LUNAR MASS SPECTROMETER
RELIABILITY PREDICTION

Contract No. NAS 9-5829

Presented in this ATM are the Lunar Mass Spectrometer (LMS) reliability prediction and mathematical models.

The A Revision herein has been updated to include the Lock Out Switching Circuit (page 11).

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ALSEP Reliability

Introduction

Presented herein are the mathematical models and results of the updated numerical reliability analysis as performed on the Lunar Mass Spectrometer. Two types of logic are presented, one type for before experiment deployment, and the other type for after experiment deployment. The former considers all elements as serially connected while the later excludes those elements whose final function is executed during deployment and also provides for degraded mode analysis.

Results

Table I presents a summary of the results of this analysis.

Assumptions

The following assumptions were applied to the numerical reliability analysis herein:

1) Operating temperature of the electronic parts are in accordance with Table II.

2) Derating factors are in accordance with ATM 241E.

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

4) Expected semiconductor or integrated circuit junction thermal rises were extrapolated from "ALSEP, Array E Electronic Packaging Thermal Design Guidelines," Letter No. 9712-101.

5) Probability of success was calculated through the mathematical formulation

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

where

R is the probability of success
λ is the electronic component part failure rate given in %/1000 hours
t is the mission or storage time

6) The dormant or storage failure rate was calculated as follows:

Active Failure Rate X 0.01

7) The transient failure rate (non-operating from Launch to Experiment deployment) was calculated as follows:

Active Failure Rate X 0.1

8) The storage time used in the mathematical models was two years or 17,520 hours.

9) The transient time used in the mathematical models was 109 hours.

10) The mission time used in the mathematical models was two years or 17,520 hours.

11) Degraded Modes were defined by expansion of $(R+Q)^3$ reference "Lunar Mass Spectrometer Reliability Block Diagram" (After Experiment Deployment).

12) Junction temperatures for discrete devices (transistors and semiconductors) were normalized in accordance with MIL-HDBK 217A and ATM 605A tables as follows:

$$\theta_{J\text{-}A} = \frac{T_{J_{max}} - T_S}{P_{J_{max}}}$$

where

$\theta_{J\text{-}A}$ is thermal resistance from junction to circuit board (°C/W)

$T_{J_{max}}$ is the maximum rated temperature (°C)

T_S is the ambient temperature, 25°C

$P_{J_{max}}$ is the maximum power rating for the device (watts)

$$T_j = T_a + (\theta_{J-A}) P_j$$

where:

T_j is the actual junction temperature in the application or design.

T_A is the actual ambient temperature at the circuit board in °C.

θ_{J-A} is the thermal resistance from junction to the circuit board in °C/watt.

P_j is the average power dissipated (watts in the circuit application or design.

13) It is to be noted that the reliability prediction herein reflects the results of the component application analysis and not the failure modes and effects analysis.

14. Loading of 54L and 54 series I. C. 's:

The "limiting parameter" loading must be followed when determining the maximum fan out for a device. This is summarized in T.I. 's catalog CC201-R pages 12-1 through pages 12-3.

To summarize the tables:

1) A 54 series loaded by a 54 series: N = 10 where N = 1 is -1.6 Ma (limiting parameter).

2) A 54L series loaded by a 54L series: N = 10 where N = 1 is -.18 Ma limiting parameter).

The above values must be derated in accordance with ATM 241E to 75 percent. This limits the TTL devices to:

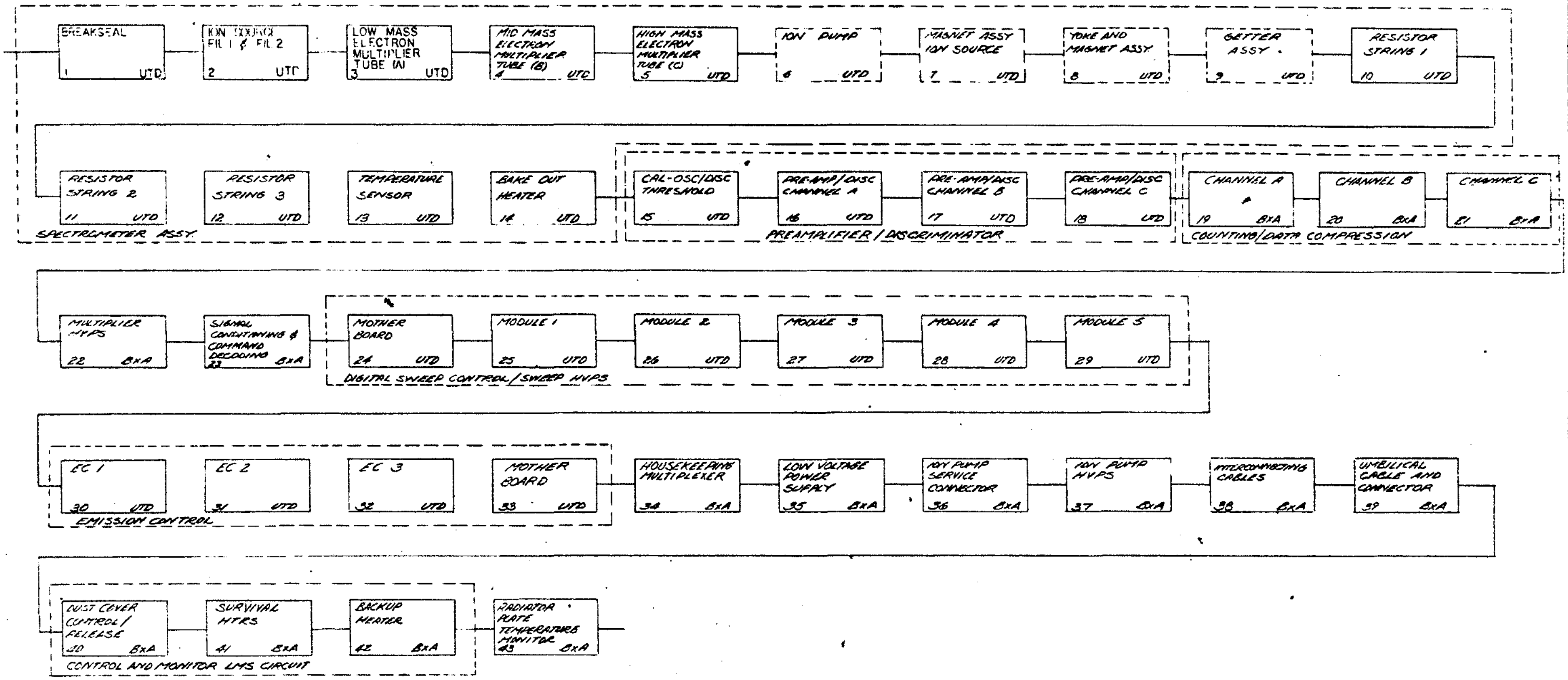
1) A 54 series may be loaded with as many as seven 54 series single inputs or thirty-two 54L series single inputs.

2) A 54L series may be loaded with as many as seven 54L series single inputs or one 54 series single input.

Under no circumstances may a circuit be loaded over 80%.

Conclusions

Section I - The overall reliability goal for the Lunar Mass Spectrometer is .90. The Reliability prediction for two years operation on the lunar surface using failure rates from the Parts Application Analysis, is .858. This value is increased to .876 when using the Q values from the Failure Modes and Effect Analysis.



NOTES

1. TIME INTERVAL FOR THIS DIAGRAM IS FROM AIA THROUGH EXPERIMENT DEPLOYMENT.
2. MATHEMATICAL MODEL FOR THE PROBABILITY OF EXPERIMENT SUCCESS BEFORE EXPERIMENT DEPLOYMENT.

$$R_T = \prod_{R_1}^{R_5} R_i \prod_{R_{10}}^{R_{43}} R_i$$

PROPRIETARY NOTICE

RELIABILITY APPD	PREDICTION
TJM	6-3-71

REVISIONS: ZONE | LTR | DESCRIPTION | DATE | APPROVED

QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO	ITEM

LIST OF MATERIALS

PART NO.	NEXT ASSY	END ITEM NO.	SERIAL NO.

