bearing	2	2×10^{-6}
	TOTAL 87199	-	3.3×10^{-5}

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PART NO.	NOMENCLATURE — DESCRIPTION	QTY. PER UNIT	Failure Rate
B87144	Sleeve-Pull Pin	1	1×10^{-6}
B87145	Pin Pull	1	1×10^{-6}
	#24 Awg. Buss wire per QQ-W-343 1/2" lg.	1	2×10^{-6}
	TOTAL 87146-01		4×10^{-6}

TITLE

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
A Hack Watch Movement (D87108)	Overbanking due to either low gravity, low pressure, or position of the watch movement with respect to gravity. Overbanking is a term which refers to excessive amplitude of the balance wheel. This condition causes the balance wheel jewel to hit the back of the lever and bounce back thereby causing a faster beat rate.	Fast time base. The overbanking causes a faster beat rate thereby causing the timing drum to rotate faster then designed through the connecting mechanisms.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal. As a result, the arming pin and safing pin retract earlier than planned.	4.2×10^{-6}	1
A1 "O" Rings (A87190-x)	Loss of Seal due to leakage around the "O" rings. Could be caused by undetected foreign matter or an undetected defect in the "O" ring.	The escapement may overbank because of lower friction. The lower friction is due to the reduced air drag on the balance wheel at lower pressure.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the arming and safing pin to be retracted earlier.	4×10^{-6}	1a
A2 Position of Timer	If the position of the timer changes so as to change the axis of the balance wheel the friction of the balance wheel changes.	This effect could be contributory toward an overbanking failure. The lower friction will increase the amplitude condition and under the worst conditions of temperature and severe leakage could cause overbanking.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the arming pin and safing pin to be retracted earlier.	Zero, because this effect by itself will not cause failure. However, in conjunction with leakage and temperature it can.	1b
A3 Low Gravity	The friction in the escapement especially on the balance wheel pivots decreases with respect to gravity due to the smaller normal force involved. This decreased friction in turn means greater amplitude with the possibility of overbanking and increased beat rate.	This effect is compensated for in the design of the timer, a slight lowering of the amplitude. If incorrectly compensated this condition could cause overbanking. The overbanking condition causes the beat rate to increase.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the arming pin and safing pin to be retracted earlier.	1×10^{-7}	1c

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE — ASSEMBLY	EFFECT OF FAILURE — END ITEM	FAILURE PROBABILITY	CRITICALITY
A4 Temperature	The friction in the escapement especially on the balance wheel pivots decrease inversely with respect to an increase in temperature. This decreased friction in turn means greater amplitude.	This effect is compensated for in the design of the timer by slightly lowering the amplitude. If incorrectly compensated this condition could cause overbanking. This excessive amplitude causes the beat rate to increase.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the arming pin and safing pin to be retracted earlier.	1×10^{-7}	1d
B Watch Movement Assembly (D87204)	Slow functioning of the Watch Movement Assembly	Slow or no time base.	Timer may run slower than designed causing a "dud".	1×10^{-6}	8
B1 First Pinion (C87103)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	9
B2 Wheel Crown (C87107)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	10
B3 First Wheel (B87110)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	11
B4 Mainspring (C87111)	The mainspring fractures due to shock, vibration, or overwinding and therefore cannot store energy.	The mainspring cannot store energy and therefore no energy is available to power watch mechanism. There will be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-5}	12

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
B5 Wheel Winding (C87114)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	13
C Control Assembly (F87203)	————	Slow or no time base.	Timer may run slower than designed or not at all thereby causing a "dud".	1.3×10^{-3}	14
C1 "O" Rings (A87190-x)	The "O" rings lose their seal due to an undetected condition. The oil, Synta-Visco-Lube, evaporates thereby creating more friction in the escapement. This higher friction reduces the amplitude of the escapement.	The escapement has lower amplitude due to higher friction. This lower amplitude increases the probability of the escapement stopping or not starting. If the friction is sufficiently high, the escapement will not run.	Timer will not advance if the escapement stops, thereby resulting in a "dud".	4×10^{-6}	15
C2 Pawl (C87143)	A pawl tooth shears thereby either "locking up" the timing drum or allowing the drum to quickly move past the levers.	The drum either "locks up" or quickly moves past the levers. If the drum "locks up" the timer cannot operate due to the levers not operating. If the drum moves quickly, the levers allow the arming pin and safing pin to retract in quick succession.	If the drum "locks up" there is no timer operation and the unit is a "dud". If the drum moves quickly, the arming and safing pins retract in quick succession. The slide then quickly moves through the armed position to the safe position.	1×10^{-6}	2
C3 Link (C87226)	The link breaks due to flexure or fatigue. This isolates the watch from the remainder of the timer.	The pawl stops oscillating due to the connection to the watch through the link being broken.	Timer cannot advance because there is no oscillation of the pawl, thereby resulting in a "dud".	1×1^{-9}	16
C4 Coupling Drive (B87223)	Breakage in bending due to vibration, shock or operation.	The pawl ceases to oscillate due to the lack of coupling from watch. There is no effective time base.	Timer cannot advance because there is no oscillation of the pawl; thereby resulting in a "dud".	1×10^{-6}	17

