SMEI Flight Model Cameras 1 and 2

Thermal Vacuum Test Report

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1. Introduction

This document describes the test configuration, verifications performed and results obtained in the thermal vacuum acceptance testing of SMEI Flight Model Cameras 1 and 2. These tests were performed using the thermal vacuum chamber at Birmingham University during the period 12th – 19th January 2001.

2. Test Configuration

The two cameras were mounted horizontally in the thermal vacuum chamber with their z-axes (i.e. the Baffle optical axes) and their x-axes (*i.e.* the Door hinge axes) parallel to the thermally-controlled baseplate of the chamber. Each camera was supported at the spacecraft interface surface of the Strong-Box by means of an aluminium spacer plate, a few cm thick, which was attached to the baseplate.

Each camera was covered completely in a tent of MLI in order to ensure the best possible uniformity of boundary temperatures. Since the test was designed primarily as a verification of the camera electronics and mechanisms there was no provision for cooling of the CCD Radiators by means of a “cold wall”.

Six channels of external temperature monitoring were provided on each camera, using thermocouples attached at the following positions:

- Strong-Box spacecraft interface flange
- E-Box (rear end plate)
- Baffle Vane 0 (rear end of Baffle, close to Strong-Box)
- Baffle Front Section (front end of Baffle, close to Door release mechanism)
- Door (centre)
- Radiator (close to Cold Finger interface)

In addition to these external temperature monitors, the internal camera temperature monitors were read via the DHU, although some of these were off-scale during the initial cold switch-on case and during the hot cases. These monitors are located within the cameras at the following positions:

- Radiator (centre)
- CCD (on ceramic package)
- E-Box (on a PCB)
- Mirror Mounting Bracket (within Strong-Box)
- Baffle Front Section

The camera interface connections were routed through an interface plate on the chamber wall to the Flight Model DHU and the instrument EGSE, both installed outside the chamber.

The external LEDs, or “artificial stars”, were installed on the door of each camera. The Bright Object Sensor (BOS) stimulators were attached to the BOS of each camera. Power connections to these devices were routed through an interface plate on the chamber wall to external power supplies.

3. Test Profile

Six complete cycles were performed, with a 24hr cycle time, *i.e.* cold-hot and hot-cold transitions were initiated at approximately 12hr intervals.

The temperature specification for the Strong-Box spacecraft interface plate was -30°C and +61°C for the cold and hot cases, after the initial cold switch-on. These values provided at least 10°C margin relative to the camera operating temperature limits of -20°C to +30°C (Coriolis ICD Sect B9.1).

For the initial cold switch-on (Cold Cycle 1) the Strong-Box spacecraft interface plate was at -43°C, providing more than 10°C margin relative to the camera minimum switch-on temperature of -30°C and some margin relative to the camera minimum non-operating temperature of -40°C (ICD Sect B9.1).

The ramp rate used for transitions between temperature limits was set to the maximum achievable with the facility used, *i.e.* ~ 30°C/hr maximum for cold-hot and ~ 50°C/hr maximum for hot-cold transitions.

During the final cycle (Cold Cycle 6 and Hot Cycle 6), door unlatching tests were performed at the end of the cold- and hot-case functional tests. This required a transition to ambient temperature and pressure to re-latch the HOP actuators between the two parts of the final cycle.

In summary the profile performed was:

- Ambient functional test
- Cold switch-on and functional test at -43°C (Cold Cycle 1)
- Hot functional test at +61°C (Hot Cycle 1)
- Four cycles with cold and hot functional tests at -30°C and +61°C, respectively (Cycles 2-5)
- Cold functional test and door unlatch test at -30°C (Cold Cycle 6)
- Return to ambient to re-latch door
- Hot functional test and door unlatch test at +61°C (Hot Cycle 6)
- Ambient functional test

Following the initial cold switch-on, the cameras were powered continuously during the testing, except for a short period during Cold Cycle 4 when EGSE disk backups were being performed. This was also useful in accumulating burn-in time for both the cameras and the DHU (also powered continuously).

4. Camera Verification Tests

4.1 Analog and Digital Monitor Readings

Although not directly relevant to camera performance, the DHU Analog Monitor readings were recorded at the start of each functional test, to confirm overall functionality of the system.

The camera Analog and Digital Monitor readings were then recorded.

4.2 Bright Object Sensor Tests

The BOS thresholds were checked by varying the input voltage to the BOS Stimulators in order to find the dark-Sun transition levels.

Expected Level = 3.60 V ± 10%

4.3 HOP Actuator, De-Icer Heater and Shutter Motor Tests

The HOP Actuator, De-Icer Heater and Shutter Motor circuits were activated in turn to verify correct currents drawn from 28V bus. In the case of the HOP Actuators, the HOP_TEST command was used (4s pulse only). When the Shutter Motor Phases were tested the Shutter Digital Monitor readings were verified.

