esa european space agency
european space research and technology centre

MEMORANDUM ref. QS/93/57/331/NV ESTEC, 26 Feb. 1993

From: N. Valisena (QSR)

To : J. P. Magny (QZ)
CC. : L. Tedeman (Q), J. Marcoux (QP), R. Atkins (QSR)

Subject: PSS-01-302 Failure Rates for ESA Spacesystems - Draft 5

Attached please find copy of Draft 5 of PSS-01-302.

Draft 5 is a full revision of the previous draft.

Major elements of revision including the addition ex novo of new aspects are as follows:

i) the harmonisation for data content and conditions with the ESA QPL, the PPL, and PSS-01-301

ii) the establishment of Quality Factors to be used with the test levels of the SCC system of specs.

iii) the revision of the prediction method

iv) the introduction of the failure rates for nonoperating conditions

v) the introduction of the prediction model for nonelectronic components

vi) the revision of the failure modes distribution data

vii) the extension of the data to additional classes of components (e.g. Microprocessors, MMIC), and the inclusion of other components (e.g. Switches, circuits breakers, lamps)

viii) the update to version F of MIL-HDBK-217

The specification is supported by a technical note documenting some of the specific tasks of the revision (e.g. the development and implementation of the model for evaluation and comparison of SCC and Military parts specifications to accomplish point ii) above). All the assumptions and the conditions under which the data have been derived are also documented.

The note (ref. QS/93/57/334/NV "The derivation of Quality Factors and other supporting data for PSS-01-302") will be mailed to you in the coming days.

Regards.
N. Valisena

ESA PSS-01-302

FAILURE RATES FOR ESA SPACE SYSTEMS

ISSUE 1

DRAFT

Unofficial copy
Not published

NOTE:
This Draft 5 was never authorized to be referenced in a project.

Prepared by:

Product Assurance & Safety Department
European Space Research and Technology Center
Noordwijk - The Netherlands

European Space Agency 8-10 Rue Mario Nikis, 75738 Paris, France

ABSTRACT

This specification provides the failure rates, the failure modes distributions, and the prediction model of Electrical, Electromechanical, Electronic (EEE) components and some mechanical items to be used for reliability calculations.

CONTENTS

1. SCOPE

This specification provides the failure rates of EEE components and of a number of mechanical items to be used for the purposes of Reliability Prediction.

It also provides the prediction model and the associated factors.

In addition, data on the relative percentage distribution of failure modes, and the failure rates in nonoperating conditions are given for most of the components.

2. INTRODUCTION

Reliability prediction analyses are an integral part of the ESA reliability programme.

Estimations based on failure rates are esentially meant for EEE parts.

Data for a limited set of non electronic components including Attitude Control items, Reaction components, mechanisms elements, are however given.
Such data are in general of first approximation and the related model is simplified.

The data is organised in tables which give per each class of components

i) the failure rates point estimate in operating conditions

ii) the relative distribution of failure modes lumped in Open Circuit, Short Circuit, and Drift

iii) the failure rates in nonoperating conditions

iv) the applicable corrective factors for Quality level, and environment

The prediction methods are given in section 6.

3. APPLICABLE DOCUMENT

AD 1	ESA PSS-01-301	Derating Requirements and Application Rules for Electronic Components

4. REFERENCE DOCUMENTS

RD 1	MIL-HDBK-217	Reliability Prediction of Electronic Equipment
RD 2	ESA PSS-01-603	ESA Preferred Parts List
RD 3	ESA/SCC QPL	Qualified Parts List
RD 4	ESA/SCC ref 001	Issued SCC Specifications

RD 5	ESA PSS-01-001	Glossary of Terms
RD 6	RADC-TR-85-91	Impact of Nonoperating Periods on Equipment Reliability
RD 7	NPRD - 91	Nonelectronic Parts Reliability Data 1991
RD 8	QS/93/57/334/NV	The derivation of Quality Factors and other supporting data for PSS=01-302

5. DEFINITIONS

The definitions are given in Annex A.

6. GENERAL REQUIREMENTS

6.1 Data boundaries and constraints

The list of components, class and types, given in this specification is harmonised to the maximum extent with the ESA QPL, the ESA PPL, and the ESA SCC Detail Specifications.

When components other than those covered by the mentioned lists and specifications are foreseen for application, failure rates data shall be seeked elsewhere.
MIL-HDBK-217 is the recommended source.

The failure rates given in this document only apply to qualified components.
They are in priciple not to be used for procurements under specifications other than the ESA SCC and the US Military.

If the contractor wishes to deviate from the above, he shall propose and justify to ESA alternative modification factors, with accompanying rationale, and seek ESA agreement.

6.2 Initial estimations

The failure rates given herein are point estimates at the conditions of application defined by PSS-01-301 - DERATING REQUIREMENTS APPLICABLE TO EEE COMPONENTS FOR ESA SPACE SYSREMS.

The prediction method provided is simplified and intended for a Parts Count type of analysis.

Above conditions ensure simplification of the calculation which can be performed at the earliest stages of system definition, and the direct compliance with the ESA Derating Requirements.

The prediction models are applicable to components procured to the SCC specifications.

For parts procured to Military specifications the Quality Factors of MIL-HDBK 217 shall be used.
The failure rates and the Environmental Factors given herein continue to apply.