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY ~~Q=10~~ β	CRITICALITY
C5 Actuator Clock (B87248)	The actuator fails in either shear or bending.	The watch cannot be started due to the broken actuator.	Timer cannot operate because timer cannot be started. The result is a "dud".	1 x 10[illegible]	18
C6 Stem Control (B87181)	The stem may fail from torque, tension or bending.	Without a stem the watch cannot be started and therefore the timer cannot operate.	The timer cannot be started and therefore the unit is a "dud".	1 x 10[illegible]	19
C7 System Friction	If the system friction is greater than the output torque of the watch, the watch will stop.	No time base due to excessive friction stopping the watch.	The timer cannot operate due to no time base therefore the unit is a "dud" i.e. "fails safe".	1.3×10^{-3}	20a
C8 Misalignment	Misalignment of Parts	"	"	included in C7 System Friction	20b
D Timer Assembly (D87199)	———	Does not count "hours" generated by the watch.	No operation.	3 x 10[illegible]	21
D1 Gear, Timing (C87123)	Gear teeth shear thereby allowing the gear to advance one tooth or the loose tooth jams the gear, timing.	The gear either moves ahead one tooth and thereby activates the levers prematurely or creates a condition whereby the timer does not operate.	The timer either operates one hour early or does not operate creating a "dud".	1 x 10[illegible]	22
D2 Mainspring, Timing (C87188)	Fracture due to shock, vibration, or operation.	Without an intact mainspring there is no energy with which the timer can operate.	The timer fails to advance and is therefore a "dud".	1×10^{-6}	23
D3 Retainer, Pull Pin (B87142)	The spring fails in fatigue due to repeated insertions and withdrawals of the pull pin.	The spring clip once broken does not retain the pull pin and could possibly allow the timer to start prematurely under environmental test conditions.	It is conceivable that the timer could start prematurely, although it is under load. Other system restraints on the pull pins would preclude such an occurrence.	1 x 10[illegible]	3

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
E Base Mtg. Assy. (B87207)	———	Arming and/or Safing Pin does not retract.	Unit is a "dud". Time window is not available at proper time.	1×10^{-7}	———
E1 Arm Pin Assy. (B87163)	Shear. The arm pin assembly shears due to external load.	The arm pin shears thereby allowing the slide to move prematurely to the arm position.	The lack of an arm pin allows the slider to move to the armed position.	1×10^{-9}	4
E2 Safe Pin Assy. (B87163)	Shear. The safe pin assembly shears due to external load.	The safe pin shears thereby allowing the slide to move prematurely to the safe position.	The lack of a safe pin allows the slider to move momentarily through the arm position, to the safe position.	1×10^{-9}	24
E3 Lock, Arm Pin (C87167)	Shear. The lock arm pin fails in shear thereby allowing the arming pin to retract.	The lock, arm pin shears thereby allowint the arming pin to retract.	The arming pin retracts thereby allowing premature arming of the unit.	1×10^{-9}	5
E4 Lock, Safe Pin (C87168)	Shear. The lock, safe pin fails in shear thereby allowing the safing pin to retract.	The lock, safe pin shears thereby allowing the safing pin to retract.	The safing pin retracts thereby allowing premature safing of the unit. The unit would therefore become a "dud".	1×10^{-9}	25
E5 Lever, Arm Lock (C87169)	Bending. The lever, arm lock fails in bending.	The lever, arm lock fails thereby releasing the arming pin allowing it to retract.	The arming pin is released and retracting allows the slide to move to the armed position. Premature Arming.	1×10^{-9}	6
E6 Latch (B87249)	Shear. The latch on arming pin fails in shear.	The latch fails in shear thereby allowing the arming pin to be released and retract.	The arming pin is released and retracting allows the slide to move to the armed position Premature Arming.	1×10^{-9}	7
E7 Latch (B87249)	The latch on safing pin fails in shear.	The latch fails in shear thereby allowing the arming pin to be released and retract.	Slider goes through arm position, directly to the safe position.	1×10^{-9}	26
F Pull Pin Assy (B87148-01)	———	Cannot activate timer.	No operation	———	27

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
F1 Pull Pin (B87145)	The pull pin fails in tension.	Cannot activate timer because the pull pin assembly separates under approx. 18 lb. load, and the pull pin remains in place "locking up" the timing drum and the watch is never started.	No operation because the watch is never started.	4×10^{-6}	28
F2 Sleeve (B87144)	Local Bending	Cannot activate timer.	No operation "dud".	1×10^{-6}	29
F3 #24 AWG Bus Wire	The bus wire is used as a "shear pin" in the pull pin assy. If the bus wire shears at a very low stress value the pull pin assy cannot start the timer.	If the bus wire shears the assembly cannot complete its function and start the watch.	If the bus wire shears the pull pin remains in the timer hanging up the drum. The watch also is not started.	2×10^{-6}	30

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
A Hack Watch Movement (D87108)	Overbanking due to either low gravity, low pressure, or position of the watch movement with respect to gravity. Overbanking is a term which refers to excessive amplitude of the balance wheel. This condition causes the balance wheel jewel to hit the back of the lever and bounce back thereby causing a faster beat rate.	Fast time base. The overbanking causes a faster beat rate thereby causing the timing drum to rotate faster then designed through the connecting mechanisms.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal. As a result, the firing pin and switches are activated earlier than planned.	48×10^{-7}	1
A1 "O" Rings (A8.7190-x)	Loss of Seal due to leakage around the "O" rings. Could be caused by undetected foreign matter or an undetected defect in the "O" ring.	The escapement may overbank because of lower friction. The lower friction is due to the reduced air drag on the balance wheel at lower pressure.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the firing pin and switches to be activated.	4×10^{-6}	1a
A2 Position of Timer	If the position of the timer changes so as to change the axis of the balance wheel, the friction of the balance wheel changes.	This effect could be contributory toward an overbanking failure. The lower friction will increase the amplitude condition and could become part of the cause of overbanking.	The timer may run faster than normal causing premature operation. This is due to the timing drum rotating faster than normal. When the slot in the drum is in the correct position, the firing pin and switches are activated.	zero, because this effect by itself will not cause failure. However, in conjunction with leakage and temperature it can.	1b
A3 Low Gravity	The friction in the escapement especially on the balance wheel pivots decreases with respect to gravity due to the smaller normal force involved. This decreased friction in turn means greater amplitude with the possibility of overbanking and increased beat rate.	This effect is compensated for in the design of the timer by slightly lowering the amplitude. If incorrectly compensated this condition could cause overbanking. This excessive amplitude causes the beat rate to increase.	The timer may run faster then normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the firing pin and switches to be activated.	1×10^{-7}	1c
A4 Temperature	The friction in the escapement especially on the balance wheel pivots decreases inversely with respect to an increase in temperature. This decreased friction in turn means greater amplitude.	This effect is compensated for in the design of the timer by slightly lowering the amplitude. If incorrectly compensated this condition could cause overbanking. This excessive amplitude causes the beat rate to increase.	The timer may run faster then normal causing premature operation. This is due to the timing drum rotating faster than normal, causing the firing pin and switches to be activated.	1×10^{-7}	1d

