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HIGH RESOLUTION DYNAMICS LIMB SOUNDER

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Subject/Title: **SSH LTM Thermal Vacuum and Life Test Report**

Description/Summary/Contents:

The HIRDLS Sunshield Subsystem (SSH) Life Test (LTM), serial number LTM001, was subjected to design qualification and life test. Thermal-Vacuum and Life testing was at RAL and Vibration testing at MMS-P.

The objective of the test program was to subject the SSH to :-

1. Qualification level testes defined in the Sunshield Subsystem Specification and test procedure, and to confirm the ability of the SSH to survive the test and operate within specification.

2. Life test to demonstrate that the tribological elements of SSH meet the on-orbit operating life requirements defined in the Sunshield subsystem Specification and test procedure.

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Keywords: LTM, SSH Assembly, Thermal Vacuum Test, Life Test

Purpose of this Document: Test Report on SSH assembly Thermal Vacuum and Life Tests

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EOS

SSH LTM THERMAL VACUUM AND LIFE TEST REPORT

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NOTE: The appendices shown below have been retained at MMS and are available for inspection on request.

APPENDIX 1 SSH Electrical Pin Survey

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APPENDIX 3 Hinge drive stepper motor count/potentiometer error calibration results

APPENDIX 4 Hinge drive motor thermal time constant characterisation results

1. INTRODUCTION

The HIRDLS Sunshield Subsystem (SSH) Life Test (LTM), serial number LTM001, was subjected to design qualification and life tests. Thermal-Vacuum and Life testing was carried out at RAL and Vibration testing at MMS Portsmouth.

The objective of the test program was to subject the SSH to :-

1. Qualification level testes defined in the Sunshield Subsystem Specification (AD1) and test procedure (AD3), and to confirm the ability of the SSH to survive the test and operate within specification.

2. Life test to demonstrate that the tribological elements of SSH meet the on-orbit operating life requirements defined in the Sunshield subsystem Specification (AD1) and test procedure (AD3).

This report summarise the test results and if any deviations from the procedure.

1.1 Executive summary

The test results confirm HIRDLS SSH has successfully survived the Qualification and Life test programme, and operates without any signifcant change in operating performance.

1.1.1 Qualification test results:

1.1.1.1 SSH Door Opening Operation Torque margins

Hinge bearings and potentiometer - 0.09 Nm
Anti-backlash torsion spring (max. Torque) - 0.70 Nm.

Min. measured overall Torque margin - **2.62**
(Torque margin determined by reducing motor current with resistors in series with motor windings)

Design requirement specified in GSFC 424-11-13-01 (para3.4.5.3)
Minimum test verified torque ratio is - **2.25**
This is the appropiate margin as 88% of resistive torque is the spring load.
Comments
Anti-backlash torsion spring will be redesigned for FM, to eliminate coil binding anomaly
Max.spring torque design target - 0.5 Nm.
This torque reduction would increase overall operating margin to **3.5**

1.1.1.2 SSH Latch Opening Operation Torque margins

Maximum latch operating torque - 0.4 Nm.
Maximum torsion spring torque - 1.4 Nm.
Minimum HOP actuator output torque - 4.0 Nm.

Torque margin - **2.86**

Design requirement specified in GSFC 424-11-13-01 (para3.4.5.3)
Minimum test verified torque ratio is - **2.25**
This is the appropiate margin as 78% of resistive torque is the spring load.
Comments
The HOP Actuator minimum output torque is based on lowest force output at start of operation, when torsion spring torque is at a minimum of 1 Nm and force increases towards the end of stroke.
Note HOP actuator nominal output force is a 1/3 of maximum.

2. APPLICABLE DOCUMENTS

AD1	SP-HIR-50 Issue D	Sunshield Subsystem Specification
AD2	HRIL 100 Issue 1	Sunshield/HDA Assembly
	(HRIL 101 Issue 1	Salvage to HRIL 100)
AD3	TPE-MMS-398 Issue 1	Sunshield Subsystem Test Procedure
AD4	TC-MMS-400 Issue 1	Manual for SSH and SVA Test Equipment
AD5	TR-MMS-412 Issue A	SSH LTM Vibration Test Report
AD6	AIV-98-060-MSC	HIRDLS SSH Thermal Vacuum Test and Life Test Report

3. TEST SPECIMAN

The unit to be tested is the SSH LTM Serial No LTM 001 as defined in drawing (AD2)

4. TEST SEQUENCE

4.1 Preliminary Characterisation Test Results

4.1.1 HDRM Latch Operating Torques

Resistive torque on latch compress seal	0.2Nm
Resistive torque on fully lock door	0.4Nm
Latch torsion spring, Fully open	0.7Nm
Latch torsion spring, Fully closed	0.5Nm

Latch operates acceptably with 1 torsion spring.