6.3 Estimation at the actual stress levels

Reliability prediction to the actual stress levels (to which the EEE parts are submitted as per their application within circuits) shall use the models of MIL-HDBK-217 to its latest version.
The data and method for Parts Count (i.e. for initial estimations) provided herein are coeherent with the data of the mentioned military document.

The Quality Factors to be used with the models of MIL-HDBK-217 for EEE components acquired to the ESA SCC Specifications are given for each class of components in the tables of Section 7.

7. DATA AND METHOD

7.1 Assumptions

The listed failure rates for EEE parts are in the majority of the cases for an ambient temperature (Ta) of 30 C.

They refer to Ta= 25 C when the temperature defined by the SCC Detail specification at the maximum derated conditions is 25 C (e.g. for wirewound power, and chassis mounted resistors).

Junction temperatures for discrete devices correspond to the particular device Characteristic/Temperature curve defined by its SCC Detail Specification at the maximum rating conditions specified by PSS-01-301.

Detailed conditions (e.g. package types, number of devices, number of pins) and application validity (e.g. cycling factors, ...) are given as necessary in the relevant tables.

7.2 Data

Basic failure rates for EEE parts are listed in tables 7.1 to 7.15, organised per classes of components.

Within the same table for each class of components, are also given:
- the failure mode distributions,
- the Quality Factors (Pi Q) and Environmental Factors (Pi E)
- the nonoperating failure rates

The definitions for the Environments are those given in RD 1.

Table 7.11 contains both the data and the prediction method for Hybrid Microcircuits.

Listed failure rates are for the sole component i.e. do not include interconnections and connections.
Failure rates for these are given in table 7.13.

7.2.1 Failure modes

The failure rates listed in this document can be apportioned into failure mode contributions by using the relative percentages given in the tables.

The failure modes data are applicable to active conditions only. Recommended source of information for nonoperating conditions is RD 6.

The symbol "e" means that the relative probability of the failure mode is several orders of magnitude more remote than the other failure modes, and so can be ignored in calculations.
However, this does not mean that the failure mode in question can be ignored in FMECA's or safety analyses.

In most cases, the failure rate is apportioned into contributions related to:

short circuit (S);
open circuit (O);
drift failure (D);

Normally for reliability predictions, 100% of the failure rate shall apply.
However, in conjunction with FMECA, the listed failure mode proportions may be used.

Failure modes distribution are only given for active conditions.
The same values cannot be implied for nonoperating conditions.
For nonoperating conditions RADC-TR-85-91 and NONOP 1 are recommended references.

In tables 6.1 to 6.16, an * against the failure mode distribution indicates that the value is not available.

7.3 Prediction method

The method applies within the conditions of Section 6.2 (i.e. Parts Count analysis).

The model to be used is the following (operating conditions):

$$FR_t = \mathrm{Sum}_i\,(FR\,b_i * Pi\,Q_i) * Pi\,E \qquad (1)$$

FR_t : failure rate for the circuit, the assembly, or the unit at the application conditions of environment and employed quality

FR b : basic failure rates listed in tables from 7.1 to 7.15

Pi Q : quality factor given in tables 7.1.1 to 7.15.1 (SCC levels)

Pi E : environmental factor given in tables 7.1.2 to 7.15.2

Equation (1) embraces all the failure modes.

Failure rates for PCB interconnections, and components/circuits connections need to be explicitly introduced in equation 1 (see section 7.2 above).

The above model applies to all EEE components with the exception of Hybrid Microcircuits for which the model of Table 7.11 shall be used.

7.3.1 Corrective factors

The Quality Factors given in this specification (ref table 7.1.1 to 7.1.2) are only applicable to the SCC test levels B and C.

For EEE parts acquired under Military Specifications, the quality factors of MIL-HDBK-217 (Part Stress Analysis method) shall be used.

The values for the environmental factors given herein cover the SF, GB, GF, and MF environments only.
For operations in environments other than these, the values of MIL-HDBK-217 for the specifc component type will have to be used.

7.4 Nonoperating conditions

The failure rates provided in the respective tables are point estimates and refer to the Space Flight environment (SF).

The model of equation (1) may be used as first approximation for the nonoperating conditions.
The same corrective factors per Environment and Quality may be applied.
Further the switching frequency factor given in the tables shall be applied.

For more accurate estimates the models of RD 6 are recommended.

7.5 Non electronic components

Failure rates for non electronic components are listed in tables 7.16 to 7.19.

Those values and the method of 7.5.1 below do not consider the effect of the particular operating conditions, the environment, and parts characteristics.

Their use shall thus be restricted to preliminary estimation.

When reliability prediction based on failure rates are required at later stages the criteria of Para 7.5.2 shall be followed.

7.5.1 Prediction model

The basic expression for the computation of the failure rate is the following:

FR = FR b * Pi E

FR b : basic failure rates from tables 7.16 to 7.19

Pi E : Environmental factor from table I below

Table I : **Environmental factors**
(nonelectronic components)

Environment (*)	Pi E
Space Flight (SF)	1
Ground Benign (GB)	1
Ground Fixed (GF)	3
Missile Launch (ML) (includes Reentry)	40

(*) conditions for the environment are as for the definition of MIL-HDBK-217

The factors of table I are only applicable to qualified parts.

As a general rule higher Pi E shall be adopted for off the shelf (commercial) components (see 7.5.2).