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
B Watch Movement Assembly (D87204)	Slow functioning of the Watch Movement Assembly.	Slow or no time base.	Timer may run slower than design causing a "dud".	1×10^{-6}	6
B1 First Pinion (C87103)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	7
B2 Wheel Crown (C87107)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	8
B3 First Wheel (B87110)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1 x [illegible]	9
B4 Mainspring (C87111)	The mainspring fractures due to shock, vibration, or overwinding and therefore cannot store energy.	The mainspring cannot store energy and therefore no energy is available to power watch mechanism. There will be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	10
B5 Wheel Winding (C87114)	Tooth shears thereby preventing transmission of energy through the gear train to the mainspring.	Gear train cannot supply energy to mainspring and therefore no energy is available to power watch mechanism. There will then be no time base.	Timer cannot operate due to no time base from the watch. The timer fails in a safe condition.	1×10^{-6}	11
C Control Assembly (F87203)	———	Slow or no time base.	Timer may run slower than designed or not at all thereby causing a "dud".	1.3×10^{-3}	———

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
C1 O Rings (A87190-x)	The "O" rings lose their seal due to an undetected condition. The oil, Synta-Visco-Lube, evaporates thereby creating more friction in the escapement. This higher friction reduces the amplitude of the escapement.	The escapement has lower amplitude due to higher friction. This lower amplitude increases the probability of the escapement stopping or not starting. If the friction is sufficiently high, the escapement will not run.	Timer will not advance if the escapement stops, thereby resulting in a "dud".	4×10^{-6}	12
C2 Pawl (C87143)	A pawl tooth shears thereby either "locking up" the timing drum or allowing the drum to quickly move past the levers.	The drum either "locks up" or quickly moves past the levers. If the drum "locks up" the timer cannot operate due to the levers not operating. If the drum moves quickly, the levers allow the release of the firing pin.	If the drum "locks up" there is no timer operation and the unit is a "dud". If the drum moves quickly allowing the lever to release the firing pin, the firing pin will "lock up" on its pull pin. If the pull pin is removed, the firing pin will fire outside the available time window.	1×10^{-6}	2
C3 Link (C87226)	The link breaks due to flexure or fatigue. This isolates the watch from the remainder of the timer.	The pawl stops oscillating due to the connection to the watch through the link being broken.	Timer cannot advance because there is no oscillation of the pawl, thereby resulting in a "dud".	1×10^{-9}	13
C4 Coupling Drive (B87223)	Breakage in bending due to vibration, shock or operation.	The pawl ceases to oscillate due to the lack of coupling from watch. There is no effective time base.	Timer cannot advance because there is no oscillation of the pawl; thereby resulting in a "dud".	1×10^{-6}	14
C5 Actuator Clock (B87248)	The actuator fails in either shear or bending.	The watch cannot be started due to the broken actuator.	Timer cannot operate because timer can not be started. The result is a "dud".	1×10^{-6}	15
C6 Stem Control (B87182)	The stem may fail from torque, tension or bending.	Without a stem the watch cannot be started and therefore the timer cannot operate.	The timer cannot be started and therefore the unit is a "dud".	1×10^{-6}	16
C7 System Friction	If the system friction is greater than the output torque of the watch, the watch will stop.	No time base due to excessive friction stopping the watch.	The timer cannot operate due to no time base therefore the unit is a "dud" i.e. "fails safe".	1.3×10^{-3}	17a
C8 Misalignment	Misalignment of Parts	"	"	included in C7 System Friction	17b

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
D Timer Assembly (D87205)	————	Does not count "hours" generated by the watch.	No operation	3×10^{-6}	18
D1 Gear, Timing (C87123)	Gear teeth shear thereby allowing the gear to advance one tooth or the loose tooth jams the gear, timing.	The gear either moves ahead one tooth and thereby activated the levers prematurely or creates a condition in which the timer does not operate.	The timer either operates one hour early or does not operate creating a "dud".	1×10^{-6}	19
D2 Mainspring Timing (C87188)	Fracture due to shock, vibration or operation.	Without an intact mainspring there is no energy with which the timer can operate.	The timer fails to advance and is therefore a "dud".	1×10^{-6}	20
D3 Spring Clip (B87245)	The spring fails in fatigue due to repeated insertions and withdraws of the pull pin.	The spring clip once broken does not retain the pull pin and could possible allow the timer to start prematurely under environmental test conditions.	The timer starts prematurely thereby allowing premature operation of the firing pin. The firing pin would then "lock-up" on its pull pin creating a "dud". If the pull pin for the firing pin is withdrawn the timer will operate prematurely.	1×10^{-6}	3
E Base Mtg. Assy. (D87207)	————	Firing pin does not activate.	Unit is a "dud".	————	22
E1 Body, Firing Pin (B87171)	The body, firing pin fails in tension.	The firing pin may or may not operate depending upon the spring action on the head of the firing pin. The firing pin may dig into the containing walls stopping its action.	The unit is a possible "dud".	1×10^{-6}	23
E2 Tip, Firing Pin (B87172)	Compression crushing the tip so that it cannot "set off" the slider explosing charge.	Firing pin does not initiate thermal battery timer.	The experiment becomes a "dud" due to the thermal battery primer not being initiated.	1×10^{-6}	24
E3 Spring, Firing Pin (B87201)	The spring fails in shear but being a compression spring it catches the next turn and functions but probably not with the same force.	The spring fails thereby decreasing the force on the firing pin.	The experiment may become a "dud" due to the lack of sufficient impact force to initiate thermal battery primer.	1×10^{-6}	25

