HIRDLS

SP-HIR-044

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HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: C. L. Hepplewhite Date: 02-Nov 99

Subject/Title: **In-Flight Calibrator Subsystem Specification Document**

This document is the specification for the in-flight calibrator sub-system.

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Keywords: IFC, Sub-system, Specification, Performance, Verification matrix.

Purpose of this Document: Technical, performance and verification specification

Reviewed by: Date (yy-mm-dd):			

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In-flight Calibrator
Subsystem Specification Document

SP-HIR-044

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HIRDLS Oxford Document Change Record			
Rev #	AN #	pp/s/ll changed	Summary of change
27Aug97	initial		
9Jun98	draft		Whole document revised & updated
11Aug98	draft		review comments from Whitney, Johnosn included.
23Nov98	draft		§3.2.1.1.4 subsumed into §3.2.7.2.5, §3.2.4.6 deleted, §3.2.7.2.1 deleted, §3.2.7.3 heading changed.
2Feb99	draft	§3.2.1.1.2.5 §3.2.1.1.2.6 §4.2 & 4.3	Updated. Heater impedance value updated. Tidied up.
14Apr99	A_draft	Various	Include flow-down & update to 28V -> 15 V heater supply.
15Sep99		3.1.1 3.1.2 3.2.1.1.2.1 3.2.1.1.2.2.5 3.2.1.1.2.4 3.2.1.1.2.6 3.2.1.1.3.4 3.2.1.1.3.5 3.2.3.1.1.3 3.2.3.1.3 3.2.3.3.1	Change “baffle” to “outer cover aperture”. Change “low emissivity” to “low reflectivity”. Delete reference resistor oven, Add small TCR. Add “…in vacuum”. Change temperature range and add second range. Delete reference resistor oven. Delete resistance requirement. Change “baffle” to “outer cover”. Change “emissivity” to “reflectivity”. Change to Supply Tolerance. Delete specification for wires. Update thermal interface requirements.
28Sep99		 3.2.1.1.2.1 3.2.1.1.2.2.5 3.2.1.1.2.2.6 3.2.1.1.2.5 3.2.1.1.3.4 3.2.1.1.5 3.2.3.1.2.2 3.2.4.2 3.2.7.1.1 3.2.7.1.2 3.2.7.1.3 3.2.7.2.4 3.2.7.3.2 & .3 App 2.	Comments from review mtg, 21Sep99 at Oxford Change wording for clarity. Update temperature ranges for each accuracy requirement. Add information on sensor conditioning. Add ref. to ITS para. on stability. Clarification. Delete – ref. Dick Carter. Change heading to ‘word’. Delete paragraph. Clarification: add sine & reference. Update ref. delete last part. Clarification. Tidy up. Tidy up. VCRM Updated
02Nov99			Minor wording changes in response to CDA action items.

1.0 Introduction

1.1 Purpose

This document provides the performance requirements and specifications for the in-flight calibrator (IFC) subsystem. It provides an overview of the IFC function within the HIRDLS instrument and covers interface, functional, performance, and verification requirements.

1.2 Scope

This document defines the IFC subsystem interface, functional, performance, and verification requirements. Performance is understood to be tested given the interface conditions defined in the ICDs. The IFC test plans and specifications are covered by a separate document

1.3 Description

The in-flight calibrator (IFC) is a subsystem that provides a known and adjustable internal source of thermal radiation to the instrument for the purpose of calibrating the radiometer during flight. The radiative source is mounted so that the telescope subsystem can be configured to align its LOS with the clear view of the source aperture, to direct the radiant flux onto the detectors.

2.0 Documents

The following documents, of the exact issue shown, form a part of this document to the extent specified herein.

2.1 Applicable Documents

2.1	SP-HIR-111	Subsystem thermal design & test requirements.
2.2	SP-HIR-216	IFC/STH interface control document.
2.3	SP-HIR-246	IFC/TSS interface control document.
2.4	SP-HIR-266	IFCBB/BEU interface control document.
2.5	SP-HIR-267	IFC/IPS interface control document.
2.6	SP-HIR-013	Instrument technical specification.

2.2 References

2.7	PA-OXF-152	Oxford performance assurance implementation plan.
2.8	TP-HIR-008	HIRDLS performance verification plan.
2.9	TP-OXF-179	IFC test plan.
2.10	SP-HIR-103	Command & Telemetry Handbook.
2.11	SP-HIR-038	IPS requirements & specification.
2.12	TC-HIR-057	System Performance Requirements & Allocation Tables.
2.13	TC-OXF-154	HIRDLS IFC Blackbody Cavity Design.
2.14	TC-OXF-196	IFC Electronics Unit Design.
2.15	SP-HIR-200	Instrument ICD (system section).
2.16	GSFC 422.11.12.10	General Interface Requirements Document.
2.17	SP-HIR-169	Instrument power, grounding and switching requirements.
2.18	SP-HIR-064	HIRDLS Performance Verification Specification
2.19	GSFC 424.11.13.01	HIRDLS Mission Assurance Requirements Document
2.20	SP-HIR-188	HIRDLS Subsystem Environmental Requirements
2.21	PA-HIR-006	HIRDLS Contamination Control Plan

2.3 Precedence

In the event of a conflict between this specification and a referenced document, the contents of this document shall take precedence UNTIL THE CONFLICT IS RESOLVED.