For applications outside the definition of the environments given above (e.g. Cryogenic applications, special heat and humidity conditions, dust, sand etc) specific factors are to be proposed by the contractor.

7.5.2 Unlisted failure rates, other environments, and conditions

Failure rates for unlisted components are to be proposed by the contractor.
Recommended sources, beside industrials' inhouse data, is RD 7 at its latest version.

Further the prediction method shall be enhanced to include as minimum the set of factors given below.

systematic Pi factors (all items):

- i) Pi stress
- ii) Pi temperature
- iii) Pi Quality

specific Pi factors (per technology):

- i) Pi construction (e.g. type, style, size, materials)
- ii) Pi application (e.g. mode of operation: continuos/discountinuos, operating/contact fluid, speed)

TABLES

TABLE 7.1
CAPACITORS

Type	Similar to style	Failure Rate per 10E9 hrs active	nonop	F. Modes O	S	D
Ceramic, fixed (C<3.3 nF)	CKR, CLC, DLZ,CQ COG, DKX, UTZ, CFC	1.4	0.18	25	30	45
Ceramic T Comp.	CCR (C<81 pF)	0.4	0.2	25	30	45
Ceramic chip	CDR, (C<81 pF) 1210,1812, 2220 0805, 1805,0504	0.4	0.2	25	30	45
Tantalum solid	CSR (C<100 nF)	1.1 (1)	0.08	30	50	20
		2.4 (2)	0.08	30	50	20
Tantalum non-solid	CLR (C<20 microF)					
Foil, hermetic		3.	3.	20	65	15
Slug, hermetic		6.	3.	20	65	15
Slug, all TAntalum		0.9	3.	20	65	15
Metallised plastic (C<140nF)	CRH,MKU,CPM,KD CKM,IEXXX,MKT	1.1	0.6	e(3)	70	30
Plastic, Metallised plastic	CFR (C<330nF)	2.	0.6	40	40	20
Paper and Plastic film	CQR (C< 33nF)	1.	0.6	40	40	20
	CQ	10.	0.6	40	40	20
Glass fixed	CYR (C<30 pF)	0.16	0.16	30	60	10
	(30<C<3000pF)	0.3	0.2	30	60	10
Mica fixed	CMR (C<300pF)	0.25	0.25	15	70	15
	(300<C<30000pF)	0.47	0.4	15	70	15
Aluminum						
Dry Electrolyte	CE (C<0.4 mF)	34.	3.7	30	60	10
Solid Electr	121, 123 series	2.9 (4)	2.9	30	60	10
Electrolitic	CUR (C< 0.4 mF)	9.5	3.7	30	45	25
Variable						
Air trimmer	CT	200.	8.7	10	40	50
Ceramic	CV	105.	5.6	10	40	50
Piston	PC	49.	2.2	10	40	50

(1) circuit resistance R > 0.4 ohms per volt

(2) circuit resistance 0.1 <R < 0.4 ohms per volt
maximum voltage stress = 60% (PSS-01-301)
(3) if energy is above 500 microJoules
(4) first approximation only (based on limited amount of test data)

Note: nonoperating failure rates refer to 1 on/off cycle/1000 hrs
multiply by 2.2 for up to 1 cycle/100 hrs
multiply by 7.8 for up to 1 cycle/20 hrs

Table 7.1.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	3.
SCC C	3.5

Table 7.1.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Ceramic, Mica, Glass, Plastic, Tantalum non sol. Aluminium	1	2	4	68
Tantalum solid paper/plastic	1	2	4	58
Metall. Plastic	1	2	8	22
Variable	1	2	6	100

TABLE 7.1
RESISTORS

Type	Style		Failure Rate per 10E9 hrs			F. Modes		
			active		nonop	O	S	D
Fixed film	RNR,RNC		0.28 (1)		0.02	65	e	35
	RLR		0.23 (1)		0.02	65	e	35
Fixed composition	RCR		0.23 (1)		0.03	75	e	25
Fixed wirewound accurate	RBR				0.48	70	5	25
Tolerance		1%	.5%	.1%				
R(Ohm)								
R < 10 K		4.	3.3	3.				
10K < R < 100K		6.7	5.7	5.3				
100K < R < 1M		12.	10.	9.				
Fixed wirewound								
Power	RWR		5.		0.18	70	5	25
Power chassis mtd	RER		3.7		0.30	70	5	25
Variable, wirewound	RTR		8.7		0.52	50	15	35
Variable, non-wirewound	RJR		10.		2.7	20	5	75
Thermistor	RTH	bead	disk	rod		50	10	40
		10.	32.	52.	1.4			
Integrated thin film	-		0.015		-	20	e	80
Chip	WA		0.015		-	20	e	80
Fixed film networks	RZ		0.12 (2)		-	80	10	10

(1) Resistance < 1 Mohm

(2) Per resistor; to be multiplied for the number (Nr) of resistors actually used. If Nr is not known then Nr=10.

