INTRODUCTION

Presented herein are the results of a preliminary numerical reliability analysis performed on the Lunar Surface Gravimeter. Prediction Appendix I presents the detail analysis; Figure 1 presents the LSG Reliability Block Diagram and Figure 2 presents the LSG Reliability Block Diagram operating in a degraded mode.

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RESULTS

Table I presents a summary of results of this analysis.

ASSUMPTIONS

The following assumptions were made and applied to the numerical LSG reliability analysis presented in Section I of this report.

1) Operating temperature of the electronic parts 50°C.

2) Derating factor: 20% of the rated power or voltage.

3) Failure rates were developed from Bendix Document ATM 605 Rev. A.

4) All component parts will be of an established reliability level unless otherwise it will be stated.

5) Probability of success was calculated through the mathematical formulation

$$R = e^{-\lambda t}$$

where;

R is the probability of success

λ = is the electionic component part failure rate given in %/1000 Hrs.

t = is the mission time

6) A reliability parallel redundant path is calculated as follows:

$$R = P_1 + P_2 - P_1P_2$$

where;

$$P = e^{-\lambda t}$$

7) The dormant failure rate was calculated as follows:

Active Failure rate x 0.01

8) The mission time for the different equipments are as follows:

a) Servo Loop 17, 520 Hrs.

b) Motor Drive Control 100 Hrs. except the caging control 50 Hrs.

c) Temperature Control 17, 520 Hrs.

d) Power Control 17, 520 Hrs.

e) Logic 17, 520 Hrs.

9) Normalized Junction Temperature for Semiconductors was assumed to be 0.15.

10) Mission time from launch to lunar deployment up to ~200 hr

11) The LSG reliability in a degraded mode as presented in Figure 2 is based under the assumption that the scientific and in house data will be degraded by a factor of approximately 60 to 70%.

12) It is to be noticed that this reliability prediction does not reflect the results of the component application analysis and the FMEA.

SECTION I

Numerical Reliability Analysis

Figure 1 presents the LSG Reliability Block Diagram (all equipments operating) Figure 2 presents the Reliability Block Diagram in a degraded mode.

Appendix 1 presents the detail reliability analysis. Table 1 presents a summary of the reliability of individual equipments including the reliability of the complete system.

APPENDIX I

Detail Reliability Analysis

1- Stabilized Oscillator

Component Part	Qty. (n)	λ in %/1000 Hrs.	λ n
Operational Ampl.	2	.00310	.00620
Capacitor Mica	4	.00017	.00068
Capacitor Ceramic	10	.00005	.00050
Diodes Silicon	6	.00110	.00660
Relay	1	.00125	.00125
Inductor	1	.02100	.02100
Transistor	2	.00222	.00444
Resistor C. C.	8	.00002	.00016
Resistor M. F.	7	.00020	.00140
Transformer	1	.02100	.02100
			.06323

2- Instrument Housing Heater Control

Op. Amplifier	2	.0031	.00620
Cap. Sol. tant.	1	.00007	.00007
Cap. Ceramic	9	100005	.00045
Diode Silicon	6	.0011	.00660
Diode Zener	3	.00355	.01065
Relay	1	.00335	.00335
Transistor	3	.00222	.00666
Resistor M. F.	3	.0002	.00060
Resistor C. C.	12	.00002	.00024
			.03482

3- Temperature Pressure Monitor

Op. Amplifier	2	.0031	.00620
Cap. Ceramic	8	.00005	.00040
Diode Silicon	2	.0011	.00220
Resistor M. F.	10	.0002	.00200
			.01080

APPENDIX I Cont.

