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- MAINTAINABILITY PREDICTION (MTTR)
- DERATING ELECTRICAL STRESS ANALYSIS
- FAILURE MODE, EFFECTS AND CRITICALITY ANALYSIS (FMEA / FMECA)
- SAFETY HAZARD ANALYSIS
- WORST CASE (PARTS/CIRCUITS) TOLERANCE ANALYSIS
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PERFORMANCE: PAST AND PRESENT

The following is a partial list of Systems/Equipment on which PSI has performed:

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PBTS Proton Beam Treatment System
Improved Thermal Sight System, Light Armored Vehicle (LAV-25)
Geostationary Operational Environmental Satellite (GOES) N-Q
XM-Radio Missile System Prelaunch Safety Data Package (MSPSP)
ICO Final Missile System Prelaunch Safety Package
ETS-8 Propellant Tank
Emergency Escape Sequencing System Tester (EESST)
ITAS/IBAS/Missile Control Subsystem (MCS) Power Supply Assembly (PSA)
IBAS/TAS Periscope Head Subassembly (PHS) Power Supply Assembly (PSA)
IBAS/MCS Line Filter (FL1) CCA
IBAS/TAS/LTAS Reticle Projector Assembly
Wireless Ground Link Quick Access Recorder Interlock
C-17A Drogue Parachute Camera Video System
P2 Fuel Control Isolation Valve
DOT Scan Terminal and Communication Cradle
Space Based Infra Red System (SBIRS)/Central Theater Processing Program (CTPP)
Talon Shield
Automated Tape Library Systems
Attack and Launch Early Reporting to Theater
Stabilized Infrared Scanner
Passenger Entertainment System
High Performance Power Supply
ASW Digital Computer Unit, MK38/MOD 0
IDL System Pod Data Terminal and Peculiar Support Equipment (PSE)
Torpedo System, MK49/MOD 1
L-1011 (Airbus) Automatic Flight Control System
NASA/Houston Recorder-Reproducer (Mag Tape)
Airborne Warning and Control System (AWACS) Avionics System
Air Traffic Control System
DPC Model 4910 Line Printer

ELINT Systems
ECM Systems
Computer Card-reader System
P-3C Aircraft Automatic Flight Control System
F-16 Aircraft Automatic Flight Control System
A&C Band Jammers
Magnetic Tape Transport
Single Pole Double Throw (SP2T) IF Switch With Driver
Communications Recorder Model No. VR2004A
Sea Sparrow Fire Control System
Sea Wolf Submarine Power Supply
Static Frequency Changer & Direct Current Output Supply (407L)
Low Light Level Television Camera Subsystem/Type 18 Periscope
AWACS Magnetic Tape Transport
AEGIS Shipboard MK84/Mod 1 400 Hz Power Supply System
Uninterruptible Power Supply System
SEAFIRE Program
Space Shuttle Mass Memory System
Galileo Space Program Tape Recorder
International Solar Polar Mission Magnetic Tape Transport
Space Telescope Recorder/Reproducer System
FIDS/BISS, Facility Intrusion Detection System RF Data Link
Boeing Aircraft 767 Auto-Brake/Anti-Skid Systems
TADS, Target Acquisition & Detection System Displays
Solar Panel Charger & Controls
Infra Red Aiming Light
KC-10A Inflight Refueling System
Tornado Aircraft Inflight Refueling
Commercial Aircraft Audio Entertainment System
400 Hz Frequency Converters
Static Inverter Power Supplies
Magnetic Card Reader, Mark Sense
Video Display Monitors
RF Data Link Systems
Telephone Switching Systems/Message Centers

Filter Connector for Telephone PBX Equipment
High Speed Impact Computer Printer
High Performance Aircraft Flap Controls
Elint Systems
Automated Information Storage & Retrieval Systems
Floppy Disk Drives
Advanced RF Receivers, Transmitters, and Repeaters
Bouy RF Receivers/ASW
Instrument Calibration Equipments
Aircraft Windshield Defrosters/Deicers
Electro-Mechanical Submarine Decoy Systems
AN/TPX-42A, Air Traffic Control Systems
Dish Radar, Pedestal, and Control System
Radio Management System
RADOPS RF Scorer
Nuclear Power Generating Station Equipment
Alphanumeric Graphics Printer
Deep Space Network Software Testing
C-17A Aircraft Autobrakes/Antiskid System
MD-11 Aircraft Autobrakes/Antiskid System
Boeing 747-400 Aircraft Autobrakes/Antiskid System
USN A-12 Aircraft Autobrakes/Antiskid System
RADARSAT Satellite Digital Tape Recorder
Catapult Launched Fuel-Air Explosive Land Mine Countermeasures System
Space Station Freedom EVA Portable Contamination Detector
SPOT, ERS-1 & JERS-1 Satellites Digital Tape Recorders
Sounding Rocket Inertial Navigation System

PERFORMANCE: PAST AND PRESENT

The following is a partial list of customers for which PSI has performed:

Advanced Retail Technology, Inc.
Aerojet Electro Systems Company
Aeronautical Accessories
Airborne CCTV, Division of Puritan-Bennett Aero Systems/Nellcor
Ampex Corporation, Computer Products Division
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Arco Solar Inc., Division of Atlantic Richfield Company
Arral Industries
Audio-In-Motion
AVICOM International
Avtel Corporation, Division of Aertronics, Inc.
B/E Aerospace, Avionics Division
Beckman Instruments, Inc.
Bell & Howell, Video Division/AVICOM
Bell & Howell, Instrumentation Division
Bermite, Division of Tasker Industries
BHK Inc.
Boeing Satellite Systems, Inc.
Canavco, Inc.
Cartwright Engineering Incorporated
Chatsworth Data Systems
Clary Instruments Company
Conrac Corporation, Systems-West Division
Continental Telecommunications Corporation, Division of
Continental Telephone Company
Cubic Corporation
Data Products Corporation
Dowty Corporation, Resdel Engineering Division
DRS Sensor Systems

DRS Optronics, Inc.

EECO Incorporated

EEMCO Division of Datron Systems, Inc.

Electronics Resources, Inc.

Electronics Specialty Company

Electro Optics Systems, Division of Xerox Corporation

Elgar Corporation, Division of Onan, Inc./McGraw Edison

Honeywell, Inc., Defense & Electronics Division

Honeywell, Inc., Marine Systems Center

Hydro-Aire Division of The Crane Company

Incosym, Inc., Division of Textron Corporation

Industrial Electronic Engineers, Inc.

Infodetics, Inc.

International Telephone & Telegraph, Cannon Electric Division

Kinelogic Corporation

Lear Siegler, Inc., Astronics Division

Librascope Division of Singer Aerospace & Marine Systems

Litton Data Systems Division

Lockheed Electronics Company, Division of Lockheed Aircraft Company

Magnavox Electronics Systems Company, West Coast Division

MagneTek Defense Systems Corporation

McDonnell Douglas Corporation

Naval Ship Missile Systems Engineering, Systems Effectiveness Division

Ocean Technology, Inc.

Odetics, Inc., Spaceborne, Kode and Omutec Divisions

Odetics, Inc., Advanced Intelligent Machines Division

Optivus Technologies, Inc.

Perkin-Elmer Corporation, Applied Science Division

Pertec Computer Corporation

Pressure Systems, inc.

Phaostron Instrument and Electronics Company, Division of
Sterling Electronics, Inc.

Radtec, Inc./Division of Guide Scientific Company

Sargent-Fletcher Company

Sargent Industries

Science Applications, Inc.

Sierracin Corporation/Sylmar Division

Signal Design, inc.

Static Power, Inc., Division of Gates Rubber Company

Tasker Industries/Whittaker Corporation

Teledyne Control Electronic Safety Products

Teledyne Control

Teledyne Electronic Technologies

Transco Products, Inc.

US Naval Metrology Engineering Center

Vari-L Company, Inc.