SYSTEM LSPE	PREPARED BY Louis N. Allen	NO. 891-012	REV. B
END ITEM Thermal Battery Timer	DWG NO.	PAGE 5 of 6	
ASS'Y	DWG NO.	DATE May 10, 1971	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
E4 Switch (A87186)	Random opening of contacts.	No continuity at random intervals.	Unknown.	2×10^{-4}	Unknown
E5 Actuator Switch (C87259)	The actuator fails in beinding. The actuator bends and does not contact the switch.	The bending of the actuator out of the switch creates a condition whereby the switch does not actuate.	Unknown	4×10^{-6}	Unknown
E6 Pin (Switch Actuator)	The pin fails in shear or is missing.	If the (actuating) pin is sheared off, the switches will not be actuated.	Switches will not be actuated.	1×10^{-6}	Unknown
E7 Lock, Firing Pin (D87174)	The lock, firing pin fails in shear thereby releasing the firing pin in advance.	Firing pin is released. The lock, firing pin fails in shear thereby allowing the firing pin to be released.	Firing pin is released and "locks up" on the Firing Pin Pull Pin. If the pull pin has already been removed the Firing Pin would initiate the Thermal Battery Primer prematurely; long before set time, resulting in a "dud".	1×10^{-9}	4
E8 Latch (B87231)	The Latch fails in shear thereby releasing the firing pin in advance.	Firing pin is released. The latch fails in shear thereby allowing the firing pin to be released.	Firing pin is released and "locks up" on the pull pin for the firing pin.	1×10^{-9}	5
E9 Dowel (Latch Shaft)	The Latch fails in shear thereby releasing the firing pin in advance.	Firing pin is released. The latch fails in shear thereby allowing the firing pin to be released.	Firing pin is released and "locks up" on the pull pin for the firing pin.	1×10^{-9}	34
F Pull Pin Assy (Timer) (B87146-02)	———	A failure in the pull pin assembly would prevent activation of the timer.	A failure in the pull pin assembly would prevent activation of the timer and the unit would become a "dud" i.e. The unit fails in the safe condition.	4×10^{-6}	26
F1 Pull Pin (B87151)	The pull pin snaps i.e. fails in tension.	The timer cannot be activated. Part of the pull pin remains in the timing drum preventing rotation. This same part of the pull pin by remaining in the Timing Drum does not activate the watch through the rocker yoke.	The timer cannot be activated. See Assembly.	1×10^{-9}	27

SYSTEM LSPE	PREPARED BY Louis N. Allen	NO. 891-012	REV. B
END ITEM Thermal Battery Timer	DWG NO.	PAGE 6 of 6	
ASSY	DWG NO.	DATE May 10, 1971	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS WORKSHEET

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY	CRITICALITY
F2 Sleeve (B87153)	Local Bending.	Cannot activate timer.	"Dud"	1×10^{-6}	28
F3#24 AWG Buss Wire	The buss wire is used as a "shear pin" in the pull pin assy. If the buss wire shears at a very low stress value the pull pin cannot start the timer.	The buss wire shears thereby preventing the removal of the lower piece of the pull pin assy.	The lower piece of the pull pin by remaining in place locks up the firing pin.	2×10^{-6}	29
G Pull Pin Assy (Firing Pin) (B87146-03)	————	A failure of the pull pin would prevent the operation of the firing pin.	The firing pin would not operate due to the restraining action of the pull pin.	4×10^{-6}	30
G1 Pull Pin (B87152)	The pull pin snaps i.e. fails in tension.	A piece of the Pull Pin remains in place blocking the firing pin. The rest of the pull pin has been removed from the timer.	The piece of the pull pin remaining in the timer blocks the firing pin. Once the firing pin is activated it "locks up" onto the piece of the pull pin. The unit "Fails Safe" because the firing pin can no longer activate the battery primer.	1×10^{-9}	31
G2 Sleeve (B87153)	Local bending.	Firing pin cannot activate detonator due to the pull pin remaining in position.	————	1×10^{-6}	33
G3 #24AWG Buss Wire	The buss wire is used as a "shear pin" in the pull pin. If the buss wire shears at a very low stress value the pull pin cannot be completely removed.	The buss wire shears thereby preventing activation of pull pin assy.	Pull pin cannot activate watch and remains in place "locking up" timing drum.	2×10^{-6}	32

APPENDIX C

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

SYSTEM	PREPARED BY	NO.	REV.
ALSEP	J. Staats	ATM976	
END ITEM: LSPE	DWG NO.	PAGE 1 of 19	
ASS'Y: Thermal Battery	DWG NO. 2348416	DATE 7-30-71	

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁵	CRITICALITY
1.0 Primer	1.0 Fails as shown:	1.0 Failure of Component:	1.0 EPA Affected as Shown:		
	1.1 No Fire	1.1 No Battery Output	1.1 No Explosive Detonation	0.1	V
	1.2 Punctures	1.2 White Noise on the Output	1.2 Potential False Trigger	0.05	VI
2.0 Battery	2.0 Fails as Shown:	2.0 Failure of Component:	2.0 EPA Affected as Shown:		
	2.1 No 5 Volt output	2.1 Loss of Signal Processor Function	2.1 No Explosive Detonation	0.1	V
	2.2 No 13 Volt Output	2.2 Loss of Receiver and Signal Processor Functions	2.2 No Explosive Detonation	0.1	V
	2.3 No 24 Volt Output	2.3 Loss of Firing Pulse Generator and Signal Processor Functions.	2.3 No Explosive Detonation	0.1	V
	2.4 Noise on the Output	2.4 ____________	2.4 Potential False Trigger	0.05	VI