4- Mass Change Servo Control

Component Part	Qty. (n)	λ in %/1000 Hrs.	λn
Op. Amplifier	2	.0031	.00620
Cap. Sol. tant.	1	.00007	.00007
Cap. Mylar	1	.00002	.00002
Cap. Ceramic	8	.00005	.00040
Diode Zener	4	.00355	.01420
Diode Silicon	9	.0011	.00990
Int. Ckt.	3	.0015	.00450
Relay	2	.00125	.00230
Resistor C. C.	24	.00002	.00048
Resistor M. F.	1	.0002	.00020
Transistor	9	.00222	.01998
			.05825

5- Caging Control

Capacitor Ceramic	2	.00005	.00010
Capacitor Mica	1	.00017	.00017
Capacitor Sol. tant.	2	.00007	.00014
Diode Silicon	5	.0011	.00550
Relay	1	.00125	.00125
Transistor	3	.00222	.00666
Resistor C. C.	6	.00002	.00012
			.01394

6- Shaft Encoder Electronics

Diode Silicon	1	.0011	.00110
Capacitor Ceramic	2	.00005	.00010
Capacitor Sol. tant.	1	.00007	.00007
Int. Ckt.	29	.0015	.04350
Transistor	3	.00222	.00666
Resistor C. C.	5	.00002	.00010
			.05153

APPENDIX I, Cont.

7- Digital Line Buffers and Receivers

Component Part	Qty. (n)	λ in %/1000 Hrs.	λn
Capac. Ceramic	2	.00005	.00010
Cap. Sol. tant.	3	.00007	.00021
Int. Ckt.	8	.0015	.01200
Relay	1	.00335	.00335
Transistor	2	.00222	.00444
Resistor C. C.	2	.00002	.00004
			.02014

8- Analog - Digital Converter

Op. Amplifier	5	.0031	.00155
Cap. Ceramic	10	.00005	.00050
Cap. Sol. tant.	4	.00007	.00028
Diode Silicon	3	.0011	.00330
Diode Zener	1	.00355	.00355
Int. Ckt.	16	.0015	.02400
Resistor network (each EQ. 10 resistors) M. F.	100	.0002	.02000
Resistor M. F.	2	.0002	.00040
Resistor C. C.	22	.00002	.00044
			.05402

9- Analog Multiplexer

Int. Ckt.	3	.0015	.00450
Op. amplifier	1	.0031	.00310
Resistor C. C.	6	.00002	.00012
Diode Silicon	2	.0011	.00220
Capac. Ceramic	5	.00005	.00025
			.01017

10- Analog Output Buffers

Resistor C. C.	11	.00002	.00022
Capacitor Ceramic	31	.00005	.00155
Diode Silicon	2	.0011	.00220
Op. Amplifier	11	.0031	.03410
			.03807

APPENDIX I Cont.

11- Digital Multiplexer

Component Part	Qty. (n)	λ in %/1000 Hrs.	λn
Capac. Ceramic	1	.00005	.00005
Int. Ckt.	13	.0015	.01950
			.01955

12- Digital Multiplexer Control

Capac. Ceramic	1	.00005	.00005
Int. Ckt.	13	.0015	.01950
			.01955

13- Command Decoder and Driver

Cap. Ceramic	1	.00005	.00005
Int. Ckt.	5	.0015	.00750
			.00755

14- Command Counter

Cap. ceramic	1	.00005	.00005
Int. Ckt.	7	.0015	.01050
			.01055

15- Demodulator Integrator

Resistor C. C.	11	.00002	.00022
Resistor M. F.	7	.0002	.00140
Capacitor Mica	4	.00017	.00068
Capacitor Ceramic	8	.00005	.00040
Capacitor Sol. tant.	5	.00007	.00035
Relay	1	.00125	.00125
Transformer	1	.0210	.02100
Op. Amplifier	3	.0031	.00930
Int. Ckt.	1	.0015	.00150
Diode Silicon	3	.0011	.00330
			.03940

APPENDIX I Cont.