Notes: i) the symbol (-) is used, means that no data is available. When the missing data is the failure rate in nonoperating conditions, the value of 1/10 the active failure rate is recommended.

ii) nonoperating failure rates are for 1 switching cycle per 1000 hrs.
Multuply by by 1.6 for up to 1 cycle/100 hrs
Multiply by 4 for up to 1 cycle/20 hrs

Table 7.2.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	2.5
SCC C	3.25

Table 7.2.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Fixed film, Fixed wirewound	1	2	4	70
Fixed composition Fixed networks	1	2	4	56
Variable wirew. Variab. nonwirew. Thermistor	1	2	8	100

TABLE 7.3
DIODES

Type	Failure Rate per 10E9 hrs		F. Modes		
	active	nonop	o	s	d
Low frequency					
General Purpose Analog	6.61	0.08	30	30	40
Switching	1.7	0.08	30	30	40
Power Rectifier, Fast R.	26.4	0.15	25	55	20
Power, Schottky	2.0	0.15	35	50	15
Power Rectifier (High Voltage Stacks)	3.3/junction	0.15	25	55	20
Voltage Regulator	2.9	0.15	45	20	35
Voltage Reference	2.9	0.15	25	50	55
Transient Suppressor	1.0	0.15	35	45	20
Thyristor 0-5 A	4.4	0.26	15	30	55
Microwave, RF			30	35	35
Schottky Barrier	23.6	0.9			
Step Recovery	2.2	0.98			
Varactor		0.98			
Voltage control	1.1				
Multiplier	5.5				
PIN (P < 100 Watts)	8.8	0.98			
IMPATT	550.	0.98			
Gunn	113.	0.98			
Mixer	1.4	0.9			

Note: nonoperating failure rates are for 1 switching cycle/1000hrs Multiply by 1.5 for up to 1 cycle/100 hrs and by 3.5 for up to 1 cycle/20 hrs.

Table 7.3.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
Low Frequency	
SCC B	1.5
SCC C	2.0
Microwave, RF	
SCC B	2.
SCC C	2.4

Table 7.3.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Diodes low freq., Thyristors	1	2	12	64
Microwave, RF	1	2	4	48

TABLE 7.4
OPTO-ELECTRONIC DEVICES

Type	Failure Rate per 10E9 hrs active	 nonop	F. Modes O	 S	 D
Light Emitting Diode	0.17	0.04	70	30	e
Opto-couplers and Opto-isolators			50	10	40
Single Isolators					
Photodiode	2.98	0.08			
Phototransistor	15.50	0.1			
Light Sensitive Resistor	7.62	-			
Dual Isolators					
Photodiode	3.92	-			
Phototransistor	20.23	-			
Light Sensitive Resistor	10.23	-			

Table 7.4.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.5
SCC C	2.

Table 7.4.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	2	12	64

TABLE 7.5
TRANSISTORS

Type	Failure Rate per 10E9 hrs			F. Modes		
	active		nonop	S	O	D
Si,NPN,PNP			0.098	20	75	5
	linear	switching				
Power rating [Watts]						
<.1	.51	.24				
.1 < P <.5	.94	.44				
.5 < P < 1	1.23	.57				
1 < P < 5	2.20	1.03				
5 < P < 10	2.80	1.32				
10 < P < 50	5.27	2.44				
50 < P < 100	6.74	3.14				
100 < P < 500	12.2	5.71				
Bipolar, microwave RF, low power (Si)			15.	25	70	5
Power rating (Watts)						
P < .1	85.					
.1 < P < .3	109.					
.3 < P < .5	141.					
.5 < P < .7	165.					
.7 < P < .9	183.					
Power, microwave, RF bipolar (f < 1 GHz)			15.	30	70	e
Power (Watts)	Cont. Wave	Pulsed (1)				
P < 5	44.	9.5				
5 < P < 10	46.	9.6				
10 < P < 50	57.	12.				
50 < P < 100	76.	16.				
100 < P < 200	133.	28.				
200 < P < 300	228.	48.				
300 < P < 400	399.	84.				
400 < P < 500	703.	148.				
Unijunction	27.		0.5	15	20	65

TABLE 7.5 (Cont'd)
TRANSISTORS

Type	Failure Rate per 10E9 hrs active	nonop	F. Modes S	O	D
FET, Si, Low frequency (f < 400 MHz)		0.14	15	65	20

	MOSFET	JFET
Linear (P < 2 Watts)	38.	14.
Switching Power rating (Watts)		
P < 2	18.	6.6
2 < P < 5	50.	19.
5 < P < 50	101.	38.
50 < P < 250	201.	76.

Type	Failure Rate per 10E9 hrs active	nonop	F. Modes S	O	D
FET, Si, High Frequency (f > 400 MHz)		0.14	15	65	20

	MOSFET	JFET
Av. Power < .3 W	126.	48.

Type	Failure Rate per 10E9 hrs active	nonop	F. Modes S	O	D
High Frequency, GaAs FET (Driver and Power) (2)		-	10	85	5
Low Power (P < 0.1 W) Pulsed and C. Wave	728.				

Power, Pulsed (3)

Power(W) Freq.(GHz)	1 W	2 W	4 W	6 W
4.	1176	1960	5040	13440
5.	1820	2940	7840	21000
6	2800	4480	10700	32200
7.	4200	7000	18200	49000
8.	6580	10640	28000	
9.	10800	16800		
10.	15400	25200		

(1) Duty cycle = 20 %
(2) For Continuos Wave applications multiply by 4.