SYSTEM ALSEP	PREPARED BY	NO. ATM 976	REV.
END ITEM LSPE	DWG NO.	PAGE 2 of 19	
ASS'Y Receiver	DWG NO. 2348351	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^5	CRITICALITY
1.0 Pre-amp	1.0 Failure as shown	= .319	1.0 Component failures as shown	1.0 Output affected as shown		
	1.1 No output		1.1 Q1 short L2 short C3, 4 short C14 short L5, L1 open C1 open	1.1 No output No firing pulse	Q = .0655	V
	1.2 Incorrect Output	= .678	1.2 L1, L2, Q1, C2 drift Drift	1.2 Attenuated output	Q = .1390	VI
2.0 Amp #1	2.0 Failure as shown	= .656	2.0 Component failures as shown	2.0 Output affected as shown		
	2.1 No output		2.1 C5 open C8 short AR1 short	2.1 No firing pulse	Q = 1.18	V
	2.2 Incorrect output	= .349	2.2 AR1 drifts C8 opens C5, C7 shorts R2 drift	2.2 Possibility of no firing pulse	Q = .635	V
3.0 Amp #2	3.0 Failure as shown		3.0 Component failure as shown	3.0 Output affected as shown		
	3.1 No output	= .433	3.1 C9, open C11 open L78 open Y1 opens L6, C12, R5, C15, AR2 short	3.1 No firing pulse		V
	3.2 Incorrect output	= .567	3.2 Y1 drift AR2 AR2 oscillates C12 R4 drift L6 L8 C10 short C13	3.2 Possibility of no firing pulse	Q = 2.92	V
4.0 Final Amp	4.0 Failure as shown		4.0 Component failure as shown	4.0 Output affected as shown		
	4.1 No output	= .633	4.1 C16 open C18 open R10 open	4.1 No firing pulse	Q = .685	V

SYSTEM ALSEP	PREPARED BY	NO. ATM 976	REV.
END ITEM LSPE	DWG NO.	PAGE 3 of 19	
ASS'Y Receiver	DWG NO. 2348351	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^5	CRITICALITY
		4.1 AR3 short R7 short R11 open			
	4.2 Incorrect output = .367	4.2 L4 open or short R8 RT1 open or short AR3 drift R10, R7 drift R11 drift	4.2 Possibility of no firing pulse	Q = .685	V
5.0 AGC	5.0 Failure as shown	5.0 Component failure	5.0 Output affected as shown		
	5.1 No AGC = .707	5.1 CR1 open AR4 short or open	5.1 Possible no firing pulse	Q = 2.96	V
	5.2 Incorrect AGC = 2.94	5.2 C17 short R12 open AR4 drift	5.2 Possible no firing pulse	Q = 1.23	V

SYSTEM ALSEP	PREPARED BY	NO. ATM 976	REV.
END ITEM LSPE	DWG NO.	PAGE 4 of 19	
ASS'Y Firing Pulse Gen	DWG NO. 2348360	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
1.0 Trigger	1.0 Failure as shown		1.0 Component failures as shown	1.0 Failure as shown		
	1.1 No output	$\alpha = 1$	1.1 Q1 open C2, 4 short R4 short	1.1 No firing pulse	Q = 32.4 x 10	V
	1.2 Erroneous output		1.2 Q1 short	1.2 Output on leading edge of firing gate		
2.0 Amplifier	2.0 Failure as shown		2.0 Component failure as shown	2.0 Failure as shown		
	2.1 No output	$\alpha = .9975$	2.1 CR2 open C1, 3 short R1 open CR1 open R3 short R2 short	2.1 No firing pulse	$Q = 20.4 \times 10^{-4}$	V
	2.2 Constant output	$\alpha = .0025$	2.2 CR1 short	2.2 Firing at incorrect time	$Q = 5.36 \times 10^{-6}$	VI

SYSTEM ALSEP	PREPARED BY	NO. ATM976	REV.
END ITEM LSPE	DWG NO.	PAGE 5 of 19	
ASS'Y DC/DC Converter	DWG NO. 2347809	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁻⁵	CRITICALITY
1.0 Oscillator	1.0 Fails as shown	1.0 Component failures	1.0 DC levels affected as shown		III
	1.1 Frequency drift α = .225	1.1 C 13, 9, 6, drift AR1 regulator drift	1.1 Possible amplitude drift	Q = .2522	
	1.2 No output α = .775	1.2 T1, T2 open or short CR5, CR9, CR7 short Q1, 2 open or short AR1 regulator open or short	1.2 No dc	Q = .868	III
2.0 Regulator	2.0 Failure as shown	2.0 Component failures	2.0 DC levels affected as shown		
	2.1 No output α = .632	2.1 Q3 open Q4 AR1 no output, open or short No feedback CR12, 13 open or short	2.1 No dc	Q = .868	III
	2.2 Constant output α = .183	2.2 Q3, 4 short AR1 loses control	2.2 No regulation with load	Q = .2522	III
	2.3 Oscillating output = .183	2.3 AR1 oscillates	2.3 Noise in B+ to other circuitry	Q = .2522	III
3.0 +28V DC rect. & filter	3.0 Fails as shown	3.0 Component failure	3.0 +28 volt bus is affected as shown		
	3.1 No output α = .9838	3.1 Shorts: C2, C1, T2 secondary Opens: L1, CR1, 2 DC return P7 on T2 R1 Short	3.1 No +28V	Q = .1024	III
	3.2 Ripple α = .0162	3.2 CR1 OR CR2 opens or shorts L1 shorts R1 opens C1, C2 opens	3.2 Noise in +28 VDC bus	Q = .011288	III
4.0 +12V DC	4.0 Fails as shown	4.0 Component failure	4.0 +12 affected as shown		
	4.1 No output α = .909	4.1 Shorts: C4, 5 T2 secondary	4.1 No +12 VDC 2.54	Q = .111408	III

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

SYSTEM	PREPARED BY	NO.	REV.
ALSEP		ATM976	
END ITEM: LSPE	DWG NO.	PAGE 6 of 19	
ASS'Y: DC/DC Converter	DWG NO. 2342809	DATE 7/20/71	