16- Free modes filter

Component Part	Qty. (n)	λ in %/1000 Hrs.	λn
Operational Amplifier	1	.0031	.00310
Capacitor Ceramic	7	.00005	.00035
Capacitor Sol. tant.	2	.00007	.00014
Resistor M. F.	10	.0002	.00200
Resistor C. C.	2	.00002	.00004
			.00563

17- Post-Amplifier

Op. Amplifier	1	.0031	.00310
Capacitor Ceramic	10	.00005	.00050
Diode Silicon	4	.0011	.00440
Int. Ckt.	5	.0015	.00750
Resistor C. C.	8	.00002	.00016
Resistor M. F.	5	.0002	.00100
			.01666

18- Power Converter

Capac. Ceramic	5	.00005	.00025
Capac. S. tant.	4	.00007	.00028
Capac. mylar	1	.00002	.00002
Diode Silicon Pwr.	15	.0017	.02550
Inductor	2	.0210	.04200
Transistor Pwr.	8	.00444	.03552
Resistor C. C.	10	.00002	.00020
Transformer	1	.0210	.02100
			.12477

19- Tilt servo

Cap. Ceramic	2	.00005	.00010
Diode Silicon	8	.0011	.00880
Transistor	18	.00222	.03996
Relay	2	.00125	.00250
Resistor C. C.	20	.00002	.00040
Int. Ckt.	7	.0015	.01050
			.06196

APPENDIX I Cont.

20- Temp. Controller/Monitor Assy.

Component Part	Qty. (n)	λ in %/1000 Hrs.	λn
Resistor C. C.	10	.0002	.00200
Resistor M. F.	10	.0002	.00200
Capac. Ceramic	3	.00005	.00015
Transistor	3	.00222	.00666
Diode Zener	7	.0011	.00770
Thermistor	1	.0300	.03000
Op. Amplifier	1	.0031	.00310
			.05161

21- Fixed Gain Preamp.

Op. Amplifier	1	.0031	.00310
Capacitor Ceramic	6	.00005	.00030
Resistor M. F.	6	.0002	.00120
			.00460

22- Screw Servo System

Resistor M. F.	3	.0002	.00060
Resistor C. C.	25	.00002	.00050
Relay	2	.00125	.00250
Diode Silicon	15	.0011	.01650
Diode Zener	2	.00355	.00710
Capac. S. tant.	2	.00007	.00014
Capac. Ceramic	6	.00005	.00030
Transistor	13	.00222	.02886
Op. Amplifier	3	.0031	.00930
Int. Ckt.	16	.0015	.02400
Motor (1000 rpm)	2	.0400	.08000
			.16980

23- Seismic Filter

Resistor M. F.	8	.0002	.00160
Resisotr C. C.	1	.00002	.00002
Capac. S. tant.	4	.00007	.00028
Capac. Ceramic	1	.00005	.00005
Op. Amplifier	2	.0031	.00620
			.00815

APPENDIX I Cont

24- ADL reliability of thermal and mechanical components

a)	100% operation	.960385
b)	Degraded Performance	.976182

25- LaCoste and Romberg sensor reliability was assumed to be .99999 for two year mission.