Volt Technical

Xerox Electro-Optical System Corporation

EXAMPLES OF RELIABILITY ANALYSIS TABLES

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Section 1.0

RELIABILITY PARTS STRESS PREDICTION

Section 1.1

RELIABILITY MATHEMATICAL MODELLING

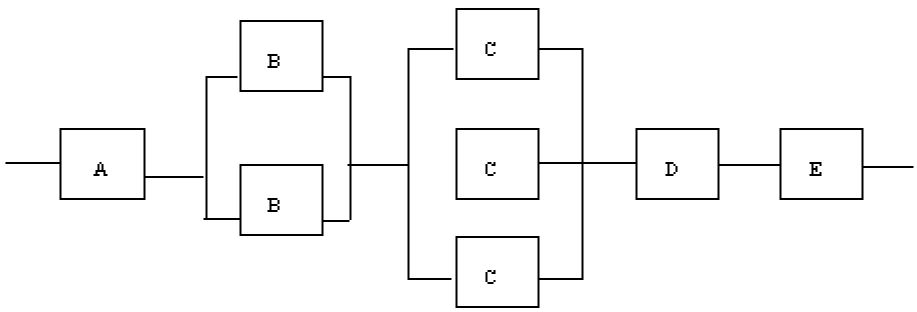
MIL-STD-785B, Task 201

MIL-STD-756B, Task 102

Reliability Logic Block Diagram

Reliability Mission Mathematical Model

Block	Assembly Name Schematic No.	Failure Rate, λ -- PPM
A	Converter/30684941	λ_A = 12.1937
B	Encoder/30684944	λ_B = 6.1375
C	Inverter A/30684942	λ_C = 15.2983
D	Inverter B/30684943	λ_D = 16.3430
E	Splitter/30684945	λ_E = 4.1355
Total	**Sam Power Supply**	**λ_{SPS} = 54.1080**



$$R_{SPS} = R_A\,(2R_B - R_B^2)\ (3R_C - 3R_C^2 + R_C^3)\ R_D\ R_E$$
$$= 6R_AR_BR_CR_DR_E - 6R_AR_BR_C^2R_DR_E + 2R_AR_BR_C^3R_DR_E$$
$$- 3R_AR_B^2R_CR_DR_E + 3R_AR_B^2R_C^2R_DR_E - R_AR_B^2R_C^3R_DR_E$$
$$R_{SPS}\,(t) = 6e^{-\lambda_{SPS}t} - 6e^{-(\lambda_C+\lambda_{SPS})t} + 2e^{-(2\lambda_C+\lambda_{SPS})t}$$
$$- 3e^{-(\lambda_B+\lambda_{SPS})t} + 3e^{-(\lambda_B+\lambda_C+\lambda_{SPS})t} - e^{-(\lambda_B+2\lambda_C+\lambda_{SPS})t}$$
$$MTBF_{SPS} = \int_0^\infty R_{SPS}\,(t)\,dt = \frac{6}{\lambda_{SPS}} - \frac{6}{\lambda_C+\lambda_{SPS}} + \frac{2}{2\lambda_C+\lambda_{SPS}}$$
$$- \frac{3}{\lambda_B+\lambda_{SPS}} + \frac{3}{\lambda_B+\lambda_C+\lambda_{SPS}} - \frac{1}{\lambda_B+2\lambda_C+\lambda_{SPS}}$$
$$MTBF_{SPS} = 27{,}020\ \text{Hours}$$

Figure 1, Reliability Logic Block Diagram and Mean Time Between Failure (MTBF) Mathematical Model for Redundancy Equation

Section 1.2

RELIABILITY STRESS AND FAILURE RATE DATA

MIL-STD-785B, Task 203

MIL-HDBK-217F, Section 5.1

MIL-STD-756B, Type III, Method 2005, Task 202

System: SAM Power Supply

Assembly: Converter

Schematic No.: 30684941

Part Ambient Temperature,

Worst Case: 55 Degrees Celsius

Environment: Space, Flight (SF)

RELIABILITY STRESS AND FAILURE RATE DATA

System: SAM Power Supply   Assembly: Converter   Schematic No.: 30684941

Part Ambient Temperature, Worst Case: 55.00 Degrees Celsius   Environment: SF   Prepared By: J. Smith

Ref. Desig.	Description/ Part Number	Type/ Value	Specification	Stress		Stress Ratio	Pi E	Pi Q	Pi	Pi	Pi	Failure Rate in Parts Per Million Hours	
				Rated	Applied							Base	Total
U1	Intgrtd Ckt. 54LS00 Quadruple 2-Input Positive-NAND Gates	LSTTL H FP	Mil-Std-883/ Class B-1	Tj 175.00 Deg. C	Tj 55.519 Deg. C	14 Pins, θjc,°C/W = 22.00	Pi E 0.5 Type=Logc,C1=0.0025,C2=0.0037	Pi Q 2.00	Pi T 0.6	Pi L 1.00		<=100 Gates 5.00 Supply Voltage 0.024 Watts Dissipated	0.00671
U2	Intgrtd Ckt. LM139AJ Linear, Voltage Comparators	LIN BIP H DIP	Mil-Std-883/ Class B-1	Tj 150.00 Deg. C	Tj 56.602 Deg. C	14 Pins, θjc,°C/W = 28.00	Pi E 0.5 Type=Logc,C1=0.0100,C2=0.0048	Pi Q 2.00	Pi T 1.1	Pi L 1.00		<=100 Trans. 12.00 Supply Voltage 0.057 Watts Dissipated	0.02748
CR1	Diode 1N4148-1 Switching	General Purpose	Mil-S-19500/ 116 JANTX	Tj 175.00 Deg. C	Tj 55.240 Deg. C	Pd, W = 0.002 θjc,°C/W = 120.00	Pi E 0.5	Pi Q 1.00	Pi T 2.6	Pi S 0.108	Pi C 1.00	0.00100 40.00 Applied Volts 100.00 Rated Volts	0.00014
VR1	Diode 1N4474 Voltage Regulator and Voltage Reference (Aval./Zener)	Zener/ Avalnch	Mil-S-19500/ 406 JANTX	Tj 175.00 Deg. C	Tj 58.000 Deg. C	Pd, W = 0.024 θjc,°C/W = 125.00	Pi E 0.5	Pi Q 1.00	Pi T 1.9	Pi S 1.000	Pi C 1.00	0.00200	0.00190
Q1	Transistor 2N2222A NPN and PNP Linear Amplification	NPN/PNP	Mil-S-19500/ 225 JANTX	Tj 150.00 Deg. C	Tj 55.210 Deg. C	Pd, W = 0.003 θjc,°C/W = 70.00	Pi E 0.5	Pi Q 1.00 Pi Sub R = 0.77 Pr= 0.50Watts	Pi T 1.9	Pi A 1.50	Pi S 0.21	0.00074 25.00 Applied Volts 50.00 Rated Volts	0.00017
Q2	Transistor 2N2907A NPN and PNP Switching	NPN/PNP	Mil-S-19500/ 291 JANTX	Tj 150.00 Deg. C	Tj 56.411 Deg. C	Pd, W = 0.014 θjc,°C/W = 98.00	Pi E 0.5	Pi Q 1.00 Pi Sub R = 0.71 Pr= 0.40Watts	Pi T 2.0	Pi A 0.70	Pi S 0.30	0.00074 37.00 Applied Volts 60.00 Rated Volts	0.00011
R1	Resistor RCR07G102JS	1.00K Ohms	Mil-R-39008, S Insltd Fxd Comp	0.250 Watts	0.001 Watts	< 0.1	Pi E 0.5	Pi Q 0.03	Pi R 1.00			0.00053	0.00001
R2	Resistor RWR74S1210FP	121.00 Ohms	Mil-R-39007, P Power Fixed WW	5.000 Watts	0.065 Watts	< 0.1	Pi E 0.3	Pi Q 0.30	Pi R 1.00			0.00632	0.00057
R3	Resistor RJR24FW501P	500.00 Ohms	Mil-R-39035, P Trimmer NonWW	0.500 Watts	0.004 Watts	< 0.1	Pi E 0.5	Pi Q 0.20	Pi R 1.00	Pi V 1.00	Taps 1.00	0.02548 3 Tap Connect'ns on Pots	0.00255
R4	Resistor M83401/01	50.00 Ohms	Mil-R-83401,Mil Netwrk Fxd Film	1.750 Watts	0.800 Watts	0.5	Pi E 0.5	Pi Q 1.00		Pi T 8.37	N R 8	0.00006 8 Film Resistors in use	0.00201
C1	Capacitor CKR06BX104KP	100.00 nF	Mil-C-39014, P Ceramc,Gen.Pur.	100.0 Volts	25.00 Volts	0.3	Pi E 0.4	Pi Q 0.30	Pi CV 1.45			0.00118	0.00021
C2	Capacitor CMR06F471JPDP	470.00 pF	Mil-C-39001, P Mica, Dipped	500.0 Volts	24.00 Volts	< 0.1	Pi E 0.5	Pi Q 0.30	Pi CV 1.06			0.00046	0.00007
C3	Capacitor CLR73BH330KGP	33.00 uF	Mil-C-39006, P Tntlm Elctrlytc	30.0 Volts	12.00 Volts	0.4	Pi E 0.5	Pi Q 0.30	Pi CV 1.03	Pi C 2.00		0.00521 Slug,Hermetic Construct'n	0.00161
C4	Capacitor CSR13F476KP	47.00 uF	Mil-C-39003, P Tntlm Elctrlytc	35.0 Volts	12.00 Volts	0.3	Pi E 0.4	Pi Q 0.30	Pi CV 1.59	Pi SR 0.07		0.00964 Cir. Res. = 1.0 Ohms/Volt	0.00012
T1	Transformer TF4R03GA203	Power	Mil-T-27 ,Mil Audio,Pwr,HiPwr Power Transformers and Filters	130.00 Deg. C	75.00 Deg. C		Pi E 0.5	Pi Q 8.00				0.00354	0.01416

0.05782

RELIABILITY STRESS AND FAILURE RATE DATA

System: SAM Power Supply Assembly: Converter Schematic No.: 30684941

Part Ambient Temperature, Worst Case: 55.00 Degrees Celsius Environment: SF Prepared By: J. Smith