Note: nonoperating failure rates are for a switching frequency of 1 cycle/1000 hrs
Multiply by 1.4 for up to 1 cycle/100 hrs, and by 3.3 for up 1 cycle/20 hrs

Table 7.5.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
Low Frequency	
SCC B	1.5
SCC C	2.
Microwave, RF	
SCC B	2.
SCC C	2.4

Table 7.5.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Low frequency Bipolar & FET	1	2	12	64
All others	1	2	4	48

TABLE 7.6
DIGITAL INTEGRATED CIRCUITS

Failure Rate
per 10E9 hrs

Type	TTL, ASTTL,CML HTTL,FTTL,DTL, ECL, ALSTTL (1)		LTTL,STTL,F LSTTL		III, IIIL ISL		MOS	
Gates	active	nonop	act.	nop	act.	nop	act.	nop
1 to 100	5.4	.9	5.8	.9	6.5	1.	7.8	1.
101 to 1000	6.4	3.	7.3	3.	8.6	3.	11.	3.
1001 to 3000	8.5	5.	10.	5.	12.	5.	18.	6.
3001 to 10000	12.	7.	16.	8.	21.	9.	32.	11.
10001 to 30000	21.	12.	28.	14.	38.	16.	60.	20.
30001 to 60000	38.	21.	51.	25.	72.	30.	105.	35.

Digital MOS, VHSIC, VLSI CMOS (2)	Dual In-Line Package	Pin Grid Array
Logic and custom	467.	470.
Gate array	667.	670.

(1) 24 active PINS assumed, Tc= 30 C, Tj= 55 C, Pi L=1, class B (Pi Q=1) Hermetic: DIP, SMT, or flatpack
(2) more than 60.000 gates

Failure modes distribution

Mode	Probability	
	Bipolar	MOS
Input Open	22 %	36 %
Output Open (*)	22 %	36 %
Output stuck High	23 %	9 %
Output Stuck Low	23 %	9 %
Degraded operation	10 %	10 %

(*) Short Circuit failure modes to be considered are:
Power supply + to power supply -
each input to power supply +
each input to power supply -
each output to power supply +
each output to power supply -

Note: nonoperating failure rates are for 1 on/off cycle per 1000 hrs

Multiply by 1.2 for up to lcycle/100 hrs and by 2 for up to 1 cycle/20 hrs.

Table 7.6.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.
SCC C	1.5

Table 7.6.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	1	4	24

TABLE 7.7
LINEAR INTEGRATED CIRCUITS

Bipolar and MOS (1) Number of transistors	failure Rate per 10E9 hrs active	nonop
1 to 100	14.	4.
101 to 300	24.	14.
301 to 1000	44.	39.
1001 to 10.000	64.	56.

CMOS (2)	Dual In-Line Package	Pin Grid Array
Logic and custom	1210.	1212.
Gate array	1782.	1784.

(1) Hermetic package: Dual In-line Package, Pin Grid Array, SMT (w/ and w/o leads).
(2) More than 60.000 gates

Notes: i) nonoperating failure rates are for a switching frequency of 1 cycle/1000 hrs.
multiply by 1.3 for up to 1 cycle/100 hrs, and by 2.5 for up to 1cycle/20 hrs.
ii) No nonoperating failure rates available for CMOS.
For low switching cycles (below 1 cycle/5000 hrs (tbc)) 1/10 or more of the active failure rate is recommended.

Failure Modes distribution

Mode	Probability
Improper output	60 %
No Output	30 %
Output stuck Low	10 %

Table 7.7.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.
SCC C	1.5

Table 7.7.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	1	4	24

TABLE 7.8
MICROPROCESSORS, PROGRAMMABLE LOGIC ARRAY AND PROGRAMMABLE ARRAY LOGIC

Microprocessors	up to 8 BITs	up to 16 BITs	up to 32 BITs
Bipolar			
Functional pins			
24	29.	54.	105.
40	32.	58.	108.
64	38.	63.	113.
128	52.	77.	127.
MOS			
Functional pins			
24	53.	102.	200.
40	56.	105.	203.
64	61.	110.	208.
128	75.	124.	222.

Programmable Logic Array
Programmable Array Logic

Bipolar (hermetic DIP)

	24 pins	40 pins
Gates: up to 200	8.	12.
201 to 1000	13.	16.
1001 to 5000	22.	25.

MOS (hermetic DIP)

Gates: up to 500	5.	8.
501 to 1000	5.5	8.7
2001 to 5000	6.7	9.9
5001 to 20000	9.1	12.

Note: no nonoperating failure rates available

Failure Modes distribution

Mode	Probability
Degraded Output	70 %
No Output	10 %
Shorted	20 %

Table 7.8.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.
SCC C	1.5

Table 7.8.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	1	4	24

TABLE 7.9
SEMICONDUCTOR MEMORIES

Bipolar

Size (m) [Kbits]	ROM, PROM	SRAM
m < 16	12.	9.
16 < m < 64	21.	14.
64 < m < 256	37.	23.
256 < m < 1000	71.	43.

MOS

Size (m) [Kbits]	ROM	PROM,UVEPROM EAPROM	EEPROM (1)	DRAM	SRAM
m < 16	5.	5.	6.	4.	10.
16 < m < 64	6.	6.	7.	6.	18.
64 < m < 256	7.	8.	10.	9.	31.
256 < m < 1000	12.	13.	17.	13.	58.