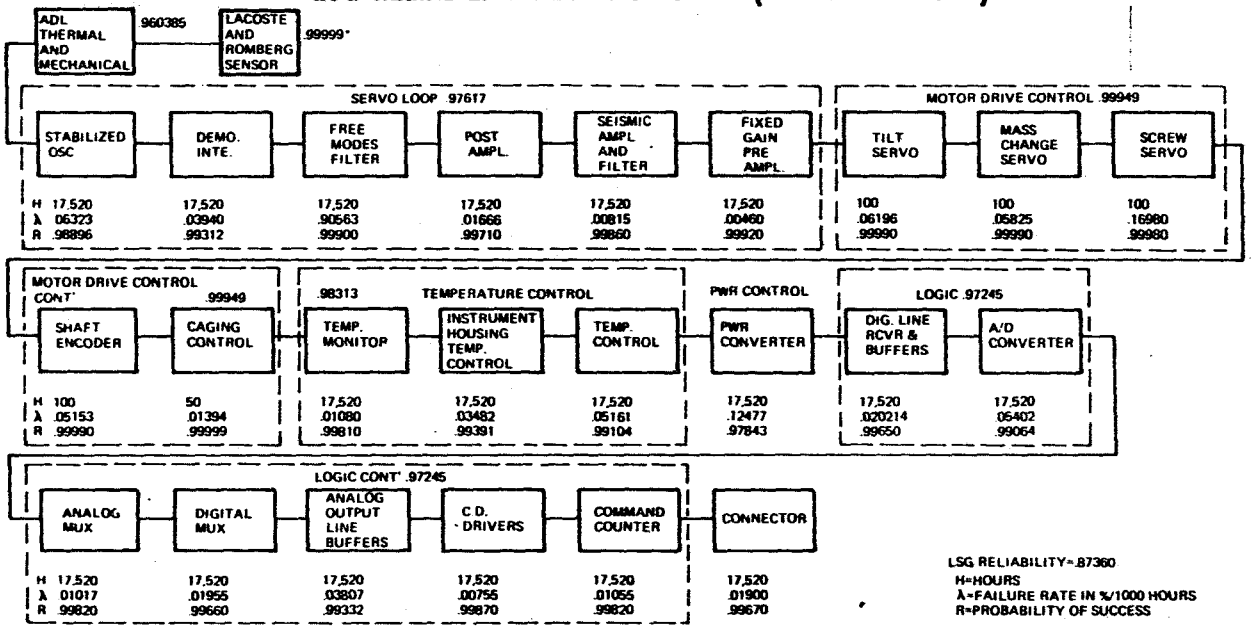
TABLE 1 LSG RELIABILITY SUMMARY OF RESULTS

EQUIPMENTS	RELIABILITY FOR TWO YEAR MISSION		RELIABILITY LAUNCH TO LUNAR DEPLOYMENT
	COMPLETE OPERATION	DEGRADED MODE	
1- SERVO LOOP	.97617	SAME	
A) OSCILLATOR	.98896		
B) DEMODULATOR-INTEGRATOR	.99312		
C) FREE MODES FILTER	.99800		
D) POST AMPLIFIER	.99710		
E) SEISMIC AMPL. AND FILTER	.99860		
F) FIXED GAIN PRE-AMPLIFIER	.99920		
2- MOTOR DRIVE CONTROL	.99949	SAME	
A) TILT SERVO	.99990		
B) MASS CHANGE SERVO	.99990		
C) SCREW SERVO	.99980		
D) SHAFT ENCODER	.99990		
E) CAGING CONTROL	.99999		
3- TEMPERATURE CONTROL	.98313	SAME	
A) TEMP. MONITOR	.99810		
B) INSTRUMENT HOUSING TEMP CONTROL	.99391		
C) TEMP. CONTROL	.99104		
4- PWR CONTROL	.97843	SAME	
5- LOGIC	.97245	.99327	
A) DIG. LINE RCVRS & BUFFERS	.99650		
B) A/D CONVERTER	.99064		
C) ANALOG MUX	.99820		
D) DIGITAL MUX	.99660		
E) ANALOG OUTPUT LINE BUFFERS	.99332		
F) COMMAND DECODER DRIVERS	.99870		
G) COMMAND COUNTER	.99820		
6- CONNECTOR	.99670	INCLUDED IN THE LOGIC	
7- ADL - THERMAL & MECHANICAL	.96038	.97618	
8- LACOSTE AND ROMBERG SENSOR	.99999		
LSG RELIABILITY	.87360	.90999	.99977
LSG MISSION RELIABILITY	.87460	.90978	

1) LSG RELIABILITY IS DEFINED AS THE PRODUCT OF BXA ELECTRONICS, ADL AND LA COSTE AND ROMBERG RELIABILITIES.