4.1.2 Door Hinge Friction Torque

- Resistive torque of both hinges, potentiometer and grounding spring — 0.09Nm
- Detent torque of motor gearhead — 0.16Nm
- HDRM Operating torque
  - Open position - 1.4Nm
  - Closed position 1.0Nm

-

- Latch preload of 30N, deflection measures - HDRM position shimmed to provide this preload — 0.005”
- Force to compress seal at latch — 20N

4.1.3 Electrical Tests

Refer to Appendix 1 for results of SSH Pin Survey.

4.1.4 Grounding

Grounding resistance between door panel and HDA panel terminals was 0.5Ω but hinge plates and latch plate were not grounded, due to insulated finish on the surface of the CFRP .

The surface needs to be abraded locally to remove this finish prior to fitting these items , to ensure complete electrical grounding of all components.

4.1.5 Hinge Backlash

Motor/Gearhead assembly; HRIL 002 had an angular backlash of 0.6°. This variation in angular position exceeds the positional knowledge requirement of the door.

Uprated grounding torsion spring at hinge will be introduced prior to TV/Life test. The spring will bias the door in the closed direction and stabilise the effect of hingedrive backlash.

Introduction of spring will reduce the door opening torque margin, but it will be operating against a known resistive torque.

4.2 Baseline Function Test

4.2.1 HRDM

The HRDM HWA was operated. Deployment/retract times, microswitch operations and thermistor temperatures were recorded with respect to time. The test results were plotted and are contained in Appendix 2.

HWA starts to open latch after 2 min power up, when temperature of HWA reaches 70°C
HWA fully open latch after 3 min power up, when temperature of HWA reaches 95°C

HDRM operates within specification.

4.2.2 Hinge Drive

Brake torque required to overcome powered motor detent - 2.92Nm

Hinge potentiometer resistive torque 0.09Nm

Torque margin = $\frac{2.92}{.09} => 5$

Operation of door under 1g (hinge axis centreline, horizontal) is satisfactory.

Stepper motor count / potentiometer output voltage results were plotted to calibrate the potentiometer errors (using data regression). Results are plotted in Appendix 3

Stepper motor was switched ON and temperature rise was recorded against time.

Start temperature motor	27°C
After 10 mins, motor	43.4°C

Refer to Appendix 4 for thermal characterisation curve
This was considered satisfactory and a maximum temperature operating limit of 60°C was set in the EGSE table.

4.3 Vibration Test (15-20 October 1998)

Refer to SSH LTM Vibration test reports TR-MMS-412 (AD5) for vibration test results.

4.4 Post Vibration Function Test

4.4.1 HDRM

HDRM operation characteristics test results are detailed in Appendix 2

4.4.1.1 Hinge Drive

Hinge drive and microswitch all operated satisfactorily.
Motor step count/potentiometer output voltage calibrated, test results are detailed in Appendix 3

4.4.2 Test Results

The HDRM and hinge drive test results compare favourably with baseline test and show no significant change in operating characteristics.

4.5 Thermal Vacuum Test (9-18th November 1998)

Prior to the thermal vacuum test, the anti-backlash torsion spring was fitted to SSH EM in accordance with Salvage drawing HRIL 101.

Maximum additional resistive torque of torsion spring is 0.7Nm.

The SSH /Fixture interface was reconfigured after initial pump down as the predicted thermal gradient between the chamber cold plate and the SSH aperture plate and door was 90°C. This involved changing the size of bolts to accommodate the relative movement, without stressing the SSH mounting cleats.

The EM unit has been tested in vacuum ($<10^{-5}$ torr) at its upper and lower qualification temperature limits and operated by representative electronics (EGSE Ref. AD4).

The SSH was mounted in the test chamber with the hinge axis vertical and functional tests were performed at the following stages :

- Prior to closing chamber (to verify operating clearances and harness)
- at -35°C
- at +35°C
- at ambient temperature (After 8 thermal cycles)

Refer AD6 RAL test chamber report for thermal vacuum temperature cycling details.

4.5.1.1 HDRM

The HDRM Life Test operations were conducted during this phase of testing.

- 5 operations at -35°C and +35°C.
- Temperature / Time characteristics of HOP actuator and operation of status switches recorded. (see results and plot in Appendix 2)
- 20 operations after 8 thermal cycles at ambient temperature in vacuum.

4.5.1.2 Hinge Drive Operations at 28V

Test Results

	Potentiometer Voltage	Status Switches
@ -35°C		
Door closed (initial)	1.390	OK
Door open prime winding	4.849	OK
Door closed redundant winding	1.390	OK
@ +35°C		
Door closed (initial)	1.388	OK
Door open prime winding	4.851	OK
Door closed redundant winding	1.388	OK
@ +35°C (Post 40°C soak)		
Door closed (initial)	1.388	OK
Door open prime winding	4.865	OK
Door closed redundant winding	1.390	OK
@ -35°C (Re-test post 40°C soak)		
Door closed (initial)	1.390	OK
Door open	4.865	OK
Door closed	1.391	OK
@ Ambient (22°C)		
Door closed	1.388	OK
Prime Door open	4.865	OK
Door closed	1.390	OK

All AD590 thermistors operated satisfactorily.
Potentiometer /Step count calibration were performed at temperature extremes refer to Appendix 3

SSH was inspected and no obvious degradation or damage was noted. All operations were nominal at temperature extremes.