Expected values were as follows:

	Input Current (at 28V Bus Voltage)	**Shutter DMON**
HOP Actuators	600 mA ± 20%	N/A
De-Icer Heaters	450 mA ± 20%	N/A
Shutter Motor Phase 0	120 mA ± 20%	Closed
Shutter Motor Phase 1	120 mA ± 20%	Open
Shutter Motor Phase 2	120 mA ± 20%	Closed
Shutter Motor Phase 3	120 mA ± 20%	Closed

4.4 CCD Camera Performance

The current drawn by the camera E-Box was measured during frame readouts and between readouts.

Expected Values = 215 mA ± 10% during readouts
= 195 mA ± 10% between readouts

The primary verification of the CCD and camera readout was performed by making observations in Engineering Mode with each camera in turn. Sample images were checked for:

- Correct frame readout format, *i.e.* correct number of rows and columns, underscan and overscan regions, *etc*.
- Expected structure and amplitude of peak from “Artificial Star”.
- Statistical analysis of pixel amplitudes in a region in the underscan (for readout electronics bias and noise) and in the image region (for dark charge statistics).

Expected values for the statistical analysis were as follows:

	Underscan Region		**Image Region**	
	Mean (ADU)[1,2]	**Sigma (ADU)[3]**	**Mean (ADU)**	**Sigma (ADU)**
Ambient	≈ 1050	< 3.0	~ 1150 - 1250	~ 60 - 100
Cold Case	≈ 1000	< 3.0	Same as u/scan ± 1 ADU	< 3.0
Hot Case[4]	≈ 1700	~ 10	~ 6000 - 7000	Large!

Notes:
1. The specification for readout electronics bias is ≈ 1000 ADU. This value is not critical but ensures that if the bias level drifts slightly it will remain within the ADC dynamic range.
2. There is some drift of readout electronics bias with temperature. This is due to change in DC offsets of the two CCD output nodes. It is not important as it can be corrected for in data analysis.
3. Conversion factor is 1 ADU ≈ 4.5 e^-. Readout noise spec for SMEI is better than 15 e^- rms.
4. In the hot case, performance in the image region is dominated by dark charge.

Observations were made in various other camera modes and shutter positions, including use of the internal “Flat Field” LED, and similar checks to the above were performed on typical images. The cameras were also left in Observing Mode during the transition and soak periods of the test.

5. Test Results

5.1 Temperature Profiles

Plots of the temperature profiles for the external temperature monitors appear in Part B of this report, Pages 1-6. Unfortunately, the data for the final hot cycle (Hot Cycle 6) was lost, although the temperature monitor readings at the time of the last hot-case functional test, door deployment test and the subsequent ambient test were all recorded in the test logs.

Using the MIL-STD-1540C (Sect 3.5.7) requirements for temperature stabilisation in thermal vacuum testing (*i.e.* within ± 3°C of temperature specification and < 3°C/hr rate of change for 30 minutes, *at the unit baseplate*) a soak period of ~ 4-6 hr was achieved in all cases.

5.2 Verification Test Results

Test result sheets appear in Part B of this report, Pages 7-49.

The results conform to the specified functionality and performance requirements given in Sect 4.

During the initial cold switch-on case CCD camera performance was tested, and image data acquired, with CCD temperatures of –33.5°C and –35.5°C for Cameras 1 and 2, respectively. During the subsequent cold-case tests the CCD temperatures were typically –24°C and –26°C, respectively. These values compare with the nominal CCD operating temperature of –30°C. However, it should be noted that CCD dark charge and readout noise performance is essentially unchanged from –10°C to –30°C (or lower) so a useful verification of performance was provided at the temperature achieved (the operating temperature specification of –30°C itself carries a significant margin).

Door unlatch tests were carried out successfully at the end of the final cold-case and hot-case functional tests.

6. Accumulated Burn-In Time

During the testing FM Camera 1, FM Camera 2 and the FM DHU were operated continuously (without failure) during the periods:

Start		**End**		
Date	**Time**	**Date**	**Time**	**Burn-In Time (hr)**
12 Jan 2001	22:30	15 Jan 2001	10:45	60.25
15 Jan 2001	17:55	19 Jan 2001	10:00	88.08
				Total = 148.33

7. Conclusions

The two flight model cameras under test operated correctly within specifications throughout the six cycles of thermal vacuum testing.

Although the CCD operating temperatures in the initial cold switch-on case only carried a small margin relative to the nominal operating temperature of –30°C subsequent door deployment tests are providing a further opportunity to test with the CCD significantly cooler.