DRAWING AND PART APPLICATION

DRAWING CLASS A ☐ B ☐ C ☐

FINISH

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
TOLERANCES DECIMAL .X ± .XX ± .XXX ± ANGLES ± CHAMFER ± 5°
SURFACE FINISH MICROINCHES RMS

MATERIAL:

CONTR NO.
DRAWN 3-28-71
CHECKED
STRESS WT
DSGN SUPV
PROJ ENGR
QUAL CONT
SYS ENGR
DSGN APPL
MFG
CUSTOMER

THE BENDIX CORPORATION
AEROSPACE SYSTEMS DIVISION - ANN ARBOR, MICHIGAN

TITLE: LUNAR MASS SPECTROMETER RELIABILITY BLOCK DIAGRAM (BEFORE EXPERIMENT DEPLOYMENT)

SIZE D | CODE IDENT NO 07038 | DRAWING NUMBER | REV

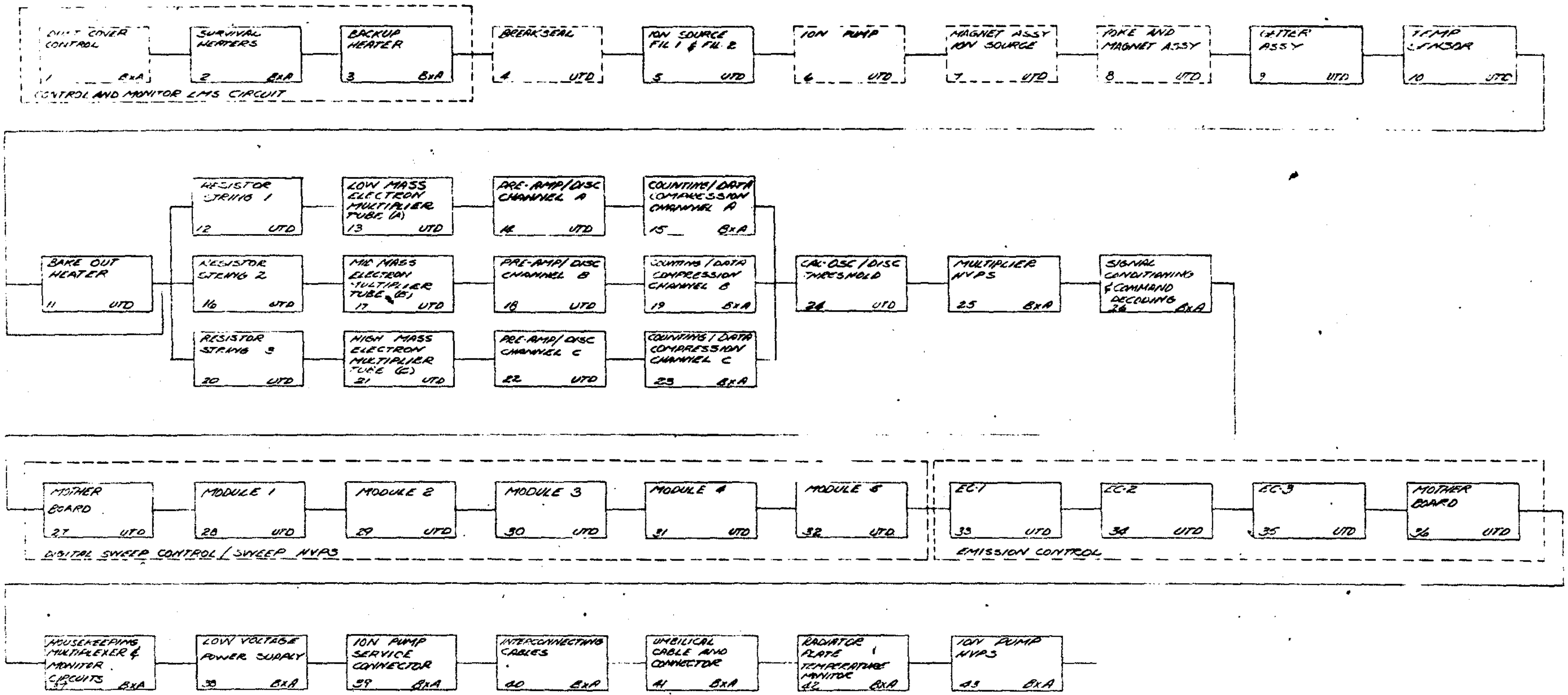
SCALE | WEIGHT | SHEET 6 of 11

NOTES (CONT)

3. TIME INTERVAL FOR THIS EXPERIMENT IS AFTER EXPERIMENT DEPLOYMENT

4. RELIABILITY BLOCK NOS 6,7,8,29 ARE EXCLUDED FROM THE MATHEMATICAL MODELS FOR BEFORE EXPERIMENT DEPLOYMENT

5. OPERATING TIME FOR BLOCK NO 1, DUST COVER CONTROL IS 5 HOURS (AFTER EXPERIMENT DEPLOYMENT)



RELIABILITY	
APPD	PREDICTION
7PH	6-3-71

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO	ITEM

LIST OF MATERIALS

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PART NO.	NEXT ASSY	END ITEM NO	SERIAL NO.

DRAWING AND PART APPLICATION

DRAWING CLASS A ☐ B ☐ C ☐

FINISH

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± .XX ± .XXX ±
ANGLES ± CHAMFER ± 5°
SURFACE FINISH MICROINCHES RMR
MATERIAL:

CONTR NO.
DRAWN [signature] 6-71
CHECKED
STRESS/WT
DSGN SUPV
PROJ ENGR
QUAL CONT
SYS SPT
DSGN APPL
MFG
CUSTOMER

THE BENDIX CORPORATION