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY
			4.1 Opens: L2 CR1, CR2 DC Return			III
	4.2 Ripple	α = .091	4.2 CR3 or CR4 opens or shorts L2 short C4, 5 opens	4.2 Noise in +12 VDC bus	Q = .011768	III
5.0 +5V DC	5.0 Fails as shown		5.0 Component failure	5.0 +5 affected as shown		
	5.1 No output	α = .477	5.1 Shorts C7, 8 T2 secondary Open L3, CR6, CR8 DC Return	5.1 No +5V DC	Q = .011470	III
	5.2 Ripple	α = .477	5.2 CR6 or CR8 opens or shorts L3 shorts C7, C8 open	5.2 Noise in +V DC bus	Q = .01046	III
6.0 -12V DC	6.0 Fails as shown		6.0 Component failure	6.0 -12V DC affected as shown		
	6.1 No output	α = .909	6.1 Shorts C11, C12 T2 secondary Open L4, CR10, CR11	6.1 No -12V DC	Q = 0.112708	III
	6.2 Ripple	α = .091	6.2 CR10 or CR11 but no both Opens or shorts L4 shorts C11, C12 open	6.2 Noise on -12V DC bus	Q = .0114	III
7.0 Board #2	7.0 Fails as shown		7.0 Component failure	7.0 Reference voltages affected as shown		
	7.1 No outputs	α = .76	7.1 VR1, 2 short R1, 3 open	7.1 No LSP Temp sens. supply No Mu-A/D col ref #2 No Mu-A/D col ref #1 Pin #1 opens lose E1, 3, 4	Q = .25600	III
	7.2 Incorrect output	α = .24	7.2 VR1, 2 open R8 opens R9, R6, R7	7.2 References are at improper level	Q = .081000	III

SYSTEM ALSEP	PREPARED BY	NO. ATM 976	REV.
END ITEM LSPE	DWG NO.	PAGE 7 of 19	
ASS'Y Signal Processor	DWG NO. 2348356	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{5}$	CRITICALITY
1.0 Pre-Amp	1.0 Failure as shown		1.0 Component failure	1.0 Output affected as shown		
	1.1 No output	α = .999733	1.1 AR1, AR2 output shorts R6 R4 R13 shorts—R14, opens	1.1 No firing pulse No firing gate	Q = 1.142	III
	1.2 Incorrect output	$\alpha = .267 \times 10^{-3}$	1.2 Drift of components R1, R2, R4, R8, R11, R7, R10, R5, R6, Cp1, R13, R14	1.2 No firing pulse No firing gate	$Q = 39 \times 15^{-4}$	III
2.0 Pulse Counter	2.0 Failure as shown		2.0 Component failure as shown	2.0 Output affected as shown	$Q = 39 \times 10^{-4}$	III
	2.1 No output	α = .60	2.1 R12 opens, Q1 opens or U3 shorts to ground U1 or U2 short to ground Rg opens or R3 shorts	2.1 No firing pulse No firing gate	Q = 1.2	
	2.2 Constant output	α = .40	2.2 Q1 shorts U3 shorts to B+ U2 shorts to B+	2.2 No firing pulse No firing gate	Q = .004	III
3.0 One shot	3.0 Failure as shown		3.0 Component failure	3.0 Output affected as shown		
	3.1 No output	α = .99653	3.1 U4 hangs up No pulse out (short to B+ short to ground, no output)	3.1 No firing pulse No firing gate	Q = .4	III
	3.2 Incorrect output	α = .00347	3.2 C2 or R5 drifts C2 shorts or open R5 shorts or open	3.2 Incorrect firing pulse Incorrect firing gate	Q = 13.90	III
4.0 Firing Gate Amplifier	4.0 Failure as shown		4.0 Component failure	4.0 Output affected as shown		
	4.1 No output		4.1 Q3 shorts or opens Q2 shorts or opens VR1 shorts R20 opens R19 opens R18 opens	4.1 No firing gate	Q = .228	III

SYSTEM ALSEP	PREPARED BY	NO. ATM976	REV.
END ITEM LSPE	DWG NO.	PAGE 8 of 19	
ASS'Y X-Mitter	DWG NO. 2347821	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE		FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
		ASSEMBLY	END ITEM		
1.0 Rf oscillator	1.0 Fails as shown	1.0 Failure of components	1.0 Rf affected as shown		III
	1.1 No output $\alpha = 1$	1.1 Short or open of Q6	1.1 No r-f to antenna		
	1.2 Oscillator drifts	1.2 X-tal drift 1.	1.2 r-f amplitude decreases	Q = .0232	
2.0 Trigger amp	2.0 Fails as shown	2.0 Component failure	2.0 R-f affected as shown		III
	2.1 Loss of output $\alpha = 1$	2.1 Short or open	2.1 No r-f out		
	2.2 Noise on input	2.2 Open C10, R3, R4	2.2 Spurious output	$Q = 45.2 \times 10^{-4}$	
	2.3 Continuous output	2.3 Q1 short Q2 open	2.3 Continuous output		
3.0 R-f Amp	3.0 Fails as shown	3.0 Component failure	3.0 R-f affected as shown		III
	3.1 Loss of input $\alpha = .37$	3.1 CR2, R12, C10 open; C23, L11, R18 short	3.1 No r-f to antenna	$Q = 64 \times 10^{-4}$	
	3.2 Loss of output	3.2 Q3, Q4, Q4, Q5 short; C11, C12, C13, C14 open	3.2 No r-f to antenna		
	3.3 Loss of B+ $\alpha = .37$	3.3 C1, 2, 3, 4, 5 short R1 open	3.3 No r-f to antenna	$Q = 37 \times 10^{-4}$	
4.0 Line	4.0 Failure as shown $\alpha = .135$	4.0 Failure of components	4.0 R-f affected as shown		III
	4.1 No output	4.1 C15, 16, 17. Short L10 short L5, 6 open R9, 14 short	4.1 No detonation	$Q = 132 \times 10^{-4}$	
	4.2 Output amplitude incorrect $\alpha = .865$	4.2 Parameter drift L10, 5, 6 C15, 16, 17 R9, 14 L5, L6, short C15, 16, 17 open.	4.2 R-f amplitude incorrect	$Q - 840 \times 10^{-4}$	