Ref. Desig.	Description/ Part Number	Type/ Value	Specification	Stress		Stress Ratio	Pi E	Pi Q	Pi	Pi	Pi	Failure Rate in Parts Per Million Hours	
				Rated	Applied							Base	Total
L1	Coil CL3500GA203	Variabl	Mil-C-15305,Mil Fxd and Var, RF Variable Construction	125.00 Deg. C	75.00 Deg. C		Pi E 0.5	Pi Q 4.00	Pi C 2.00			0.00063	0.00251
K1	Relay, SPST RL 53441	Resistv Load	Mil-R-39016, R General Purpose Balanced Armature	1.000 Amps.	0.100 Amps.	0.1	Pi E 0.5	Pi Q 0.10 Pi Sub L = 1.02	Pi C 1.00	Pi F 5.0	PiCyc 10.0	0.00683 0-5 Amp. Contact Rating 125°C. Rated, 1 Cycls/Hr.	0.01735
J1	Connector G06 Series	0.40A/ Contact 20 Ga.	Mil-C-24308,Mil Rack and Panel 22 Actv Cntcts				Pi E 0.5		Pi P 4.31	Pi K 2.00		0.00105 1.00 Mating Cycls/1K Hrs B Insert Material	0.00454
J2	PCB Connector TP 32PSTR	0.40A/ Contact 20 Ga.	Mil-C-55302,Mil PCB Two-Piece 32 Active Pins				Pi E 0.5		Pi P 5.94	Pi K 2.00		0.00053 1.00 Mating Cycls/1K Hrs	0.00314
J3	IC Socket ICS 16PSTR		Mil-S-83734,Mil Plug-in Socket 16 Actv Cntcts				Pi E 0.5		Pi P 3.42			0.00042	0.00072
P1	Intercon Assy 3068491 PWB	1 Ckt. Planes	,Mil Printed Wiring				Pi E 0.5	Pi Q 1.00	Pi C 1.00			0.000041 N1= 40 Wave solder PTHs. N2= 6 Hand solder PTHs.	0.00254
	Connections	Manual Tools	Standard ,Mil Solderless wrap				Pi E 0.5	Pi Q 1.00				0.0000035 N = 10 Connections	0.00002

0.03082

Section 2.0

MAINTAINABILITY PREDICTION

Mean Time To Repair (MTTR)

MIL-HDBK-472, Procedure IIA

MIL-STD-470A, Task 203

Table 1, Maintainability Analysis Worksheet

Environment: SF

SAM Power Supply Assemblies

Assembly Name Schematic No.	Failure Rate: Lambda--PPM	Average Corrective Maintenance Task Times --Minutes							Repair Time:Rp --Mins.	Lambda x Rp
		Locali-zation	Isola-tion	Dissas-sembly	Inter-change	Reas-sembly	Align-ment	Check-out		
Converter 30684941	0.1937	4.00	4.00	3.00	3.00	3.00	4.00	4.00	25.00	4.8425
Inverter A 30684942	0.2983	4.00	4.00	2.50	2.00	2.50	4.00	4.00	23.00	6.8609
Inverter B 30684943	0.3430	4.00	4.00	2.00	2.00	2.00	4.00	4.00	22.00	7.5460
Encoder 30684944	0.1375	4.00	4.00	4.00	4.00	4.00	4.00	4.00	28.00	3.8500
Splitter 30684945	0.1355	4.00	4.00	3.00	3.00	3.00	4.00	4.00	25.00	3.3875
Page Totals:	1.1080								123.00	26.4869
Grand Totals:	1.1080								123.00	26.4869

Total Failure Rate, $\lambda = 1.1080 / 10^6$ Hours

For normal distribution of R:

$$\text{MTTR} = \left[\frac{\sum_{i=1}^{n} \lambda_i R_i}{\sum_{i=1}^{n} \lambda_i} \right] = \frac{26.4869}{1.1080}$$

$$= 23.9051 \text{ Minutes } = 0.3984 \text{ Hours}$$

For $R = M_{ct}$, M_{maxct} at 95% Confidence Level is

$$M_{maxct} = \mu + 1.645\sigma = 28.3871 \text{ Minutes} = 0.4731 \text{ Hours}$$

Where,

$$\sigma = \left[\frac{\sum_{i=1}^{n} (\mu - R_i)^2}{n-1} \right]^{0.5} = 2.3022 \text{ Minutes}$$

$$\mu = \frac{\sum_{i=1}^{n} R_i}{n} = 24.6000 \text{ Minutes}$$

$$n = \text{ Quantity of repairables, } 5 \text{ LRUs}$$

Figure 1, MTTR and M_{maxct} Calculation for Normal Distribution

Table 1, Maintainability Analysis Worksheet

Environment: SF

SAM Power Supply Assemblies

Assembly Name Schematic No.	Failure Rate: Lambda--PPM	Average Corrective Maintenance Task Times --Minutes							Repair Time:Rp --Mins.	Lambda x Log Rp
		Locali-zation	Isola-tion	Dissas-sembly	Inter-change	Reas-sembly	Align-ment	Check-out		
Converter 30684941	0.1937	4.00	4.00	3.00	3.00	3.00	4.00	4.00	25.00	0.6235
Inverter A 30684942	0.2983	4.00	4.00	2.50	2.00	2.50	4.00	4.00	23.00	0.9353
Inverter B 30684943	0.3430	4.00	4.00	2.00	2.00	2.00	4.00	4.00	22.00	1.0602
Encoder 30684944	0.1375	4.00	4.00	4.00	4.00	4.00	4.00	4.00	28.00	0.4582
Splitter 30684945	0.1355	4.00	4.00	3.00	3.00	3.00	4.00	4.00	25.00	0.4362
Page Totals:	1.1080								123.00	3.5134
Grand Totals:	1.1080								123.00	3.5134

Total Failure Rate, $\lambda = 1.1080/10^6$ Hours

For log-normal distribution of R:

$$\text{MTTR} = \text{Antilog}\left[\frac{\sum_{i=1}^{n} \lambda_i \text{ Log } R_i}{\sum_{i=1}^{n} \lambda_i}\right] = \text{Antilog}\left[\frac{3.5134}{1.1080}\right]$$

$$= 23.8294 \text{ Minutes} = 0.3972 \text{ Hours}$$

For $R = M_{ct}$, M_{maxct} at 95% Confidence Level is

$$M_{maxct} = \text{Antilog}\left[\mu + 1.645\sigma\right] = 28.5441 \text{ Minutes} = 0.4757 \text{ Hours}$$

Where,

$$\sigma = \left[\frac{\sum_{i=1}^{n} (\mu - \text{Log } M_{ct_i})^2}{n-1}\right]^{0.5} = \text{Log } 0.0925 \text{ Minutes}$$

$$\mu = \frac{\sum_{i=1}^{n} \text{Log } M_{ct_i}}{n} = \text{Log } 3.1993 \text{ Minutes}$$

$$n = \text{Quantity of repairables, } 5 \text{ LRUs}$$

Figure 2, MTTR and M_{maxct} Calculation for Log-Normal Distribution

Section 3.0

DERATING ELECTRICAL STRESS ANALYSIS

MIL-STD-785B, Task 207

MIL-STD-975G

RELIABILITY STRESS DERATING ANALYSIS

System: SAM Power Supply Assembly: Converter Schematic No.: 30684941

Part Ambient Temperature, Worst Case: 55.00 Degrees Celsius Environment: SF Prepared By: J. Smith

Ref. Desig.	Description/ Part Number	Type/ Value	Specification	Electrical and Thermal Stress: Maximum Rated	Derating Factor	Derated	Actual	Stress Ratio: Actual / Derated	Remarks
U1	Intgrtd Ckt. 54LS00	LSTTL H FP	Mil-Std-883/ Class B-1						Quadruple 2-Input Positive-NAND Gates.
	Parameter:								
	Supply Voltage			5.50	1.00	5.50	5.00	0.9	
	Power Dissipation (Watts)			0.031	1.00	0.031	0.024	0.8	
	Input Voltage			5.50	1.00	5.50	5.00	0.9	
	Junction Temperature (°C.)			175.00	0.57	100.00	55.52	0.6	Tc = 55 °C.; Θjc = 22 °C./Watt.
	Output Current (Amperes):								
	Pin 1			0.004	0.80	0.003	0.001	0.3	
	Pin 2			0.004	0.80	0.003	0.001	0.3	
	Pin 3			0.004	0.80	0.003	0.001	0.3	
	Pin 4			0.004	0.80	0.003	0.001	0.3	
U2	Intgrtd Ckt. LM139AJ	LIN BIP H DIP	Mil-Std-883/ Class B-1						Linear, Voltage Comparators.
	Parameter:								
	Supply Voltage			30.00	0.90	27.00	12.00	0.4	
	Power Dissipation (Watts)			0.800	0.75	0.600	0.057	< 0.1	
	Input Voltage			36.00	1.00	36.00	12.00	0.3	
	Junction Temperature (°C.)			150.00	0.67	100.00	56.60	0.6	Tc = 55 °C.; Θjc = 28 °C./Watt.
	Output Current (Amperes):								
	Pin 1			0.010	0.80	0.008	0.006	0.8	
	Pin 2			0.010	0.80	0.008	0.006	0.8	
	Pin 3			0.010	0.80	0.008	0.006	0.8	
	Pin 4			0.010	0.80	0.008	0.001	0.1	
CR1	Diode 1N4148-1	General Purpose	Mil-S-19500/ 116 JANTX						
	Parameter:								
	Junction Temperature (°C.)			175.000	0.71	125.000	55.240	0.4	Tc = 55 °C.; Θjc = 120 °C./Watt.
	PIV			100.000	0.70	70.000	40.000	0.6	Power Dissipation = .002 Watts.
	Surge Current (Amperes)			0.399	0.50	0.200	0.150	0.8	
	Forward Current (Amperes)			0.160	0.50	0.080	0.002	< 0.1	
VR1	Diode 1N4461	Zener/ Avalnch	Mil-S-19500/ 406 JANTX						Iz Derated (Amps.) = Iz Nom. + 0.5(Iz Max. - Iz Nom.) Iz Nom. = 0.1668, Iz Max. = 0.5243
	Parameter:								
	Junction Temperature (°C.)			175.000	0.71	125.000	55.850	0.4	Tc = 55 °C.; Θjc = 125 °C./Watt.
	Power (Watts)			1.192	0.50	0.596	0.007	< 0.1	
	Zener Current (Amperes)			0.524	0.66	0.346	0.001	< 0.1	
Q1	Transistor 2N2222A	NPN/PNP	Mil-S-19500/ 225 JANTX						
	Parameter:								
	Junction Temperature (°C.)			150.000	0.83	125.000	55.210	0.4	Tc = 55 °C.; Θjc = 70 °C./Watt.
	Power (Watts)			0.379	0.50	0.190	0.003	< 0.1	
	Voltage			50.000	0.75	37.500	25.000	0.7	
	Current (Amperes)			0.607	0.75	0.455	0.003	< 0.1	
Q2	Transistor 2N2907A	NPN/PNP	Mil-S-19500/ 291 JANTX						
	Parameter:								
	Junction Temperature (°C.)			150.000	0.83	125.000	56.411	0.5	Tc = 55 °C.; Θjc = 98 °C./Watt.
	Power (Watts)			0.299	0.50	0.150	0.014	< 0.1	