AEROSPACE SYSTEMS DIVISION - ANN ARBOR, MICHIGAN

TITLE
LUNAR MASS SPECTROMETER
RELIABILITY BLOCK DIAGRAM
(AFTER EXPERIMENT DEPLOYMENT)

SIZE D | CODE IDENT NO 07038 | DRAWING NUMBER | REV

SCALE | WEIGHT | SHEET 7 of 11

RELIABILITY		REVISIONS				CONFIG MGT.
APPD	PREDICTION	ZONE	LTR	DESCRIPTION	DATE	APPV'D
FM	6-3-71					

NOTES (CONT.)

6. MATHEMATICAL MODELS

PATH	CHANNELS WORKING	CHANNELS FAILING	MATH MODELS FOR EXPERIMENT WITH DEGRADED MODE	MATH MODEL FOR EXPERIMENT RELIABILITY WITH NORMAL OPERATION
1.	A	B, C	$\prod_{R_{12}}^{R_{15}} R_i \left[1-(R_{16}R_{17}R_{18}R_{19})\right]\left[1-(R_{20}R_{21}R_{22}R_{23})\right]$	
2.	B	A, C	$\prod_{R_{16}}^{R_{19}} R_i \left[1-(R_{12}R_{13}R_{14}R_{15})\right]\left[1-(R_{20}R_{21}R_{22}R_{23})\right]$	
3.	C	A, B	$\prod_{R_{20}}^{R_{23}} R_i \left[1-(R_{12}R_{13}R_{14}R_{15})\right]\left[1-(R_{16}R_{17}R_{18}R_{19})\right]$	
4.	A, B	C	$\prod_{R_{12}}^{R_{19}} R_i \left[1-(R_{20}R_{21}R_{22}R_{23})\right]$	
5.	A, C	B	$\prod_{R_{12}}^{R_{15}} R_i \prod_{R_{20}}^{R_{23}} R_i \left[1-(R_{16}R_{17}R_{18}R_{19})\right]$	
6	B, C	A	$\prod_{R_{16}}^{R_{23}} R_i \left[1-(R_{12}R_{13}R_{14}R_{15})\right]$	
7	A, B, C	NO FAILURES		$R_2R_3R_5 \prod_{R_{10}}^{R_{23}}$

7. REFERENCE NOTE 6: PATH 7 DEFINES THE PROBABILITY OF SUCCESS FOR THE LMS DURING OPERATION FOR TWO YEARS ON THE LUNAR SURFACE. THE REMAINING PATHS ARE TO BE USED TO SUPPORT RELIABILITY TRADE OFF STUDIES AND OPTIMIZATION OF THE CIRCUIT DESIGNS.