(1) up to 100 programming cycles

Table 6.9.1 - Number of functional pins

size (m) [Kbits]	Bipolar and MOS/ROM, PROM, UVEPROM, EAPROM	MOS/EEPROM, DRAM, SRAM
m <16	24	18
16< m <64	28	22
64< m <256	28	24
256< m <1000	40	28

Notes: i) Failure rates are for Hermetic Dual In-Line Package
ii) No nonoperating failure rates available

Failure modes distribution

Mode	Probability	
	Bipolar	MOS
Degraded Operation & Bit loss	40 %	45 %
Opened	30 %	25 %
Shorted	30 %	30 %

Table 7.9.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.
SCC C	1.5

Table 7.9.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	1	4	24

TABLE 7.10
GaAs MICROWAVE MONOLITHIC INTEGRATED CIRCUITS
GaAs DIGITAL IC (MESFET)

GaAs MMIC	Failure rate per 10e9 hrs	
No. of parts:		
1 to 100	3.	(DIP, 16 pins)
101 to 1.000	8.	(DIP, 40 pins)
GaAS Digital IC (MESFET)		
No. of parts:		
1 to 1000	7.	(DIP, 36 pins)
1.001 to 10.000	13.	(PGA, 64 pins)

Notes:
- (i) No. of parts includes active elements i.e. transistors and diodes
- (ii) Failure rates are for Hermetic Dual In-Line Package and/or Pin Grid Array
- (iii) No nonoperating failure rates available

Failure Modes distribution

Mode	Probability
Degraded Output/Drift	5 %
No Output/Opened	45 %
Shorted	50 %

Table 7.10.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.
SCC C	1.5

Table 7.10.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	1	4	24

TABLE 7.11
HYBRID MICROCIRCUITS

Failure rates for Hybrids shall be calculated with the following formula:

FR = Sum (Nc * FRc)*(1.+0.2* Pi E)*Pi F * Pi Q * Pi L

Nc	:	number of each component type
FRc	:	failure rate of each component type (see table 7.11.1 for its calculation)
Pi E	:	environmental factor (from table 7.11.3)
Pi F	:	circuit function factor (from Table 7.11.4)
Pi Q	:	quality factor (from Table 7.11.2)
Pi L	:	maturity factor (from table 7.11.5)

Table 7.11.1
Failure rates reference table

component type (1)	use table(s) (2)
microcircuits	6.11.6, 3.11.7
transistors	6.5
diodes	6.3
optoelectronic devices	6.4
capacitors	6.2

(1) components not listed in the table (e.g. resistors, inductors) are supposed to contribute insignificantly to the hybrid failure rate.
Passive components shall only be accounted for when they constitutes more than 50% of the Hybrid components (tbc).

(2) to calculate the failure rate FRc for Discrete Components and Capacitors the Environmental Factor Pi E for Ground Benign (GB) shall be used.

Table 7.11.2
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	1.
SCC C	1.5

Table 7.11.3
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	1	4	24

Table 7.11.4
Circuit function factor (Pi F)

circuit type	Pi F
digital	1.
linear	5.8
video (10 MHz to 1 GHz)	1.2
microwave (f > 1 GHz)	2.6
power	21.

Table 7.11.5
Maturity factor (Pi L)

Years in prod.	Pi L
< .1	2.
.5	1.8
1.	1.5
1.5	1.2
> 2	1.

Table 7.11.6
Failure rates for Microcircuits

Digital

Type	TTL, ASTTL, CML HTTL, FTTL, DTL, ECL, ALSTTL	LTTL, STTL, F LSTTL	III, IIIL ISL	MOS
Gates				
1 to 100	1.	1.	2.	4.
101 to 1000	2.	3.	4.	7.
1001 to 3000	4.	5.	9.	14.
3001 to 10000	8.	10.	17.	28.
10001 to 30000	17.	20.	34.	56.
30001 to 60000	34.	40.	68.	102.

Linear

Bipolar and MOS

Number of transistors	
1 to 100	9.
101 to 300	17.
301 to 1000	34.
1001 to 10.000	51.

VHSIC, VLSI CMOS (**)

	digital	linear
logic and custom	465.	1210.
gate array	665.	1780.

(**) More than 60.000 gates

Microprocessors	up to 8 BITs	up to 16 BITs	up to 32 BITs
Bipolar	25.	50.	100.
MOS	50.	98.	196.

Programmable Logic Array
Programmable Array Logic

Bipolar Gates:	
up to 200	4.
201 to 1000	9.
1001 to 5000	18.

MOS Gates:	
up to 500	0.3
501 to 1000	0.6
2001 to 5000	1.2
5001 to 20000	2.4

Table 7.11.7
Failure rates for memories and MMIC

Memories

Bipolar

Size (m) [Kbits]	ROM, PROM	SRAM
m < 16	8.	4.
16 < m < 64	16.	9.
64 < m < 256	32.	18.
256 < m < 1000	64.	36.

MOS

Size (m) [Kbits]	ROM	PROM, UVEPROM EAPROM	EEPROM (*)	DRAM	SRAM
m < 16	0.5	0.7	1.	1.	7.
16 < m < 64	1.	1.	3.	2.	14.
64 < m < 256	2.	3.	5.	4.	26.
256 < m < 1000	4.	6.	11.	9.	54.