SYSTEM ALSEP	PREPARED BY	NO. ATM976	REV.
END ITEM LSPE	DWG NO.	PAGE 9 of 19	
ASS'Y X-Mitter	DWG NO. 2347821	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{-5}$	CRITICALITY
5.0 Detector	5.0 Failure as shown $\alpha = 1$	5.0 Component failure	5.0 No effect	$Q = 2.16 \times 10^{-4}$	III
	5.1 No output	5.1 CR3, L13 open; R17, C24, C25 short			
	5.2 R-f output	5.2 CR3 short			

SYSTEM ALSEP	PREPARED BY	NO. ATM976	REV.
END ITEM LSPE	DWG NO.	PAGE 10 of 19	
ASS'Y Digital Processor	DWG NO. 2347826	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁻⁵	CRITICALITY
1.0 Increment Clock Ckt	1.0 Failure as shown	α = 1	1.0 Component failure	1.0 Output affected as shown	Q - 1.2	III
	1.1 No output	α = 1	1.1 No input U-8C, 48D, 410D Short or open	1.1 No increment clock A or B	Q = 1.2	III
2.0 Calibration and Data Clock Circuit	2.0 Failure as shown		2.0 Component failure	2.0 Output affected as shown		
	2.1 No output	α = .332	2.1 No input (power off) (data stops.) U14 fails lock up B+ or gnd. C9 opens, shorts U128 or U8F short or open, C10 shorts	2.1 No increment clock pulse	Q = 2.6	III
		α = .358	2.1.1 No output data select circuits U14 fails (lock up) B+ or gnd Cg opens or sheets U12E or U8F short or open, C10 shorts. 47B and U10E short or open	2.1.1 No data select outputs	Q = 2.8	III
		α = .309	2.1.2 Output calibration pulse Short or open R7, R6, Q B, Vel, R5, U30, R4, C7, C8, U13, U12B, U12C, C6		Q = 2.42	III
3.0 CAL Pulse Monitor	3.0 Failure as shown	α = 1	3.0 Component failure	3.- Output affected as shown	Q =.015	III
	3.1 No output	α = 1	3.1 U8B, U9B, U13, U12B, U12C, C6 Short or open	3.1 No calibration pulse monitor	Q = 3.0	III
4.0 SDS Amp	4.0 Failure as shown	α = 1	4.0 Component failure as shown	4.0 Output affected as shown	Q = 2.6	III

SYSTEM ALSEP	PREPARED BY	NO. ATM976	REV.
END ITEM LSPE	DWG NO.	PAGE 11 of 19	
ASS'Y Digital Processor	DWG NO. 2347826	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^{5}$	CRITICALITY
	4.1 No output response α = 1	4.1 C5 Short No input C4 short U4C Opens, shorts U5C	4.1 No SDS Amp gain signal Gain remains high	Q - 3.6	III
5.0 SDS Gain Monitor	5.0 Failure as shown	5.0 Component failure as shown	5.0 Output affected as shown		
	5.1 No output response α =1	5.1 C5, 4 short U4C, U5C, U5B, U12D Open, short, No input	5.1 SDS gain monitor does not change state	Q = 3.4	III
6.0 Line Filter	6.0 Failure as shown α = 1	6.0 Component failure as shown	6.0 Output affected as shown	Q = 0.9	III
	6.1 No output α = .5	6.1 C3 short	6.1 No +5 VDC	Q = 0.9	III
	6.2 Noise α = .5	6.2 C3 open	6.2 Noise in +5V line		
7.0 X-mit code	7.0 Failure as shown	7.0 Component failure as shown	7.0 Output affected as shown		
	7.1 Output does not change state α = 1	7.1 U1A, B, C; U2A, B, C; U3A, D, C; U4D; U6D, A, B, C; U4A; U5A } open or short C1, 2 short	7.1 No X-mit code or X-mit AGC	Q = 8.2	III
8.0 MUX 1, 6, 11, 16	8.0 Failures as shown	8.0 Component failures as shown	8.0 Output affected as shown		
	8.1 No output (does not change state) α = .768	8.1 U7C, U20A, B, C short or open U22, A, B short or open U11C, D,U12F, U21 Short or open	8.1 No channel select command for for 1, 6, 11, 16	Q - 4.0	III
	8.2 Incorrect output α =.232 No clear	8.2 U10C shorts U22A, B shorts or opens	8.2 Incorrect cycling of information channels	Q - 1.2	III

SYSTEM ALSEP	PREPARED BY	NO. ATM976	REV.
END ITEM LSPE	DWG NO.	PAGE 12 of 19	
ASS'Y Digital Processor	DWG NO. 2347826	DATE 7/20/71	

FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE	(α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁻⁵	CRITICALITY
9.0 OR Invert	9.0 F ilures as shown		9.0 Component failure as shown	9.0 Output affected as shown		III
	9.1 No output	α = .667	9.1 U19, U8E Short or open	9.1 Output UC 3 + 7 + 11 + 5		
	9.2 Incorrect output	α =.333	9.2 U19 input ckts fail	9.2 One output signal could be missing	Q = .4	
10.0 MUX 2, 3, 4, 5, 6 7, 8, 9 12, 14, 15, 13	10.0 Failures as shown		10.0 Component failures as shown	10.0 Output affected as shown		
	10.1 Output incorrect	α =.857	10.1 U15 ABC U16 ABC open or short U17 ABC U18 ABC	10.1 No channgel command for particular failure output does not change state.	Q = 4.8	III
		α =.103	U6#, F open or short	Output does not change state	Q = .8	