8. TO DETERMINE TOTAL EXPERIMENT RELIABILITY WITH DEGRADED MODE(S), ADD PATH 7 AND THE DESIRED PATH(S), 1 TO 6.

QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO.	ITEM

LIST OF MATERIALS

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DRAWING AND PART APPLICATION

DRAWING CLASS A ☐ B ☐ C ☐

FINISH

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES

TOLERANCES: DECIMAL .X ± .XX ± .XXX ± ANGLES ± CHAMFER ± 5°

SURFACE FINISH MICROINCHES RHR

MATERIAL:

CONTR NO.
DRAWN [signature] 5-25-71
CHECKED
STRESS/WT.
DSGN. SUPV
PROJ. ENGR.
QUAL. CONT.
SYS. SPT.
DSGN. APPL.
MFG
CUSTOMER

THE BENDIX CORPORATION
AEROSPACE SYSTEMS DIVISION – ANN ARBOR, MICHIGAN

TITLE: LUNAR MASS SPECTROMETER RELIABILITY BLOCK DIAGRAM (AFTER EXPERIMENT DEPLOYMENT)

SIZE C | CODE IDENT NO. 07038 | DRAWING NUMBER | REV.

SCALE | WEIGHT | SHEET 8 OF 11

TABLE I

LMS RELIABILITY SUMMARY

LOGIC NO BEFORE DEPLOY	LOGIC NO AFTER DEPLOY	EQUIPMENT	λ OPERATE %/1000 HRS	λ STORAGE %/1000 HRS	RELIABILITY FROM PIA TO LAUNCH (2 YRS STORAGE) t = 17,520 HRS	RELIABILITY FROM LAUNCH TO DEPLOYMENT t = 109 HRS	RELIABILITY FOR TWO YEAR OPERATION AFTER DEPLOYMENT: UTD OPERATION	B + A OPERATION	COMPLETE OPERATION A, B, C	DEGRADED OPERATION: A, $\overline{B}$, $\overline{C}$	B, $\overline{A}$, $\overline{C}$	C, $\overline{A}$, $\overline{B}$	A, B, $\overline{C}$	A, C, $\overline{B}$	B, C, $\overline{A}$	RELIABILITY AFTER PIA THROUGH 2 YR OPERATION
		SPECTROMETER ASSY	.034409	.000344	.999940	999996	.993990		.993990							993926
1 *	4 *	BREAKSEAL	.000100	.000001	.999999	.999999	.99982									999980
2 *	5 *	ION SOURCE FIL 1 / FIL 2	.008200	.000082	.999986	.999999	.998564		.998564							998549
3 *	13 *	MULTIPLIER TUBE (A)	.004000	.000040	.999993	.999999	.999299		.999299							999291
4 *	17 *	MULTIPLIER TUBE (B)	.004000	.000040	.999993	.999999	.999299		999299							999291
5 *	21 *	MULTIPLIER TUBE (C)	.004000	.000040	.999993	.999999	.999299		.999299							999291
6 *	6 *	ION PUMP	.050	.00050	—	—	—		.999513							
7 *	7 *	MAGNET ASSY ION SOURCE	—	—	—	—	—		—							
8 *	8 *	[illegible] MAGNET ASSY	—	—	—	—	—		—							999916
9 *	9 *	GETTER ASSY	—	—	—	—	—		—							999916
10 *	12 *	RESISTOR STRING 1	.000443	.000004	.999999	999995	.999922		999922							.999916
11 *	16 *	RESISTOR STRING 2	.000443	.000004	.999999	999995	.999922		999922							.999478
12 *	20 *	RESISTOR STRING 3	.000443	.000004	.999999	.999995	.999922		.999922							.998242
13 *	10 *	TEMP SENSOR	.00278	.000028	.999995	.999970	.999513		.999513							.999478