(*) up to 100 programming cycles

GaAs MMIC

No. of parts (*)	
1 to 1000	0.01

GaAS Digital IC (MESFET)

No. of parts (*)	
1 to 1000	0.04
1.001 to 10.000	0.08

(*) No. of parts includes active elements i.e. transistors and diodes

TABLE 7.12
RELAYS, ELECTROMAGNETIC AND SWITCHES

Type	Failure Rate per 10E9 cycles			F. Modes		
				O	S	D
RELAYS				70	15	15
Contact Current [A]:	0 - 5	5 - 20	> 25			
Latching						
SPDT	67.	40.	161.			
DPDT	115.	69.	276.			
3PDT	163.	98.	392.			
4PDT	211.	127.	507.			
Non Latching/Armature						
SPDT	40.	40.	94.			
DPDT	69.	69.	161.			
3PDT	98.	98.	228.			
4PDT	126.	126.	295.			

SWITCHES					F. Modes		
	1PDT	DPST	3PST	4PST	O	S	D(1)
Toggle switches (2)	0.28	0.43	0.57	0.72	60	10	30
Basic,sensitive (2)	74.				40	28	32

(1) The actual failure mode is: sticking
(2) Valid for < 1 cycle/hr. Multiply for the number of Cycles/hr for more frequent operations.

Note : - for all relays, O relates to failure to close
S relates to failure to open
- Data is valid for operations < 10 cycles/hr
- current rating is as per PSS-01-301 (i.e. 40%, 20 %, and 10 % of rated resistive load for resistive, inductive, and filament type of load respectively).

Nonoperating conditions

	failure rate per 10E9 nonoperating hrs
<u>Relays</u>	
Hermetic	0.2
Non hermetic (contact voltage >50 mV)	1.
Non hermetic (contact voltage <50 mV)	5.
<u>Switches</u>	
Contact voltage > 50 mV	3.
Contact voltage < 50 mV	15.

Table 7.12.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
RELAYS	
SCC B - Non Latching	4.5
SCC B - Latching	5.
SWITCHES	
SCC B	1.

Table 7.12.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	2	4	132

TABLE 7.13
CONNECTORS AND CONNECTIONS

Type	Failure Rate per 10E9 hrs active	nonop
Connector, circular and rectangular	5.2 (1)	.35
Connector,Coaxial, R.F.	9.8 (2)	.35
Connector, Printed Circuit Board	4.3 (1)	2.3
Sockets,Integrated Circuit	1.	-

Interconnections, Plated Through Holes (3)

	active		nonop
	Wave soldering	Hand solder.	
PCBs	0.02	0.28	.0007
Discrete wiring	0.13	1.8	.004

Connections (4)

	active	nonop
Solder, reflow or lap auto. or manual	0.03	.0012
Hand solder		.04
w/o wrapping	1.3	
w/ wrapping	0.07	
Weld	0.025	.0008
Solderless Wrap	0.0017	.00006
Crimp (to PSS-01-726)	0.13	.006
Clip termination	0.06	.002

(1) valid for < 5 cycles/1000 hrs, and < 40 active pins
(2) valid for < 5 cycles/1000 hrs
(3) Not more than 2 circuits planes;
Failure rates are per single PTH - To be multiplied by the number of PTHs.

(4) Failure rates are per a single connection.
All processes are subjected to space qualification

Note: Connectors shall not experience more than 50 mating/demating cycles.

Failure modes distribution

Connectors and connections are assumed to fail 100 % open.

Table 7.13.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B	
Circular	5.
Rectangular	1.
Circular threaded	5.
SCC B	
R.F., Coaxial	1.5

Table 7.13.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
All	1	2	4	54

TABLE ~~6~~7.14
MICROWAVE ITEMS

Type	Failure Rate per 10E9 hrs				
<u>Crystal (quartz)</u>					
frequency [MHz]	<= 5	5<f<=20	20<f<60	60<f<100	>100
	7.5	12.	15.	18.	20.
<u>Filters</u> (1)					
hybrid	96.				
bandpass	216.				
Ceramic-Ferrite constr.	18.				
<u>Isolator, Circulator</u>					
<= 100 W	0.05				
00 W< P < 200 W	0.1				
<u>Travelling Wave Tube Amplifiers</u>					
(TWTAs), frequency band	S	C	X	Ku	Ka
	1890	950	4300	1160	3000
Attenuator, fixed, variable	6.				
Coaxial hybrid	25.				
Cavity (variable)	0.1				
Coupler, directional	negligible				
Diplexer	100.				
Ferrite junction	5.				
Load	2.				
Stripline	1.				
Switch, coax (ferrite)	10.				
Switch, ferrite W/G	12.				
Switch, mechanical WG	50.				
Tuning screw	0.5				
Waveguides	6.				
Waveguide flange	0.1				

(1) First approximation only. The failure rate for filters should be calculated on the basis of the individual components.

Nonoperating conditions

Failure rate for TWTAs: 69/ 10E9 hrs

No data available for the other items.

Table 7.14.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
SCC B Crystals	2.

