HIRDLS

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: Tony Forward Date: 14th April 1999

Subject/Title: **STH, SSH AND SVA RELIABILITY PREDICTION**

Description/Summary/Contents:

The purpose of this TC is to produce a quantitative figure to represent the reliability of HIRDLS. In addition, results from the prediction will be used to highlight weak areas in the design so that, if necessary, precautions can be taken to remove suspect areas from the design.

Keywords: HIRDLS, Structure, Thermal, Sunshield, Space View Aperture, Reliability

Purpose of this Document: STH/SSH Reliability Prediction

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EOS

ORIGINAL WHEN RED

STH AND SSH

RELIABILITY PREDICTION

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1. INTRODUCTION

This reliability prediction is generated in response AD5. The main purpose of the prediction is to produce a quantitative figure to represent the reliability of HIRDLS. In addition, results from the prediction will be used to highlight weak areas in the design so that, if necessary, precautions can be taken to remove suspect areas from the design. The results from the prediction will also be supplied to other development activities such as the FMECA. The prediction uses conventional reliability engineering methods for its calculation together with an approved sources of electronic component failure rates.

2. APPLICABLE DOCUMENTS

AD1	SP-HIR-013	HIRDLS Instrument Technical Specification
AD2	SP-HIR-031	Structure/Thermal Subsystem Specification Document
AD3	SP-HIR-050	Sunshield Subsystem Specification Document
AD4	GSFC 422-11-12-01	General Interface Requirements Document(GIRD)
AD5	GSFC 424-11-13-01	Mission Assurance Requirements (MAR)
AD6	PA-MMS-209	STH and SSH Reliability Prediction
AD7	553942	Fordsat Quantitative Reliability Assessment Specification
AD8	MIL-HDBK-217F, Notice 1	Military Handbook for Reliability Prediction of Electronic Equipment.
AD9	PSS 01-302	Failure Rates for ESA Spacecraft and Associated Equipment.

3. ABBREVIATIONS

CDA	Critical Design Audit
CDR	Critical Design Review
FITS	Failures in time units (Parts failing per 10^9, per hour)
FMECA	Failure Modes Effects, and Criticality Analysis
FR	Failure Rate
HDRM	Hold Down and Release Mechanism
HIRDLS	High Resolution Dynamics Limb Sounder
HOP	High Output Paraffin (actuator)
MMS	Matra Marconi Space UK
PDR	Preliminary Design Review
RAL	Rutherford Appleton Laboratory
SSH	Sunshield Sub-system
STH	Structure Thermal Sub-system
SVA	Space View Aperture
λ	Failure Rate

4. DEFINITIONS

Reliability:- The ability of an item to perform a required function under stated conditions, for a stated period of time. (For HIRDLS mission time is taken as five years).

Failure:- The termination of the ability of an item to perform its required function.

5. APPLICABILITY

This reliability prediction is for the HIRDLS configuration that comprises the moveable sunshield, space view aperture shield, structure, and thermal system that comprises part of the HIRDLS Instrument. The prediction excludes 'free issue items' that are part of the HIRDLS Instrument.

Active elements in the design are taken into account, other items such as inert mechanical items are disregarded.

6. FUNCTIONAL DESCRIPTION

6.1 General

The HIRDLS Instrument is planned to be flown on one of NASA's, EOS A Series, polar orbiting satellites. Matra Marconi Space UK is responsible for the design and development of two subsystems, these being the Structure and a moveable Sunshield (which includes the Space View Aperture).

HIRDLS is an infrared limb scanning radiometer designed to sound the upper troposphere, stratosphere, and megosphere. It will measure temperature, geopotential height gradients, concentrations of gasses, locations of polar stratospheric clouds, and cloud top heights. Profiles will be obtained over the entire globe including both poles, by day and night, with complete coverage being obtained over 12 hours.

The HIRDLS Sunshield Assembly is required to shield the HIRDLS light aperture to prevent direct sunlight from entering the instruments optics. The sunshield is a hinged door that is held into a closed position during the satellite launch stage by a latch mechanism. The door is released after the satellite has reached its required position in orbit. From this time onwards the sunshield is moved about its hinge point to shade the instrument aperture from direct sunlight on its optical sensors.

The HIRDLS Space View Aperture covers the Chopper reference viewport and has the function of the prevention of contamination during ground operations and launch. The SVA includes an albedo shield to prevent Earthshine entering the instrument. The shield is of a shape suitable for complete coverage of the space view aperture. There is no provision for any intermediate positions over the aperture and the cover shield is either fully closed, or fully open.