14 *	11 *	BAKE OUT HEATER	.010000	.000100	.999963	.999999	.999260		999260							.999242
15 *	24 *	CAL-OSC / DISC THRESHOLD	.013652	.000137	.999906	.999999	.997611		997611							997586
	*	PRE-AMPLIFIER; DISC	.053460	.000534	.999906	.999994	.990677		990677							.990578
16 *	14 *	CHANNEL A	.017820	.000178	.999969	.999998	.996883		.996883							.996850
17 *	18 *	CHANNEL B	.017820	.000178	.999969	.999998	.996883		.996883							.996850
18 *	22 *	CHANNEL C	.017820	.000178	.999969	.999998	.996883		.996883							996850
		COUNTING/DATA COMP	.153899	.001539	.999730	.999983		.973397	.973398							973118
19	15	CHANNEL A	.0512997	.000513	.999910	.999994		.991052	.991052							990957
20	19	CHANNEL B	.0512997	.000513	.999910	.999994		.991052	.991052							.990957
21	23	CHANNEL C	.0512997	.000513	.999910	.999994		.991052	.991052							.990957
22	25	MULTIPLIER HVPS	.043011	.000430	.999925	.999995		.992492	.992393							.992314
23	26	SIGNAL CONDITIONING & COMMAND DECODING	.061701	.000617	.999892	999993		.989248	.989248							989134
*	*	DIGITAL SWEEP CONTROL - SWEEP HVPS	.110526	.001105	.999806	.999988	.981082		.981082							980880
24	27 *	MOTHER BOARD	.080746	.000807	.999859	999991	.985949		.985949							995801
25	28 *	MODULE 1	.004082	.000041	.999993	.999999	.999285		999285							999277
26	29 *	MODULE 2	.011622	.000116	.999980	.999999	.997972		.997972							997957
27	30 *	MODULE 3	.006392	.000064	.999989	.999999	.999145		.999145							999135
28	31 *	MODULE 4	.003890	.000039	.999993	.999999	.999318		.999318							.999310
29	32 *	MODULE 5	.003794	.000038	.999993	.999999	.999336		.999335							.999327
	*	EMISSION CONTROL	.079660	.001997	.999825	.999989	.982692		.982692							982509
30 *	33 *	EC-1	.011925	.000119		.999999	.997913		.997913							.997691
31 *	34 *	EC-2	.011674	.000117	.999980	.999999	.997957		.997957							.997927
32 *	35	EC-3	.008039	.000680	.999986	.999999	.998593		.998593							.998576
33 *	36	MOTHER BOARD	.068022	.000680	.999881	—	.988151		.988151							.988029
34	37	HOUSEKEEPING MONITOR MULTIPLEXER CIRCUITS	.108941	.001089	.999809	.999988	—	.981095	.981095							.980896
35	38	LOW VOLTAGE POWER SUPPLY	.071029	—	.999876	.999981	—	.987633	.987633							.987393
36	39	ION PUMP SERV CONNECTOR	—	—	—	—	—	—	—							
37	43	ION PUMP HVPS	.038048	.000380	.999932	.999996	—	.993356	.993356							.993285

* DENOTES UTD

RELIABILITY APPD	PREDICTION
TJW	6-3-71

REVISIONS: ZONE | LTR | DESCRIPTION | DATE | APPROVED

QTY REQD | DESCRIPTION | CODE IDENT | PART OR SPECIFICATION NO. | ITEM

LIST OF MATERIALS

PART NO. | NEXT ASSY | END ITEM NO. | SERIAL NO.