Table 7.14.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Crystals	1	2	6	64
Filters	1	1.3	2.5	18
TWTAs	1	10	30	660
Ferrite devices	1	2	4	48

TABLE 7.15
TRANSFORMERS AND INDUCTORS

Type	Failure Rate per 10E9 hrs		F. Modes		
	active	nonop	O	S	D
Transformer, pulse MIL-T-27 Class S	1.8	0.14	20	20	60
Transformer, audio MIL-T-27 class S	3.6	0.03	50	40	10
Transformer, power and filters MIL-T-27 class S	12.	0.14	45	40	15
Transformer, pulse, low power MIL-T-21038 Class S	9.6	0.03	20	20	60
Transformer, RF MIL-T-55631 class B	14.	0.14	15	5	80
Coil, fixed, RF MIL-C-39010 Class F	0.19	0.07	50	30	20
Coil, variable, R.F. MIL-C-39010 Class F	0.38	0.07	50	30	20
Coil, R.F. MIL-C-15305 Class C			(50	30	20)
fixed	0.76	0.07			
variable	1.5	0.07			

Table 7.15.1
Quality Factors (Pi Q)

Quality level/class	Pi Q
Coils	
SCC B	2.
SCC C	2.4

Table 7.15.2
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Transformers	1	2	12	68
Coils	1	2	8	68

TABLE 7.16
POWER SUBSYSTEM ITEMS

Type	Failures Rate per 10E9 hrs	F.	Modes	
		O	S	D
Solar cell (1)	1.	*	*	*
Ni-Cd battery cell		e	30	70 (2)
30% DOD	55.			
40% DOD	70.			
50% DOD	90.			
60% DOD	110.			
Ni-H2 battery cell	100.	100	e	e
Circuit breaker				
magnetic	20.	30	50	20 (3)
thermal, thermo-magnetic	38.	30	70	0
Fuse	9.	30	45	25 (4)
Lamps	1250.	100	0	e
Motor	870.	*	*	*

(1) including redundancy of connections; for first approximation only.
(2) degraded output
(3) Includes intermittent operations and noise
(4) Slow blow

Table 7.16.1
Environmental Factors (Pi E)

Type \ Environm.	SF	GB	GF	ML
Circuit Breakers	1	2	4	132
Fuses	1	1	2	23
Lamps	1	1.4	3	8

TABLE 7.17
ATTITUDE CONTROL ITEMS

Type	Failure Rate per 10E9 hrs
Slip ring	10./brush
Motor	100.
Reaction wheel assembly	130.
Momentum wheel assembly	100.
Bearing	10.
Gear	10.
Bolometer(IR sensor)	100.
Thermopile	160.
Rate integration gyro	2000.

TABLE 7.18
REACTION DEVICES

Type	Failure Rate per 10E9 hrs
High temperature heater	30.
Low temperature heater	10.
Manifold (leakage)	7.
<u>Propellant tanks</u>	
Propellant tank (diaphragm)	240.
Propellant tank (surface tension)	40.

	Failure Rate per 10E9 cycles
<u>Thrusters</u>	
Hot gas	450. failure to operate
Hot gas	60. failure to close
Cold gas	300. failure to operate
Cold gas	60. failure to close
Bi-propellant RC	185. failure to operate
Bi-propellant RC	60. failure to close
<u>Valves</u>	
- latching	160.
- non-return	56./seal
- fill and drain	56./seal
- relief	10.
- pressure transducer	200.
- pressure regulator	560.

TABLE 7.19
MISCELLANEOUS COMPONENTS

Type	Failure rate per 10E9 cycles
Thermostats	50.
Springs - tension	20.
- compression	10.
Latch mechanism	20.
Hinge assembly	100.

ANNEX B

DEFINITIONS

CORRECTIVE FACTOR

The corrective factor is a coefficient by which the tabulated failure rate is to be multiplied to take into account application conditions other than those already accounted with the tabulated failure rate.

DERATING

Derating is the reduction of electrical and thermal stress to a component in order to increase its useful lifetime. The derating factor is usually given as a percentage of the maximum value of the considered parameter. These maximum rated values are defined in the document specifications.

FAILURE

A failure is the termination of the ability of an item to perform its required function.

- drift failure : drift failure is a failure resulting from deviation(s) in characteristic(s) beyond the specified limits.

- catastrophic failure : a catastrophic failure is a failure that could not be anticipated by prior examination.

FAILURE MODE

The failure mode is the characteristic by which the failure is observed.

FAILURE RATE

The number of failures of an item per unit measure of its life (cycles, time, events, etc. as applicable for the item).

The failure rates tabulated in this specification are based on Observed Failure Rates. In the reliability predictions they shall be processed like time-constant Instantaneous Failure Rates.

INSTANTANEOUS FAILURE RATE

The Instantaneous Failure Rate can be defined as the limiting value of the quotient between the failure probability for a component in an interval of time and the length of that interval, when the interval approaches zero, under the condition that the component is without failure in the beginning of the interval.

Mathematically, the Instantaneous Failure Rate is defined as:

FORMULA FR(t) = lim P(t< <t+ t/ >t)
t 0 t

where FR(t) = instantaneous failure rate at the time t
= time to failure

OBSERVED FAILURE RATE

The Observed Failure Rate is defined by the International Electrotechnical Commission (IEC) as follows:

"For the stated period of the life of an item, the ratio of total number of failures in the sample to the cumulative observed time on that sample. The observed failure rate is to be associated with particular and stated time intervals or summation of intervals) in the life of the item, and with stated conditions.

STATES

Active State

The active state applies when an item is powered or and) operating.

Dormant State

The dormant state is understood in this specification to apply when a device is assembled into a system in the normal operational configuration and environment, but experiences almost no electrical stress for prolonged periods before being used.

DRIFT FAILURE MODE

ESA PSS-01-301 defines maximum parameter changes which shall be catered for in the design and shall be applied for worst case analysis. Any parameter changes outside the range defined shall be considered to be a drift failure mode.