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^{-5}	CRITICALITY
1.0 Reset Circuit					
1.1 R1	1.1 R1 fails A. Open B. Drift	1.1 A. No RC time constant B. No effect	1.1 A. No science data B. No effect	1.1 = .44	III
1.2 R2	1.2 R2 fails A. Open B. Drift	1.2 A. No RC time constant B. No effect	1.2 A. No science data B. No effect	1.2 = .44	III
1.3 C1	1.3 C1 fails A. Short	1.3 A. No master clear	1.3 A. No science data	1.3 = .10	III
1.4 C4	1.4 C4 fails A. Short	1.4 A. No +5VDC filter	1.4 A. Some data unintelligible	1.4 = .10	I
1.5 C5	1.5 C5 fails A. Short	1.5 A. No RC time constant	1.5 A. No science data	1.5 = .10	III
1.6 U1 U5 U6 U7 U46	1.6 A. U1A, U1C, U1D, U5A, U6, U7D, U46A fails 1. high 2. low	1.6 A1 No effect - self clearing A2 No master clear and no counts	1.6 A1 No effect A2 No science data	1.6 = 90	III
2.0 Clock Control Circuit					
2.1 U1 U2 U5 U7 U46	2.1 A. U1B, U1F, U5B, U7B, U7C, U46C, U46D Fails 1. high 2. low	2.1 A1 No effect - self clearing A2 No clock pulse, no master clear and no counts	2.1 A1 No effect A2 No science data	2.1 = 64	III

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q × 10⁵	CRITICALITY
2.1 (cont.)	2.1 B. U2B fails 1. high 2. low	2.1 B1. Bad format for a few frames B2. No BINC clear	2.1 B1. No effect B2. No science data	2.1 = .1	III
3.0 BINC Counter					
3.1 C2	3.1 C2 fails A. Short	3.1 A. No frame counter preset	3.1 A. No transmitter pulse	3.1 = .1	
3.2 U2 U3 U4 U7 U9 U10 U15 U17	3.2 U2A U3A, B U4 U7A U9A, B U10A U14A-D U15 A, C, E U17A fails 1. high 2. low	3.2 1. Improper Binc counting 2. No BINC counting	3.2 1. Unintelligible data 2. No data	3.2 = 234	III
4.0 Bit, Word, Sub frame counter and decoder					
4.1 U18 U19 U20 U21 U22 U23 U24	4.1 U18A, B U19A, B U20A, B U21A, B U22A, B U23A, B U24A fails high or low	4.1 Improper formatting	4.1 No science data	4.1 = 250	III
5.0 Decoder					
5.1 U8 U11 U25 thru U42	5.1 U8 U11 U25 thru U42 fails high or low	5.1 Improper formatting	5.1 No science data	5.1 = 778	III

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10^-5	CRITICALITY
6.0 Frame Counter					
6.1 U43 U44 U45 U46 U47 U12 C3	6.1 U43A, B U44A, B U45A, B U46E, F fails U47 U12 1. high 2. low	6.1 A1. Continuous pulses to the transmitter A2. No pulses to the transmitter	6.1 1. No transmitter control 2. No science data	6.1 = 212	III
	C3 fails short	B. Improper preset for U43A and U44B.	Erratic gating of the transmitter	= .1	III

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q x 10⁻⁵	CRITICALITY
1.0 Engineering Data Formatter					
1.1 C1	1.1 C1 fails short	1.1 +5VDC shorts to ground	1.1 No data formating - No data	1.1 = .44	III
1.2 U1 thru U8 U10	1.2 U1A, B U2A, B U3A-D U4A U5 U6A-F U7A-C U8A, B U10C fails 1. high 2. low	1.2 1. Improper formating for a few frames self clearing 2. No formating	1.2 1. no effect 2. no engineering data	1.2 = 236	IV
2.0 Shift Pulse Generator					
2.1 U3 U4 U9-U14 U18 U30 U44	2.1 A. U3F U4B U10D-F U14	2.1 A. No engineering shift register function	2.1 A. No engineering data and no data in WCO	2.1 A = 86	IV
	B. U9B-F U10A, B U11A U12A, B U13A U14 U18A U30A U44A fails high or low	B. No shift data register output	B. No science data	B = 148	III

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY $Q \times 10^5$	CRITICALITY
3.0 Data Shift Register					
3.1 R1	3.1 R1 fails A. short B. drift	3.1 A. Buffer F-F output too high B. No effect	3.1 A. Data unintelligible B. No effect	3.1 = .44	III
3.2 C2	3.2 C2 fails short	3.2 No buffer F-F output	3.2 No data	3.2 = .1	III
3.3 U11 U12 U13 U15 - U30	3.3 A. U11B U12D-F U13B U15A-C U16A-D U17A-F U18B, D-F U19A, B U20 U21A, B U22A, B U23A, B U24A, B U26A, B U27A, B U28A, B U29A, B U30B-F fails high or low	3.3 A. Output data improperly formatted	3.3 A. Unintelligible data	3.3 = 634	III
	B. U25B fails high or low	B. No data output	B. No science data	B = 20	III
4.0 Engineering Data Control					
4.1 U31 U32 U33 U34 U36 U37	4.1 U31A-F U32A, B U33A-C U34A-C U36A, B U37A-F fails 1. high 2. low	4.1 1. Engineering data output erratic 2. No engineering data output	4.1 1. Unintelligible engineering data 2. No engineering data	4.1 = 200	IV IV

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FAILURE MODE, EFFECT & CRITICALITY ANALYSIS

PART/COMPONENT SYMBOL	FAILURE MODE (α)	EFFECT OF FAILURE: ASSEMBLY	EFFECT OF FAILURE: END ITEM	FAILURE PROBABILITY Q × 10⁻⁵	CRITICALITY
7.2 u11 U32 U35 U36 U38 - U53	4.2 U11C, D U32C U35A-C U36C-E U38A-F U39A-C U40A, B U41 U42 U43 U44B-F U45A-F U46A, B U47A, B U48A, B U49A, B U50A, B U51A, B U52A, B U53A, B	4.2 Erratic engineering data output	4.2 Unintelligible engineering data	4.2 = 716	IV