DRAWING AND PART APPLICATION

DRAWING CLASS A ☐ B ☐ C ☐

FINISH

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES. TOLERANCES: DECIMAL .X ± .XX ± .XXX ± ANGLES ± CHAMFER × 5°. SURFACE FINISH MICROINCHES RHR. MATERIAL:

CONTR NO. / DRAWN / CHECKED / STRESS WT / DSGN SUPV / PROJ ENGR / QUAL CONT / SYS SPT / DSGN APPL / MFG / CUSTOMER

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AEROSPACE SYSTEMS DIVISION - ANN ARBOR, MICHIGAN

TITLE

SIZE D | CODE IDENT NO. 07038 | DRAWING NUMBER | REV

SCALE | WEIGHT | SHEET 9 of 11

TABLE I.
LMS RELIABILITY SUMMARY

LOGIC NO. BEFORE DEPLOY	LOGIC NO. AFTER DEPLOY	EQUIPMENT	λ OPERATE %/1000 HRS	λ STORAGE %/1000 HRS	RELIABILITY PIA TO LAUNCH 2 YR STORAGE t = 17,520 HRS	RELIABILITY FROM LAUNCH TO DEPLOYMENT t = 109 HRS	RELIABILITY FOR TWO YEAR MISSION AFTER DEPLOYMENT: UTO OPERATION	B&A OPERATION	COMPLETE OPERATION A, B, C	DEGRADED OPERATION: A, B̄, C̄	B, Ā, C̄	C, Ā, B̄	A, B, C̄	A, C, B̄	B, C, Ā	RELIABILITY AFTER PIA THROUGH 2 YR OPERATION
38	40	INTER CONNECTING CABLES	.003620	.0000362	.999995	.999999		.999366	.999366							.999360
39	41	UMBILICAL CABLE AND CONNECTOR	.000008	.00000008	.999999	.999999		.999999	.999999							.999997
		CONTROL & MONITOR	.082070	.000821	.999856	.999991		.985733	.985733							.985582
40	1	DUST COVER CONTROL	.020918	.000209	.999963	.999998		.999999	.999999							.996303
41	2	SURVIVAL HEATER	.038808	.000388	.999932	.999996		.993224	.993224							.993152
42	3	BACKUP HEATER	.022346	.000225	.999961	.999998		.996093	.996093							.996052
43	42	RADIATOR PLATE TEMP MONITOR	.003000	.00003	.999995	.999999		.999474	.999474							.999468
	***	TOTAL UTD λ OPERATE	.311707													
		TOTAL B&A λ OPERATE	.585327													
		TOTAL UTO RELIABILITY					.947105									
		TOTAL B&A RELIABILITY						.905618								
		TOTAL LMS - 2 YR OP AFTER DEPLOY ONLY							.857715							
		TOTAL LMS A, B̄, C̄ AFTER DEPLOY ONLY								.858067						
		TOTAL LMS B, Ā, C̄ AFTER DEPLOY ONLY									.858067					
		TOTAL LMS C, Ā, B̄ AFTER DEPLOY ONLY										.858067				
		TOTAL LMS A, B, C̄ AFTER DEPLOY ONLY											.875956			
		TOTAL LMS A, C, B̄ AFTER DEPLOY ONLY												.875956		
		TOTAL LMS B, C, Ā AFTER DEPLOY ONLY													.875956	
		TOTAL LMS - AFTER PIA THRU 2 YR OPERATION														.856218

** OPERATING TIME, 5 HRS.
*** EXCLUDES ION PUMP FAILURE RATE.

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SIZE D CODE IDENT NO 07038

Lock Out Switch

This switch was added to prevent accidental turn on of the ion source filaments (numbers 1 or 2) during ground test when the chamber is back filled with argon. The switch is mounted on the base plate and is a normally closed switch. The switch, when activated, will open the +29 volt supply to the emission control inverter circuit. The switch is activated by a pin inserted through the base plate from outside the LMS. The pin is "flaged" DO NOT FLY and will be removed after final test. The switch will also be hard wired for a short circuit prior to flight.

For the reason that the switch is to be hard wired and shorted out before flight, the reliability of this switch will not effect the reliability of the LMS.

The switch is controlled by BxA SCD number 2346242-1. The Emission Control Schematic number is 151-702. The circuit is shown below.