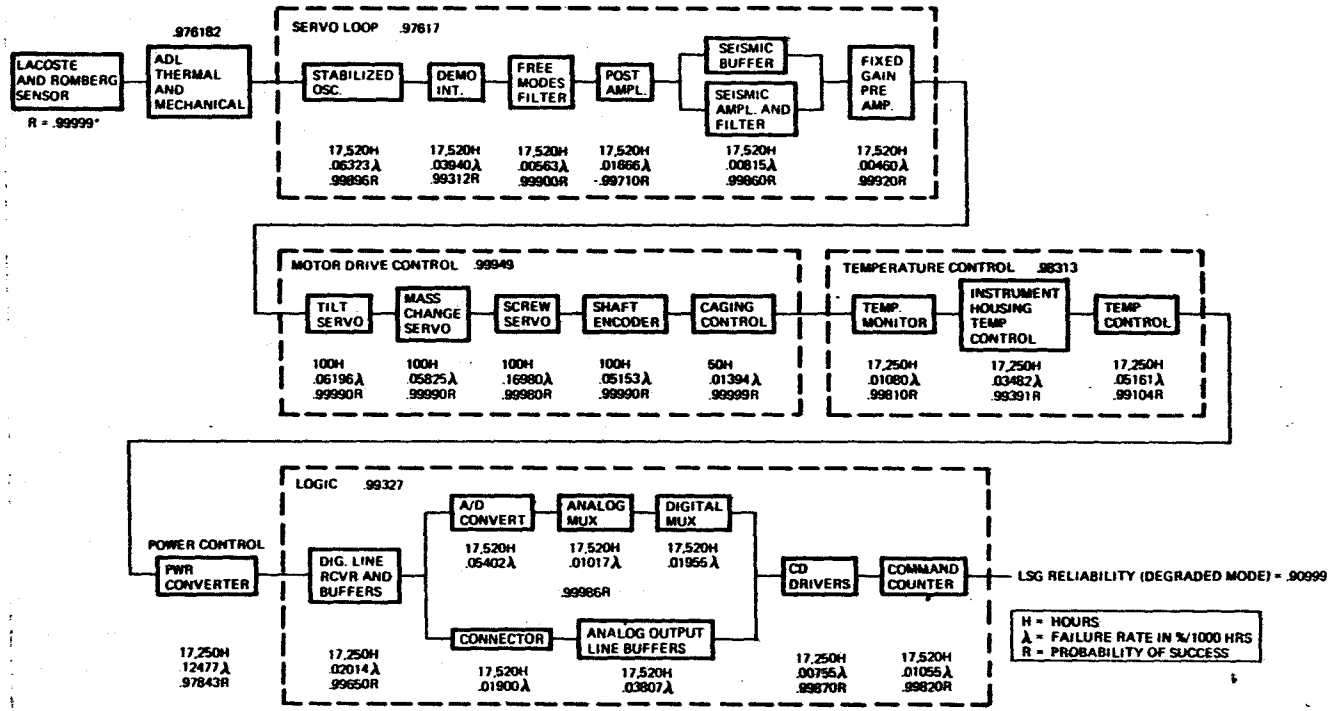
2) LSG MISSION RELIABILITY IS DEFINED AS THE PRODUCT OF COMPLETE OPERATION RELIABILITY TIMES RELIABILITY LAUNCH TO LUNAR DEPLOYMENT, AND DEGRADED MODE RELIABILITY TIMES RELIABILITY LAUNCH TO LUNAR DEPLOYMENT.

FIGURE 1
LSG RELIABILITY BLOCK DIAGRAM (DEGRADED MODE)



*THE RELIABILITY OF THE SENSOR HAS BEEN ASSUMED TO BE .99999 FOR TWO YEAR LUNAR OPERATION.

FIGURE 2
LSG RELIABILITY BLOCK DIAGRAM (DEGRADED MODE)



*THE RELIABILITY OF THE SENSOR HAS BEEN ASSUMED TO BE .99999 FOR TWO YEAR OPERATION.