RELIABILITY STRESS DERATING ANALYSIS

System: SAM Power Supply   Assembly: Converter   Schematic No.: 30684941

Part Ambient Temperature, Worst Case: 55.00 Degrees Celsius   Environment: SF   Prepared By: J. Smith

Ref. Desig.	Description/ Part Number	Type/ Value	Specification	Electrical and Thermal Stress				Stress Ratio	Remarks
				Maximum Rated	Derating Factor	Derated	Actual	Actual / Derated	
	Voltage Current (Amperes)			60.000 0.449	0.75 0.75	45.000 0.337	37.000 0.009	0.8 < 0.1	
R1	Resistor RCR07G102JS	1.00K Ohms	Mil-R-39008, S Insltd Fxd Comp						
	Parameter: Maximum Operating Temp. (°C.) Power (Watts) Voltage			130.000 0.250 15.811	1.00 0.60 0.80	130.000 0.150 12.649	55.000 0.001 1.000	0.4 < 0.1 < 0.1	
R2	Resistor RWR74S1210FP	121.00 Ohms	Mil-R-39007, P Power Fixed WW						
	Parameter: Maximum Operating Temp. (°C.) Power (Watts) Voltage			275.000 5.000 23.074	1.00 0.50 0.80	275.000 2.486 18.459	55.000 0.065 2.804	0.2 < 0.1 0.2	
R3	Resistor RJR24FW501P	500.00 Ohms	Mil-R-39035, P Trimmer NonWW						
	Parameter: Maximum Operating Temp. (°C.) Power (Watts) Voltage			150.000 0.500 2.230	1.00 0.60 0.80	150.000 0.300 1.784	55.000 0.004 1.414	0.4 < 0.1 0.8	
R4	Resistor M83401/01	50.00 Ohms	Mil-R-83401,Mil Netwrk Fxd Film						
	Parameter: Maximum Operating Temp. (°C.) Power (Watts) Voltage			125.000 1.750 9.354	1.00 0.60 0.80	125.000 1.050 7.483	55.000 0.800 6.325	0.4 0.8 0.8	
C1	Capacitor CKR06BX104KP	100.00 nF	Mil-C-39014, P Ceramc,Gen.Pur.						
	Parameter: Maximum Operating Temp. (°C.) Voltage			85.000 100.00	1.00 0.60	85.000 60.00	55.000 25.00	0.6 0.4	
C2	Capacitor CMR06F471JPDP	470.00 pF	Mil-C-39001, P Mica, Dipped						
	Parameter: Maximum Operating Temp. (°C.) Voltage			125.000 500.00	1.00 0.50	125.000 250.00	55.000 24.00	0.4 < 0.1	
C3	Capacitor CLR73BH330KGP	33.00 uF	Mil-C-39006, P Tntlm Elctrlytc						Slug,Hermetic Construction.
	Parameter: Maximum Operating Temp. (°C.) Voltage			125.000 30.00	0.88 0.60	110.000 18.00	55.000 12.00	0.5 0.7	
C4	Capacitor CSR13F476KP	47.00 uF	Mil-C-39003, P Tntlm Elctrlytc						
	Parameter:								

Section 4.0

FAILURE MODE, EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION (FMECA-MI)

MIL-STD-785B, Task 204

MIL-STD-1629A, Tasks 101, 102 and 103

MIL-STD-470A, Task 205

Section 4.1

FAILURE MODE AND EFFECTS ANALYSIS

Task 101 of MIL-STD-1629A

FAILURE MODE AND EFFECTS ANALYSIS

System: SAM Power Supply
Indenture Level: 3
Reference Drawing: Converter, 30684941
Mission: Space, Flight (SF)

Date:
Sheet: 1
Compiled By: J. Smith
Approved By: S. L. Friedman

Ident. No.	Item/Functional Identification (Nomenclature)	Function	Failure Modes and Causes	Mission Phase/ Operational Mode	Failure Effects			Failure Detection Method	Compensating Provisions	Severity Class	Remarks
					Local Effects	Next Higher Level	End Effects				
Q1-1	Transistor 2N2907A Low Frequency Bipolar (NPN/PNP)	Switch Transistor Driver	Open	Power On	5V Regulator Inoperative	Loss of 5 Volts	Converter Inoperative	No 1553 Response	Redundant Circuits	III	
Q1-2			Short	Power On	5V Regulator Full On	26 V on 5V Line. Parts Damaged	Open Primary Circuit Breaker	No 1553 Response	Redundant Circuits	IV	
CR1-1	Diode 1N4148-1 General Purpose	Overvoltage Protection	Open	Power On	Loss of Overvoltage Protection	Possible Damage to U19	Possible Converter Malfunction	Periodic Test	Redundant Circuits	IV	
CR1-2			Short	Power On	5V Applied to U19 Analog Channel 7	U19 Analog Channel 7 Inoperative	Converter Inoperative	Periodic Test	Redundant Circuits	III	
R1-1	Resistor RCR07G102JS Insulated Fixed Composition, ER	Current Limit	Open	Power On	Q1,Q2,Q3,U2 Inoperative	Current Test Inoperative	Converter Malfunctions	Periodic Test	Redundant Circuits	III	
R1-2			Short	Power On	Possible damage to Q2	Current Test Inoperative	Converter Malfunctions	Periodic Test	Redundant Circuits	III	
C1-1	Capacitor CKR06BX104KP General Purpose Ceramic, ER	Feedback Capacitor	Open	Power On	Malfunction of Active Low Power Filter	Degraded Filtering for U19, Analog Channel 7	Possible Converter Malfunction	Periodic Test	Redundant Circuits	III	
C1-2			Short	Power On	Active Low Power Filter Inoperative	Loss of Signal to U19, Analog Channel 7	Converter Inoperative	Periodic Test	Redundant Circuits	IV	

Section 4.2

CRITICALITY ANALYSIS

Task 102 of MIL-STD-1629A

CRITICALITY ANALYSIS

System: SAM Power Supply
Indenture Level: 3
Reference Drawing: Converter, 30684941
Mission: Space, Flight (SF)

Date:
Sheet: 1
Compiled By: J. Smith
Approved By: S. L. Friedman

Ident. No.	Item/Functional Identification (Nomenclature)	Function	Failure Modes and Causes	Mission Phase/ Operational Mode	Severity Class	Failure Probability: Failure Rate Data Source	Failure Effect Probability (ß)	Failure Mode Ratio (α)	Failure Rate (λp) --PPMH	Operating Time (t) --Hours	Failure Mode Crit # Cm=ßαλpt	Item Crit # Cr=Σ(Cm)	Remarks
Q1-1	Transistor 2N2907A Low Frequency Bipolar (NPN/PNP)	Switch Transistor Driver	Open	Power On	III	MIL-HDBK-217F, N1	0.50	0.40	1.10E-10	1.00E-01	2.20E-12	2.20E-12	
Q1-2			Short	Power On	IV	MIL-HDBK-217F, N1	0.10	0.60	1.10E-10	1.00E-01	6.60E-13	6.60E-13	
CR1-1	Diode 1N4148-1 General Purpose	Overvoltage Protection	Open	Power On	IV	MIL-HDBK-217F, N1	0.10	0.40	1.40E-10	1.00E-01	5.60E-13	1.22E-12	
CR1-2			Short	Power On	III	MIL-HDBK-217F, N1	0.50	0.60	1.40E-10	1.00E-01	4.20E-12	6.40E-12	
R1-1	Resistor RCR07G102JS Insulated Fixed Composition, ER	Current Limit	Open	Power On	III	MIL-HDBK-217F, N1	0.50	0.85	1.00E-11	1.00E-01	4.25E-13	6.83E-12	
R1-2			Short	Power On	III	MIL-HDBK-217F, N1	0.50	0.15	1.00E-11	1.00E-01	7.50E-14	6.90E-12	
C1-1	Capacitor CKR06BX104KP General Purpose Ceramic, ER	Feedback Capacitor	Open	Power On	III	MIL-HDBK-217F, N1	0.50	0.85	2.10E-10	1.00E-01	8.93E-12	1.58E-11	
C1-2			Short	Power On	IV	MIL-HDBK-217F, N1	0.10	0.15	2.10E-10	1.00E-01	3.15E-13	1.53E-12	