6.2 Sunshield Sub-Assembly

The sunshield is a rectangular door. The door is secured at the opposite end of the hinge line before deployment in space with a rotating latch arrangement. Thus the sunshield is held securely during launch and is unlatched once on-orbit. The door is unlatched by rotating the latch so that it clears the door. Latch movement is made with the use of a hold-down and release mechanism that uses a high output paraffin (HOP) actuator. Heat is applied to the paraffin wax within the actuator to make it expand, this in turn moves a plunger linearly that rotates the latch. Heat is generated within the HOP actuator by the application of electrical current to two resistive elements in parallel that give in reliability terms an active redundant arrangement. If any one out of the two heating elements became open circuit for any reason, then the other element is rated sufficient to allow heating to continue.

Sunshield angular movement is accomplished with the use of a stepper motor linked to a drive reduction gearbox to give sufficient angular movement torque to the door, at the desired speed. The motor and reduction gearbox are housed at the hinge line. The motor incorporates two sets of windings, one of which is held in a standby redundant mode to enhance the reliability of the motor. In the rare event of operational winding failure, i.e. open circuit, then the other winding can be switched in for operation of the motor. A rotary potentiometer is included at the hinge to sense the angular position of the sunshield and to provide a feedback signal to the drive electronics. Included in the subsystem are four microswitches to confirm when; the door is closed and latched; latch release; door fully open and door parked in the closed position.

Around the light aperture are three sun sensors devices which sense the door shadow and hence the door position. These are for indicator purposes only and do not form part of the door control loop.

The sunshield will operate 58,400 times during the 5 year mission time. The angular movement is specified to be 123°, with a requirement to reach the safe position from fully open in less than 30 seconds. From the reliability viewpoint the sunshield will be assumed to be powered up during its mission time which is taken as five years.

6.3 Space View Aperture

The SVA covers the Chopper reference viewport and has the function of the prevention of contamination during ground operations and launch. The cover is driven in an angular movement over the aperture with a brushed D.C. torque motor, and includes position micro switches. The motor has redundant windings as described for the sunshield motor. When the cover is rotated to open the space aperture it initially lifts to clear the opening. The shield has no intermediate positions, and is either completely closed or completely open. A seal is provided under the shield to exclude dust particles of size greater than 0.05 mm diameter. The shield is designed to move from the open to closed positions in less than 3 minutes.

The SVA has a requirement for a maximum of 110 operations. This is to cover both ground testing and in-orbit operation. The baseline plan calls for the door only to be used once on-orbit.