4.6 Life Test

The EM unit has been subjected to a life test that has demonstrated that the tribological elements of the SSH have met the on-orbit operating life.

The life test duration was more than x2 calculated nominal operating cycles. The test set-up was similar to the thermal-vacuum test with the following exceptions :

1. Acceptance level temperature range ±25°C
2. Hinge Drive Speed increased (x2) 40Hz (step rate)
3. EGSE was set on autocycle.

4.6.1 Door Operations

4.6.1.1 Operating Cycles at -25°C

HDRM operated

HWA starts to open latch after 3 min power up, when temperature of HWA reaches 68°C
HWA fully open latch after 4.5 min power up, when temperature of HWA reaches 94°C

- 500 cycles 0° (closed) to 123° (open)
- 3,000 cycles 70° to 123° (open)
- Stepper motor count/potentiometer voltage characteristic. (results and plot in Appendix 3).

Above stages were repeated to achieve 30,000 cycles.

After 12,000 cycles @ -25°C an anomaly was observed as the door ‘juddered’ as it approached the fully open position. The test continued but analysis of the step/potentiometer data errors indicated a worsening trend.

The chamber was opened for inspection of the SSH :

- Small quantity of black debris wre present below the hinge line.
- Door operated at 40Hz, ‘Judder’ was apparent
- Door operated at 20Hz, ‘Judder’ was not noticeable
- Anti-backlash spring was binding between coils
- Application of Braycote 601 grease to spring coils was proposed to isolate the anomoly and would reduce frictional hang-up torque.
- Operation of door was much smoother after re-lubrication, verifing the spring binding theory.
- Step/potentiometer data analysis confirm operational error has returned to normal.
- Continue with test, torsion spring design to be modified for flight model. This anomaly is recorded in QCHR 10601/13.
- Chamber was closed and pumped down to resume test

Torque margin was measured by introducing 3 resistors in series in the motor drive harness to reduce available current to the motor windings. Line to line winding resistance was 111Ω.. 90Ω resistors were fitted in series.

Motor stepping rate set at 20Hz.

Door not quite operating μ switch. Potentiometer reading 4.726

Torque margin is based on resistance change
Nominal winding resistance terminal to terminal = 111Ω

Resistance with additional resistors (2 x 90Ω) = 291Ω
Torque ∝ current ∝ resistance

Therefore Torque margin as measured = $\frac{291}{111} = 2.62$

4.6.1.2 Operating cycles at +25°C

- 500 cycles 0° (closed) to 123° (open)
- 3,000 cycles 70° (closed) to 123° (open)

Stepper motor count/potentiometer voltage characteristic (results and plot in Appendix 3)
Torque margin determined as before, similar result - Torque margin 2.62

Above stages were repeated to achieve 30,000 cycles.

4.6.1.3 Post Life Test Inspection (16 Decmber 1998

The SSH was returned to MMS Bristol for post test inspection and function tests.

- Inspection showed no apparent degradation to SSH
- SSH set up in fixture, hinge and vertical HDRM operated to fully disengage latch, μ switches operate satisfactorily.

Stepper motor drive set to 28V at 20Hz

Operation to open door was steady and even μ switch operates in open position.
Potentiometer reading 4.857.

Door returned to closed position μ switch operates.
Potentiometer reading 1.399

- Operated with 90Ω in-line resistors in drive motor circuit.
    - Door opens fully Potentiometer reading 4.846
    - Door closed potentiometer reading 1.40

- Operation in gravity (1g)
    - Hinge centre line was set horizontal
    - On-line resistors removed
    - Door was opened and closed
    - Door was opened 20° and held with power ON.

Hinge Brake Torque

The following tests were performed to detect any degradation of any tribological elements of the mechanism
The anti-backlash bias spring was removed for this test.

Door at 60° from closed position

Prime winding opening	3.03Nm
Redundant winding opening	3.17Nm
Prime winding closing	3.03 Nm
Redundant winding closing	3.17Nm
Unpowered detent	1.2Nm

Hinge / Potentiometer torque

The hinge drive actuator drive pin was disconnected for this test.

The torque to rotate hinge and potentiometer - 0.076 Nm

Anti-Backlash Bias Spring Torque

The anti-backlash bias spring was refitted and operating torque was measured at the following door positions :

Position	Nm
0° (closed)	0.37
60°	0.65
90°	0.72
120° (open)	0.84

The above torques include the hinge/potentiometer element.
No significant change from initial test results on torsion spring./

4.6.1.4 Test Results

The above results demonstrate that no significant change can be seen in the operational performance of the SSH after being subjected to the Qualification of Life Test.

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