Section 4.3

MAINTAINABILITY INFORMATION

Task 103 of MIL-STD-1629A

FAILURE MODE EFFECTS AND CRITICALITY ANALYSIS - MAINTAINABILITY INFORMATION

System/Subsystem Nomenclature: SAM Power Supply

Indenture Level: 3 Reference Drawing: Converter, 30684941

System/Subsystem Description: Converter

System Identification No.: 100-113

Mission: Space, Flight (SF)

Compensating Provisions: Redundant Convert

Date:
Sheet: 1
Prepared By: J. Smith
Approved By: S. L. Friedman

Ident. No.	Item/Functional Identification (Nomenclature)	Function	Functional Failure	Engineering Failure Mode	Mission Phase	Failure Effects			Failure Detection Method	Severity Class	Minimum Equipment List	Failure Mode MTBF and Remarks
		No.	Ltr	No.		Local Effects	Next Higher Level	End Effects				
Q1-1	Transistor 2N2907A Low Frequency Bipolar (NPN/PNP)	Switch Transistor Driver	Open	Open	Power On	5V Regulator Inoperative	Loss of 5 Volts	Converter Inoperative	No 1553 Response	III	No	MTBF~Hrs.: 9.091E+15
Q1-2			Short	Short	Power On	5V Regulator Full On	26 V on 5V Line. Parts Damaged	Open Primary Circuit Breaker	No 1553 Response	IV	No	MTBF~Hrs.: 9.091E+15
CR1-1	Diode 1N4148-1 General Purpose	Overvoltage Protection	Open	Open	Power On	Loss of Overvoltage Protection	Possible Damage to U19	Possible Converter Malfunction	Periodic Test	IV	No	MTBF~Hrs.: 7.143E+15
CR1-2			Short	Short	Power On	5V Applied to U19 Analog Channel 7	U19 Analog Channel 7 Inoperative	Converter Inoperative	Periodic Test	III	No	MTBF~Hrs.: 7.143E+15
R1-1	Resistor RCR07G102JS Insulated Fixed Composition, ER	Current Limit	Open	Open	Power On	Q1,Q2,Q3,U2 Inoperative	Current Test Inoperative	Converter Malfunctions	Periodic Test	III	No	MTBF~Hrs.: 1.000E+17
R1-2			Short	Short	Power On	Possible damage to Q2	Current Test Inoperative	Converter Malfunctions	Periodic Test	III	No	MTBF~Hrs.: 1.000E+17
C1-1	Capacitor CKR06BX104KP General Purpose Ceramic, ER	Feedback Capacitor	Open	Open	Power On	Malfunction of Active Low Power Filter	Degraded Filtering for U19, Analog Channel 7	Possible Converter Malfunction	Periodic Test	III	No	MTBF~Hrs.: 4.762E+15
C1-2			Short	Short	Power On	Active Low Power Filter Inoperative	Loss of Signal to U19, Analog Channel 7	Converter Inoperative	Periodic Test	IV	No	MTBF~Hrs.: 4.762E+15

Section 5.0

SAFETY HAZARD ANALYSIS

MIL-STD-882B, Tasks 203 and 204

SUBSYSTEM HAZARD ANALYSIS

System: SAM Power Supply
Indenture Level: 3
Reference Drawing: Converter, 30684941
Mission: Space, Flight (SF)

Date:
Sheet: 1
Compiled By: J. Smith
Approved By: S. L. Friedman

Ident. No.	Item/Functional Identification (Nomenclature)	Function	Part Failure Modes and Causes	Part Mode Failure Rate (λp)	System Event Phase	Primary Part Failure Mode			Hazard Risk Index (HRI)	Recommended Action	
						Local Effects	Next Higher Level	End Effects		Failure Detection Method	Compensating Provisions
Q1-1	Transistor 2N2907A Low Frequency Bipolar (NPN/PNP)	Switch Transistor Driver	Open	1.10E-10	All Operational Modes	5V Regulator Inoperative	Loss of 5 Volts	Converter Inoperative	III E	No 1553 Response	Redundant Circuits
Q1-2			Short	1.10E-10	All Operational Modes	5V Regulator Full On	26V on 5V Line. Parts Damaged	Open Primary Circuit Breaker	IV E	No 1553 Response	Redundant Circuits
CR1-1	Diode 1N4148-1 General Purpose	Overvoltage Protection	Open	1.40E-10	All Operational Modes	Loss of Overvoltage Protection to U19 Analog Channel 7	Possible Damage to U19 Analog Channel 7	Possible Converter Malfunction	III E	Periodic Test	Redundant Circuits
CR1-2			Short	1.40E-10	All Operational Modes	5V Applied U19 Analog Channel 7	U19 Analog Channel 7 Inoperative	Converter Inoperative	III E	Periodic Test	Redundant Circuits
R1-1	Resistor RLR07C1501FR Insulated Fixed Film	Current Limit	Open	3.97E-09	All Operational Modes	Q1,Q2,Q3,U2 Inoperative	Current Test Inoperative	Converter Malfunction	III E	Periodic Test	Redundant Circuits
			Short	3.97E-09	All Operational	Possible Damage to Q2	Current Test Inoperative	Converter Malfunction	III E	Periodic Test	Redundant Circuits
C1-1	Capacitor CKR06BX104KP General Purpose Ceramic, ER	Feedback Capacitor	Open	6.89E-09	All Operational Modes	Malfunction of Active Low Power Filter	Degraded Filtering for U19, Analog Channel 7	Possible Converter Malfunction	III E	Periodic Test	Redundant Circuits
C1-2			Open	6.89E-09	All Operational Modes	Active Low Power Filter Inoperative	Loss of Signal to U19 Analog Ch. 7	Converter Inoperative	IV E	Periodic Test	Redundant Circuits
L1-1	Filter Mil-T-27/356-39 Inductor	Input Filter Inductor	Open	2.51E-09	All Operational Modes	Loss of 26V Power	Regulator Inoperative	Converter Inoperative	III E	No 1553 Response	Redundant Circuits
L1-2			Short	2.51E-09	All Operational Modes	Degraded 2V Filtering	Possible EMI on 26V Line	Possible Converter Malfunction	III E	Periodic Test	Redundant Circuits

Section 6.0

WORST CASE ELECTRONIC PARTS/CIRCUITS TOLERANCE ANALYSIS

MIL-STD-785B, Task 206

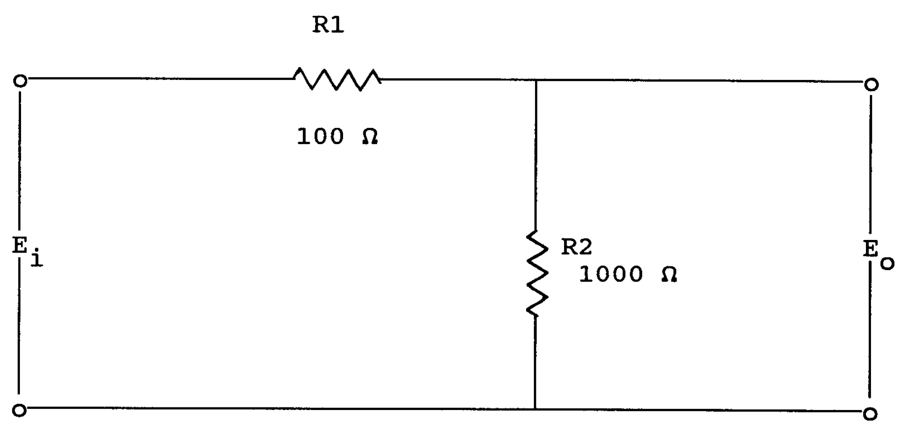


Figure 1, Voltage Divider Circuit

Note: This simple circuit is used to illustrate the procedure.