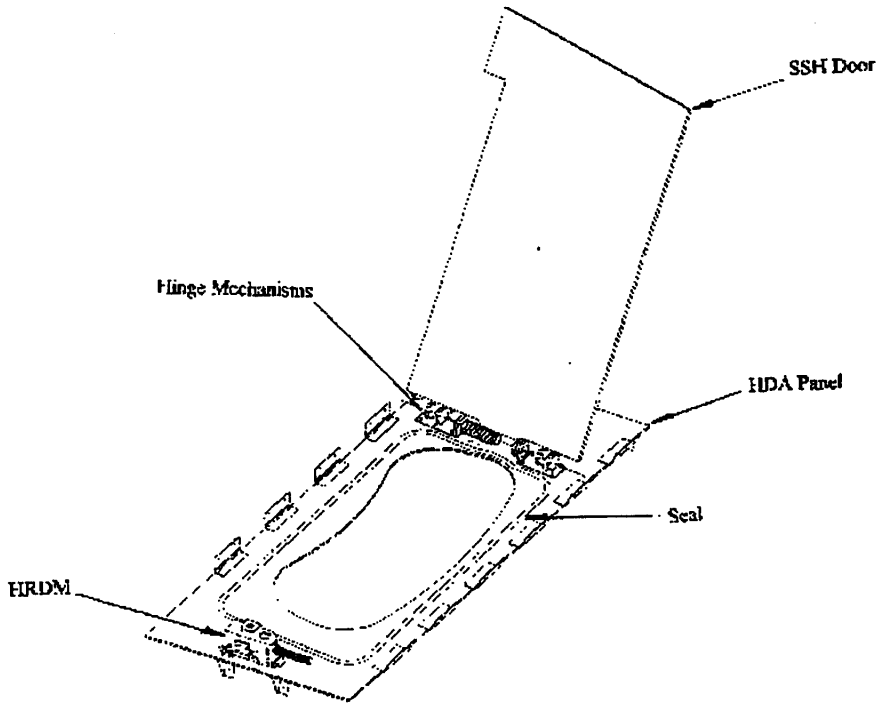

Figure 6-1 SSH Assembly

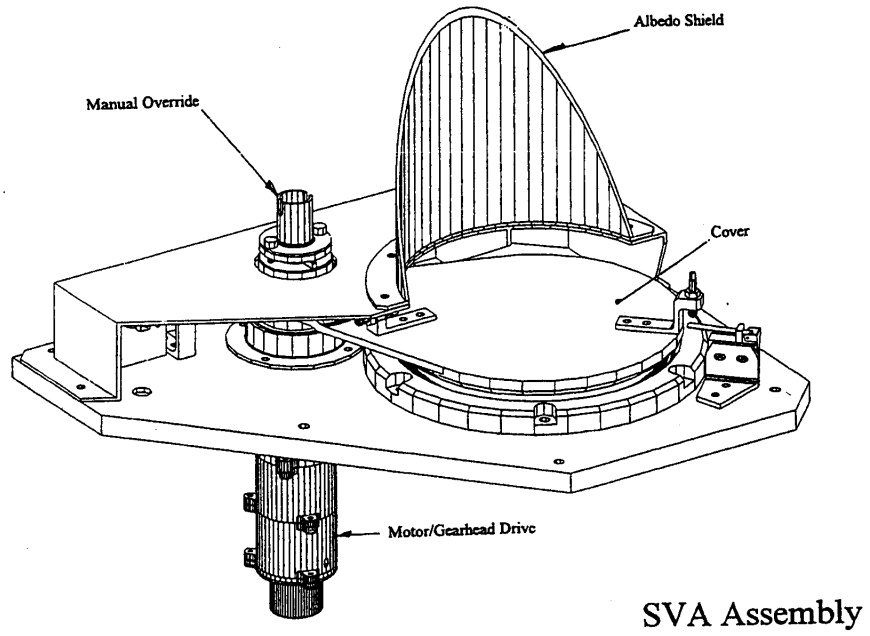

Figure 6-2 SVA Assembly

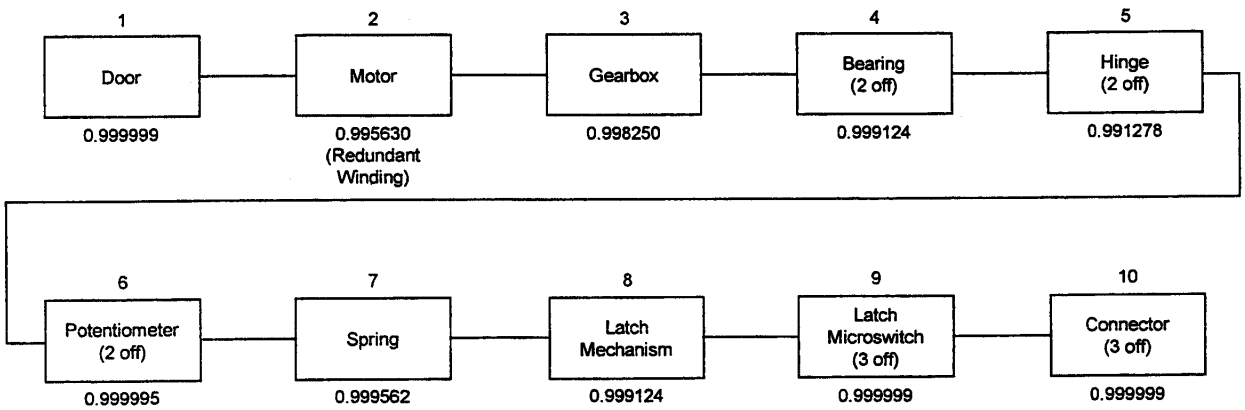

Figure 6-3 Sunshield Reliability Block Diagram

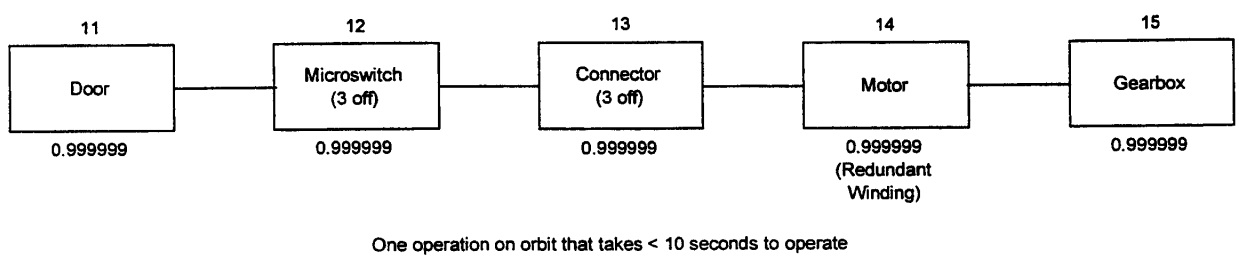

Figure 6-4 SVA Reliability Block Diagram

7. RELIABILITY ASSESSMENT

7.1 General

The reliability predictions that follow use component constant failure rates taken from a mathematical process that presumes random failures that occur in time and nature. Therefore, all elemental reliability figures in this text are derived from the negative exponential failure law, and in general:

$$R_{(t)} = e^{-(\lambda t)}$$

Where, $R_{(t)}$ is the reliability in time t.
λ is the failure rate in FITS.
t is operational time.