WORST CASE CIRCUIT TOLERANCE ANALYSIS

System: SAM Power Supply Assembly: Converter Schematic No.: 30684941

Circuit: Voltage Divider

Part Ambient Temperature, Worst Case: 55.00 Degrees Celsius Prepared By: J. Smith

Ref. Desig.	Description/ Part Number	Type/ Value	Specification	Part Nominal Value, X	Nominal Circuit Function Value, f	Initial Tolerance, ΔT_I (%)	Temp. Tolerance, ΔT_T (%)	End of Life Tolerance, ΔT_{EOL} (%)	Part Variance, σ_X^2	Partial Derivative Squared, $(\delta f/\delta X)^2$	$(\delta f/\delta X)^2 \cdot (\sigma_X^2)$
Ei	Input Voltage	DC Volts	Mil-Std-704	10.00000 Volts	9.090909 Volts	2.000000	0.200000	2.000000	0.019600	0.826532	0.016200
R1	Resistor RLR07C1000FR	100.00 Ohms	Mil-R-39017, R Insltd Fxd Film	100.0000 Ohms	9.090909 Volts	2.000000	0.550000	2.000000	2.300278	0.000068	0.000157
R2	Resistor RLR07C1001FR	1.00K Ohms	Mil-R-39017, R Insltd Fxd Film	1000.000 Ohms	9.090909 Volts	2.000000	0.550000	2.000000	230.0278	6.8E-07	0.000157
											0.01651

WORST CASE CIRCUIT TOLERANCE ANALYSIS SUMMARY

System: SAM Power Supply

Assembly: Converter

Schematic No.: 30684941

Circuit: Voltage Divider

Part Ambient Temperature, Worst Case: 55.00 Degrees Celsius

Prepared By: J. Smith

$$V_O = f(E_i, R_1, R_2)$$

$$V_0 = E_i \cdot R_2 / (R_1 + R_2)$$

$$V_O = 9.090909 \ Volts$$

$$\sigma_{V_O}^2 = (\delta V_O / \delta E_i)^2 \cdot \sigma_{E_i}^2 + (\delta V_O / \delta R_1)^2 \cdot \sigma_{R_1}^2 + (\delta V_O / \delta R_2)^2 \cdot \sigma_{R_2}^2$$

$$\sigma_{V_O}^2 = 0.016200 + 0.00015 + 0.000157$$

$$\sigma_{V_O}^2 = 0.0165143$$

$$\sigma_{V_O} = 3\sqrt{0.016514} = \pm \ 0.385522$$

$$\mu \pm 3\sigma_{V_O} = 9.090909 \ Volts \ \pm \ 0.385522 \ Volts$$

$$\mu \pm 3\sigma_{V_O} = 8.705386 \ Volts \ to \ 9.476432 \ Volts$$

Section 7.0

THERMAL ANALYSIS

MIL-HDBK-251

MIL-D-18300

MIL-T-23103

THERMAL ANALYSIS DATA TABLES

System: SAM Power Supply   Assembly: Converter   Schematic No.: 30684941

Part Ambient Temperature, Worst Case: 55.000 Degrees Celsius Environment: SF   Prepared By: J. Smith

Ref. Desig.	Description/ Part Number	Type/ Value	Specification	Power Dissipation (Watts,RMS)	Thermal Resistance θjh (°C/W)	Temperature (°C.): T Max. / Tj Max.				
						Mfr. Max. Rating	Maximum Derating	Rise	Actual	Thermal Safety Margin
U1	Intgrtd Ckt. 54LS00 Quadruple 2-Input Positive-NAND Gates	LSTTL H FP	Mil-Std-883/ Class B-1	0.0167	22.600	175.000	100.000	0.377	55.377	44.623
U2	Intgrtd Ckt. LM139AJ Linear, Voltage Comparators	LINEAR H DIP	Mil-Std-883/ Class B-1	0.0404	28.600	150.000	100.000	1.157	56.157	43.843
CR1	Diode 1N4148-1	General Purpose	Mil-S-19500/ 116 JANTX	0.0014	120.600	175.000	125.000	0.171	55.171	69.829
VR1	Diode 1N4461	Zener/ Avalnch	Mil-S-19500/ 406 JANTX	0.0048	125.600	175.000	125.000	0.604	55.604	69.396
Q1	Transistor 2N2222A	NPN/PNP	Mil-S-19500/ 225 JANTX	0.0021	70.600	150.000	125.000	0.150	55.150	69.850
Q2	Transistor 2N2907A	NPN/PNP	Mil-S-19500/ 291 JANTX	0.0102	98.600	150.000	125.000	1.004	56.004	68.996
R1	Resistor RCR07G102JS	1.00K Ohms	Mil-R-39008, S Insltd Fxd Comp	0.0007	240.600	130.000	130.000	0.170	55.170	74.830
R2	Resistor RWR74S1210FP	121.00 Ohms	Mil-R-39007, P Power Fixed WW	0.0460	50.600	275.000	275.000	2.325	57.325	217.675
R3	Resistor RJR24FW501P	500.00 Ohms	Mil-R-39035, P Trimmer NonWW	0.0028	130.600	150.000	150.000	0.369	55.369	94.631
R4	Resistor M83401/01	50.00 Ohms	Mil-R-83401,Mil Netwrk Fxd Film	0.5656	32.029	125.000	125.000	18.115	73.115	51.885
C1	Capacitor CKR06BX104KP	100.00 nF	Mil-C-39014, P Ceramc,Gen.Pur.			85.000	110.000		55.000	55.000
C2	Capacitor CMR06F471JPDP	470.00 pF	Mil-C-39001, P Mica, Dipped			125.000	110.000		55.000	55.000
C3	Capacitor CLR73BH330KGP	33.00 uF	Mil-C-39006, P Tntlm Elctrlytc			125.000	110.000		55.000	55.000
C4	Capacitor CSR13F476KP	47.00 uF	Mil-C-39003, P Tntlm Elctrlytc			125.000	110.000		55.000	55.000
T1	Transformer TF4R03GA203	Power	Mil-T-27 ,Mil Audio,Pwr,HiPwr			130.000	105.000	20.000	75.000	30.000

Note: Blank entries indicate parameters which are not applicable.

Section 8.0

FAULT TREE ANALYSIS

MIL-HKBK-338

Mathematical Model

Since all the events in the fault tree of Figure 1 are independent, the event probabilities are as follows:

$$P(C) = P(D) + P(E) - [P(D)\ x\ P(E)]$$
$$P(Top) = P(A)\ x\ P(B)\ x\ P(C)$$

Where

$P(A) =$ Probability of Event A, Servo Valve Driver Failure,
$1 - e^{\lambda_A t},\ 4.29576/10^{12}$.

$\lambda_A =$ Failure rate of Servo Valve Driver, U1, Hybrid Current Driver,
$0.61368/10^{6}$ Hours.

$t =$ Risk Exposure Time, 0.025 seconds or $7/10^{6}$ hours, for all events.

$P(B) =$ Probability of Event B, Shutoff Valve Watchdog Failure,
$1 - e^{-\lambda_B t},\ 1.13323/10^{12}$.

$\lambda_B =$ Failure rate of Shutoff Valve Watchdog Circuit, U2, Errasable Programmable Logic Device (EPLD), $0.16189/10^{6}$ hours.

$t =$ $7/10^{6}$ hours.

$P(C) =$ Probability of Event C, Display Electronics Unit (DEU) fails to display ABS fault status,

$$P(D) + P(E) - [P(D)\ x\ P(E)],\ (1 - e^{-\lambda_D t}) + (1 - e^{-\lambda_E t})$$
$$- [(1 - e^{-\lambda_D t})\ x\ (1 - e^{-\lambda_E t})],\ 2.26646/10^{12}.$$

$P(D) =$ Probability of Event D, ABS Arm Watchdog Failure,
$1 - e^{-\lambda_D t},\ 1.13323/10^{12}$.

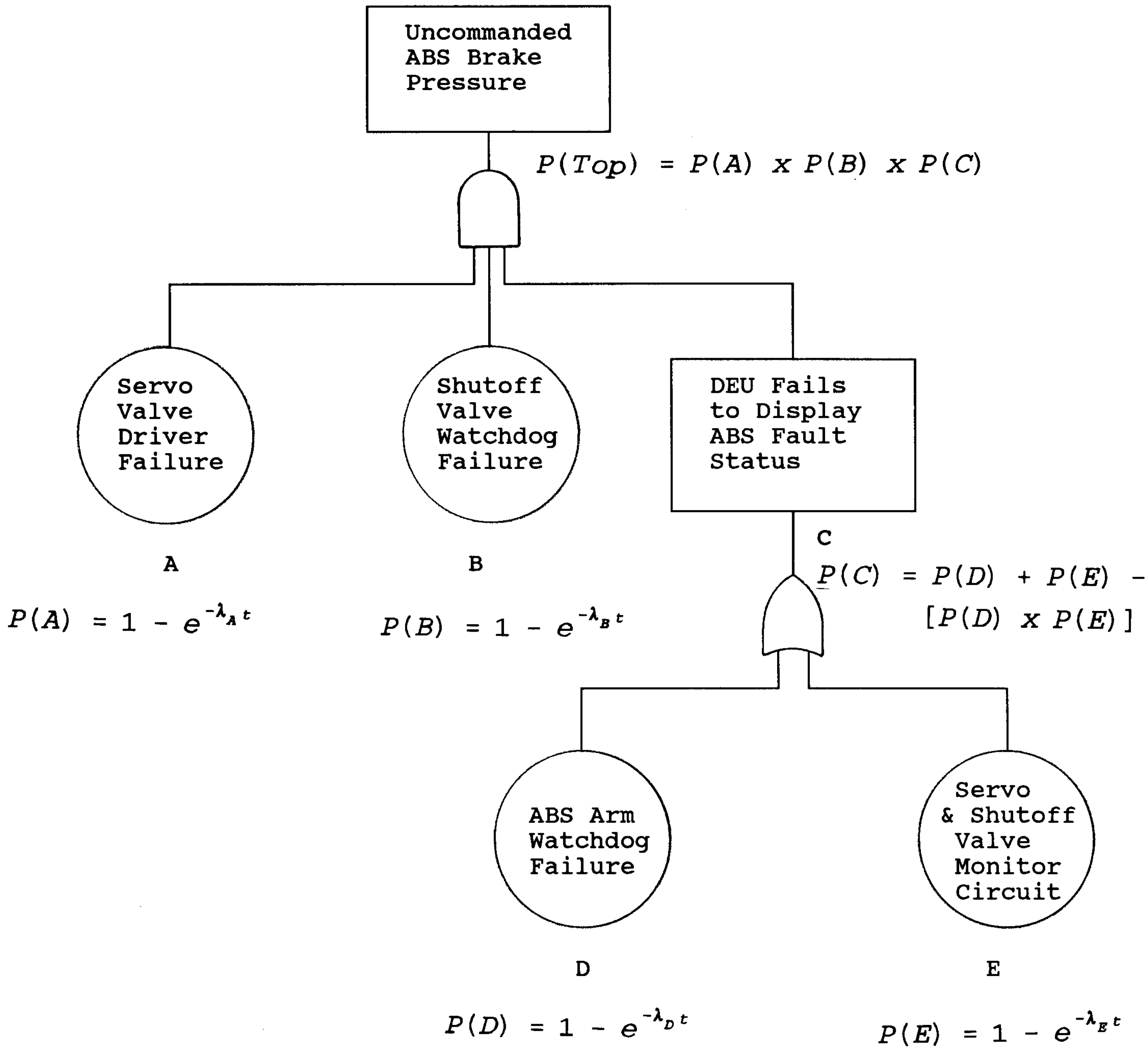


Figure 1, Automatic Brake Systems (ABS) Fault Tree Diagram

$\lambda_D =$ Failure rate of the ABS Arm Watchdog Circuit, U3, EPLD, $0.16189 / 10^6$ hours.

$t =$ $7 / 10^6$ hours.

$P(E) =$ Probability of Event E, Servo and Shutoff Valve Monitor Failure, $1 - e^{-\lambda_E t}$, $1.13323 / 10^{12}$.

$\lambda_E =$ Failure rate of the Servo and Shutoff Valve Monitor Circuit, U4, EPLD, $0.16189 / 10^6$ hours.

$t =$ $7 / 10^6$ hours.

Therefore,

$$P(Top) = P(A)\ x\ P(B)\ x\ P(C)$$

$$= (4.29576 / 10^{12})\ (1.13323 / 10^{12})\ (2.26646 / 10^{12})$$

$$= 11.033317 / 10^{36}$$ or zero.

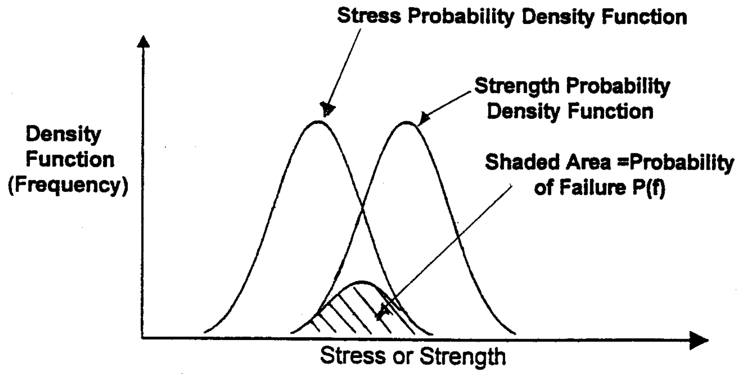
Section 9.0

MECHANICAL RELIABILITY

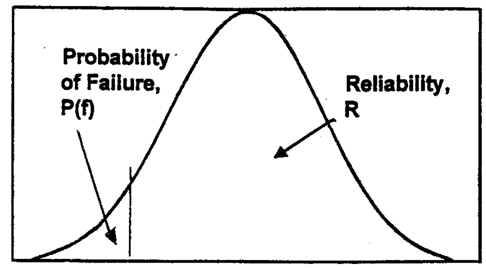
(RADC-TR-85-194)

October 1985

Stress/Strength Interference Method



Stress/Strength Interference Method



Normalized Density Function of Excess Strength Over Load

Establish a new random variable D, where the difference of strength minus stress (load) is

$D = \text{Strength (S)} - \text{Stress (L)} = S - L,\ \mu_D = \mu_S - \mu_L,\ \sigma_D = \sqrt{\sigma_S^2 + \sigma_L^2}$ and where

$\mu_D, \mu_S, \mu_L =$ Mean of the difference, strength and stress, respectively, and

$\sigma_D, \sigma_S, \sigma_L =$ Standard Deviation of the difference, strength and stress, respectively.

Then the probability of failure, P(f), is

$$P(f) = P(S - L < 0) = P(D < 0) = P\left\{\frac{D - \mu_D}{\sigma_D} < \frac{-\mu_D}{\sigma_D}\right\} = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{-\mu_D/\sigma_D} \exp(-t^2/2)\,dt$$

for the $P(f) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx$ where the standard normal random variable at

$t = \frac{x-\mu}{\sigma}$ & $-\mu_D / \sigma_D = -9.0766753347$ at $t = \frac{\mu_S - \mu_L}{\sqrt{\sigma_S^2 + \sigma_L^2}}$, the difference probability density function is normalized to a zero mean and a standard deviation of one.

The reliability prediction, 1 - P(f), for the MTA Propellant Tank, which has a ultimate strength normal distribution mean of $\mu_S = 160{,}000$ psi and a standard deviation of $\sigma_S = 17{,}660$ psi and an in-orbit stress load (MEOP) normal distribution mean of $\mu_L = 250$ psi and a standard deviation of $\sigma_L = 50$ psi, is 0.999999999.

Monopropellant Tank Reliability Mathematical Model and Prediction

Section 10.0

EXAMPLE
FAILURE RATE ANALYSIS
FOR
POPPET VALVE ASSEMBLY

Carderock Div, NSWC-92/L01,
“Handbook of Reliability Prediction Procedures
for Mechanical Equipment”, May 1992

Poppet Valve Assembly

$$\lambda_{PO} = \lambda_{PO,B} \frac{Q_a}{Q_f}$$

Where:

$\lambda_{PO} =$ Failure rate of the poppet assembly, failures/million operations

$\lambda_{PO,B} =$ Base failure rate for poppet assembly, failures/million operations

$Q_a =$ Leakage rate, in^3/min

$Q_f =$ Leakage rate considered to be valve failure, in^3/min

$$Q_a = \frac{2x10^4 \ D_{MS} \ f^3 \ (P_1^2 - P_2^2)}{V_a \ L_W \ (S_S)^{3/2}}$$

Where:

$Q_a =$ Actual fluid leakage, in^3/min

$D_{MS} =$ Mean seat diameter, in

$f =$ Mean surface finish of opposing surfaces, min

$P_1 =$ Upstream pressure, lb/in^2

$P_2 =$ Downstream pressure, lb/in_2

$V_a =$ Absolute fluid viscosity, lb-min/in^2

$L_W =$ Radial seat land width, in.

$S_S =$ Apparent seat stress, lb/in$_2$

$$\lambda_{PO} = \lambda_{PO,B} \cdot C_P \cdot C_Q \cdot C_F \cdot C_V \cdot C_N \cdot C_S \cdot C_{DT} \cdot C_{SW} \cdot C_W$$

Where:

$\lambda_{PO} =$ Failure rate of poppet assembly in failures/million operations; 1.26

$\lambda_{PO,B} =$ Base failure rate of poppet assembly, 1.40 failures/million operations

$C_P =$ Multiplying factor which considers the effect of fluid pressure on the base failure rate, 1.0

$C_Q =$ Multiplying factor which considers the effect of allowable leakage on the base failure rate, 1.0

$C_F =$ Multiplying factor which considers the effect of surface finish on the base failure rate, 1.0

$C_V =$ Multiplying factor which considers the effect of fluid fiscosity/temperature on the base failure rate, 1.0

$C_N =$ Multiplying factor which considers the effect of contaminants on the base failure rate, 1.0625

$C_S =$ Multiplying factor which considers the effect of the apparent seat stress on the base failure rate, 0.621119

$C_{DT} =$ Multiplying factor which considers the effect of the seat diameter on the base failure rate, 1.09

$C_{SW} =$ Multiplying factor which considers the effect of the seat land width on the base failure rate, 1.001182

$C_W =$ Multiplying factor which considers the effect of flow rate on the base failure rate, 1.25