7.2 Reliability Prediction Method

MMS is responsible for electronic, mechanical, electromechanical, and structural items that comprise certain parts of the HIRDLS Instrument. The reliability prediction is produced prior to the PDR stage with the use of a component failure rate count method. Electronic components, and certain electromechanical item failure rates are derived from MIL-HDBK-217F Notice 1 Appendix A. An environmental factor appropriate to space flight (S_f) is used for all failure rate calculations. Quality factors that reflect the procured component quality screening and test levels are used to factor component predicted failure rates. All component failure rates used in this prediction are assumed to be constant in time, and can therefore be added together to form a total predicted failure rate for serial items. Mechanical items are not covered in MIL-HDBK-217F Notice 1, so other failure rate sources have been used within this prediction for this type of element. Structural items within the instrument have high design margins and are known to be inherently reliable, therefore reliability figures of 0.999999 have been used for these within the prediction.

Reliability block diagrams are presented that reflect the failure criterion for the three main assemblies that comprise the HIRDLS instrument. Blocks in the diagrams represent practical hardware boundaries with annotated reliability figures taken from the failure rate count estimated for each block. Reliability mathematical models for the parts of HIRDLS are derived with the help of the reliability block diagrams. A mission time of five years is used for all reliability mathematical model calculations.

7.2.1 Component Failure Rate Model

The mathematical model taken from MIL-HDBK-217F Notice 1, for electronic, and electromechanical, item failure rate estimation is:-

$$\lambda_{Block} = \sum_{i=1}^{i=n} N_i (\lambda_G \pi_Q)^i$$

Where, λ_{Block} is the block failure rate (FITS)

λ_G is the generic failure rate for the i_{th} part (FITS)

π_Q is the quality factor for the i_{th} generic part

N_i is the quantity of the i_{th} generic part

n is the number of different generic part categories

7.3 Reliability Prediction

7.3.1 Sunshield Assembly

The Sunshield reliability block diagram is shown at Figure 6-3. The diagram represents a serial reliability model with three active redundant elements. Failure of any serial path, that includes redundant portions, is postulated to cause complete failure of the sunshield operation. It is

possible that some failure situations will cause degradation of sunshield operation, however a worst case scenario is modelled that assumes catastrophic failures. The reliability mathematical model is as follows:

In general, let R_n represent the block reliability figures in the reliability block diagram.

And, $R_{(S)}$ gives the sunshield reliability:

$$R_{(S)} = R_1 \cdot R_2 \cdot R_3 \cdots R_9 \cdot R_{10} \quad = 0.983055$$

7.3.2 SVA Door

The reliability block diagram for the SVA Door is illustrated at Figure 6-4. Here it is seen that the model is a simple serial arrangement with five blocks that represent hardware boundaries within the HIRDLS instrument. The SVA Door for reliability prediction purposes can be regarded as a 'one shot' device that operates for less than 10 seconds. Failure of any serial path, that includes redundant portions, is postulated to cause complete failure of the SVA operation. It is possible that some failure situations will cause degradation of sunshield operation, however a worst case scenario is modelled that assumes catastrophic failures. The reliability mathematical model is as follows:

$$R_A = R_{11} . R_{12} . R_{13} . R_{14} . R_{15} \quad = 0.999995$$

8. CONCLUSIONS

The requirement for the mechanisms is to have a reliability figure of better than 0.980 (AD1 Section 4.2.8 and AD3 Section 3.7). Both mechanisms have a reliability figure greater than this and are therefore fully compliant.

APPENDIX

COMPONENT FAILURE RATES

PART DESCRIPTION	N	$\lambda \times 10^{-9}$	$N\lambda \times 10^{-9}$
Sunshield Door (1)	1	-	-
Motor (1 redundant winding) (2)	1	100*	100
Gearbox (3)	1	40*	40
Bearing (4)	2	10#	20
Hinge Assembly (5)	2	100#	200
Potentiometer (6)	1	0.054	0.054
Spring, compression (7)	1	10#	10
Latch mechanism (1 redundant heater in HOP) (8)	1	20#	20
Connector, electrical (9)	3	0.55	1.65
Space View Aperture Door (10)	1	-	-
Connector, electrical (11)	1	0.55	0.55
Motor (1 redundant winding) (12)	1	100*	100
Gearbox (13)	1	40*	40

Notes:
a) Numerals in parenthesis relate to the reliability block diagrams.
b) # Failure rates taken from ESA document PSS-01-302.
c) * Failure rates taken from Ford Aerospace document 553942.
d) Unmarked failure rates taken from MIL-HDBK-217F Notice 1, Appendix A.
e) All failure rates are given in FITS.

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3164-0068	II	Document re-written to concur with design changes.	D
3164-00263	II	Subsystem descriptions updated to reflect PFM. Sections relating to heaters removed.	E