Where:

$$C_P = \left(\frac{P_1 - P_2}{3000}\right)^2$$

$$C_Q = 0.055 / Q_f \text{ For leakage (Per GPM}_\text{R}) > 0.03,$$

$$C_Q = 4.1 - (79Q_{f)} \text{ For leakage (Per GPM}_\text{R}) < 0.03,$$

$$C_F = \left(\frac{V_O}{V}\right)$$

Where: $V_o = 2\ x\ 10^{-8} \text{ lb min / in}^2$

$$C_N \left(\frac{C_0}{C_{10}}\right)^3 N_{10}\ GPM_R$$

Where:

$GPM_R =$ Rated Flow in gallons/min, 5.0

$C_{10} =$ Standard System Filter Size = 10 micron

$C_0 =$ System Filter Size in microns = 5 micron

$N_{10} =$ 1.7 Particles under 10 microns/Hour/GPM

$$C_S = \frac{1}{S_R^{3/2}} = 0.621119$$

Where:

$$S_R = \frac{12\pi D_M L_W}{D_S^2} = 0.758$$

$$S_S = \frac{P_S D_S^2}{4 D_M L_W} = 1.2$$

$$S_S = \frac{\text{Force on Seat}}{\text{Seat Land Area}} = \frac{F_S}{A_{SL}}$$

$$F_S = \frac{\pi P_S D_S^2}{4}$$

$$\text{Stress Ratio} = \mathrm{S_C} / S_S = S_R$$

Therefore, leakage varies with the seat stress as:

$$\left(\frac{1}{S}\right)^{3/2}$$

Minimum Contact Pressure $= S_C = 3P_S$ approximately three times the fluid pressure.

$$A_{SL} = \pi D_M \cdot L_W$$

Where:

$A_{SL} =$ Seat land area, in^2

$L_W =$ Land area width, in

$D_M =$ Mean land width diameter, in

$$A_{ST} = \frac{\pi (D_s)^2}{4}$$

Where:

$A_{ST} =$ Seat Area, in$_2$

$D_S =$ Diameter of seat exposed to fluid pressure, P_S, 0.70 in

$$C_{DT} = 1.1\, D_S + 0.32$$

$$C_{SW} = 3.55 - 24.52\, L_W + 72.99\, L_W^2 - 85.75\, L_W^3 \text{ for } L_W < 6$$

$$C_W = 1 + \left[\frac{F_L}{100}\right]^2$$

Where:

$F_L =$ Ratio of actual flow rate to manufacturer's rating

Section 11.0

TESTABILITY / BIT ANALYSIS

MIL-STD-2165

TESTABILITY ANALYSIS

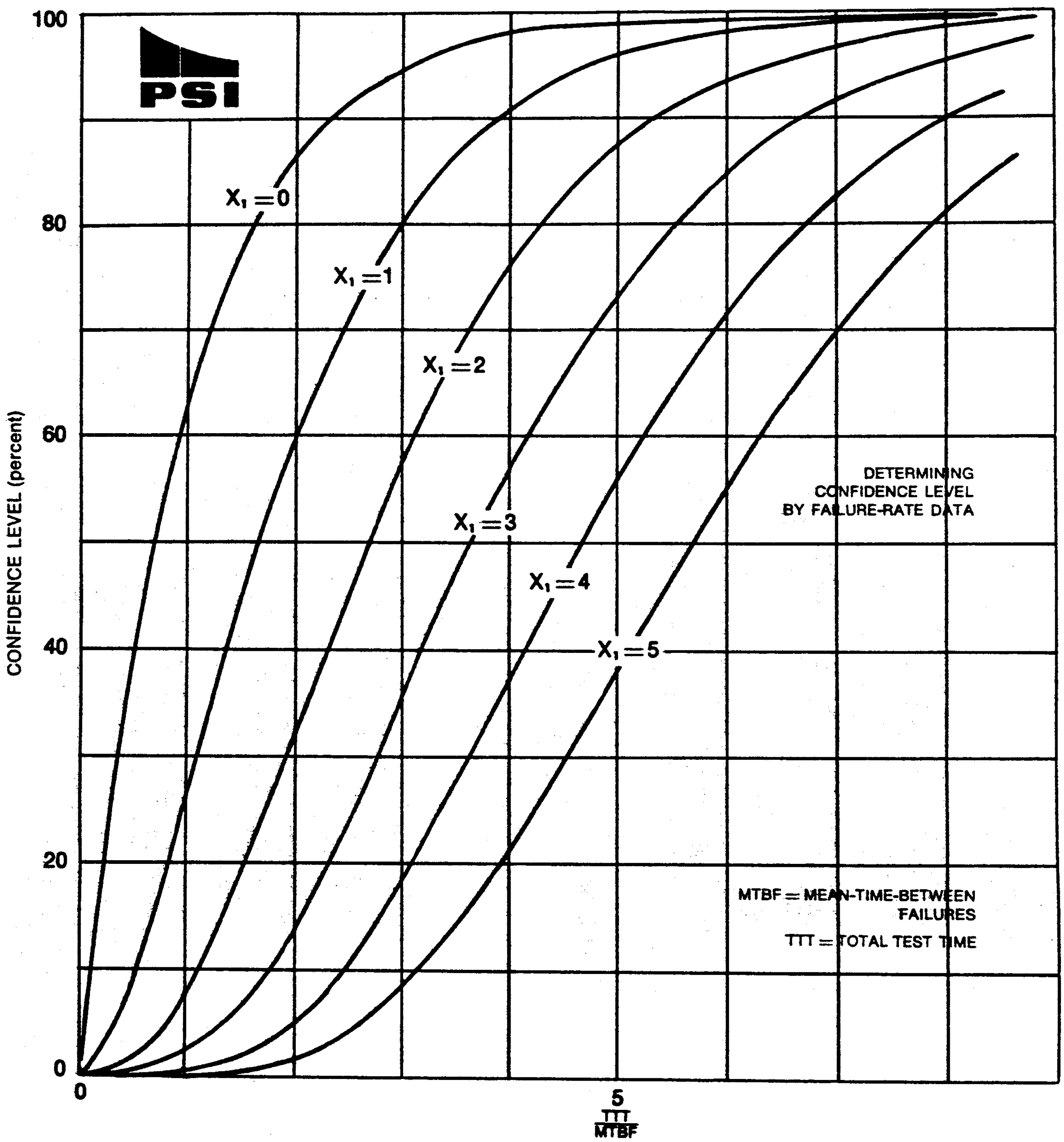
System: SAM Power Supply
Indenture Level: 3
Reference Drawing: Converter, 30684941
Mission: Space, Flight (SF)

Date:
Sheet: 1
Compiled By: J. Smith
Approved By: S. L. Friedman

Ident. No.	Item/Functional Identification (Nomenclature)	Function	Failure Mode Fault	Mission Phase/ Operational Mode	Severity Class	Probability Of Occurence, 1-Exp(-Cm)	Failure Rate (kp) --PPMH	Undetectable Failure Rate (kp) --PPMH	Undetectable Failure Acceptance Basis	Fault Isolation Functional Group
Q2-1	Transistor 2N2907A Low Frequency Bipolar (NPN/PNP)	Switch Transistor Driver	Open	Power On	III	2.20E-12	1.10E-10			Continuity Pin Drivers
Q2-2			Short	Power On	IV	6.60E-13	1.10E-10			Continuity Pin Drivers
CR1-1	Diode 1N4148-1 General Purpose	Overvoltage Protection	Open	Power On	IV	5.60E-13	1.40E-10	1.40E-10	No functional loss	Continuity Pin Drivers
CR1-2			Short	Power On	III	4.20E-12	1.40E-10			Continuity Pin Drivers
R1-1	Resistor RCR07G102JS Insulated Fixed Composition, ER	Current Limit	Open	Power On	III	4.25E-13	1.00E-11			Continuity Pin Drivers
R1-2			Short	Power On	III	7.50E-14	1.00E-11	1.00E-11	No functional loss, increased susceptability to subsequent fault	Continuity Pin Drivers
C1-1	Capacitor CKR06BX104KP General Purpose Ceramic, ER	Feedback Capacitor	Open	Power On	III	8.93E-12	2.10E-10	2.10E-10	No funtional loss, increased susceptability to subsequent fault	Power Supply
C1-2			Short	Power On	IV	3.15E-13	2.10E-10			

Section 12.0

CONFIDENCE LEVEL



Example: A customer wishes to purchase a system from a vendor, specifying that it be tested to demonstrate a mean-time-between-failure of at least 200 hours with a confidence level of 95 percent.

In this case, CL=95, X_1 = 0, and MTBF = 200 for the minimum total test time. Enter chart at 95 percent on the CL axis. Move to the right to intersect curve X_1 = 0. Drop down to TTT/MTBF and read 3.0. Solving MTBF = 200, TTT = 3.0 x 200, or, the system must be operated at least 600 hours without any failure to meet specifications. Now, should a failure occur during the 600 hour test and we wish to try again, we would read over on the X_1 = 1 curve, then drop down to TTT/MTBF = 4.8, TTT=960 hours. With just one failure at any time during the test, specifications will have been met. Of course, this chart is not one-way. Simple establish any three values and crank out the fourth. A parting shot – note that for systems which are more cycle dependent than time-dependent, feel perfectly free to substitute mean-cycles-between-failure for mean-time-between-failure.