3.0 Requirements

3.1 Sub-System Definition

The IFC subsystem consists of three assemblies; a source of thermal radiation called the IFC Black Body (IFCBB); an electrical assembly called the Blackbody Electronics Unit (BEU) that provides power to the IFCBB heaters and measurement of temperature sensors; and an electrical harness between the IFCBB and the BEU.

The IFCBB is mounted on the TSS OBA. The BEU is mounted on the OBA side of the STH Mid-X panel (the panel dividing the OBA compartment from the electronics enclosure). The IFCBB has one connector on it which the cable between the IFCBB and BEU connects. The BEU has three electrical connectors: one for the harness which connects to the IFCBB and a pair for the harness which connect to the IPU. Figure 1 shows a schematic of the IFC subsystem in relation to the TSS and IPU.

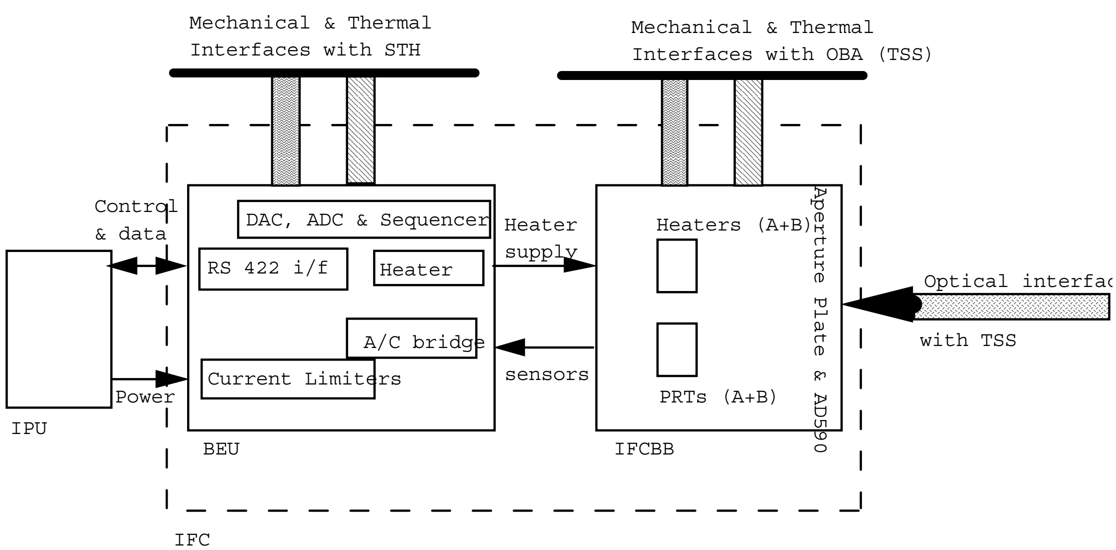

Figure 1
IFC Functional Interface Block Diagram

3.1.1 IFC Black Body Definition

The Black Body provides a source of thermal radiation which is known to high accuracy. Its temperature is controllable by the IPU.

A radiative surface coating is used in the cavity to attain very high emissivity. An outer cover aperture plate is mounted in front of the cavity aperture and provides a thermal contrast between the cavity and its immediate surrounding. This plate temperature is monitored separately from the rest of the IFC subsystem and allows for locating the cavity when steering the scan mirror. This plate is blackened on its external face.

The external surface of the IFC BB is diffuse & low reflectivity.

The IFCBB is designed to have a minimal thermal conductive path to the OBA and incorporates a thermal break internally. This is also true of the electrical connection to the BEU harness. The Black Body cavity is also designed to be radiatively de-coupled from the enclosure and incorporates radiation shields internally. An uncontrolled thermal radiative coupling will exist via the cavity aperture toward the TSS. Therefore radiative and conductive loading at its interface only weakly influences the operating temperature of the cavity.

3.1.2 Blackbody Electronics Unit Definition

The IFC electronics unit (called the BEU), in combination with the IPU, controls the temperature of the IFC Black Body. It is comprised of two fully redundant sides (one side remains “cold” while the other is used. The A and B sides of the BEU are connected to the A & B sides of the IPU respectively with no cross-strapping. The BEU contains a temperature sensor circuit. This circuit employs an AC bridge and full 4-wire measurement is used. In order to achieve a high degree of stability for the accuracy of temperature measurement, a calibration reference resistor is mounted in the BEU. This reference resistor has a very small TCR which ensures the accuracy of the bridge is maintained over the operating temperature of the BEU. The BEU also provides a means of varying the power into the heater coils on the IFCBB in response to a control word from the IPU, and to return monitor/status words to the IPU. The set point determines the duty cycle of the PWM heater to between 0% and a maximum 100 %.

3.1.3 The IFCBB-BEU Cable Definition

The cable which routes power and temperature information between the BEU and the IFCBB is specially made to meet the requirements of the temperature sensing circuits, and has particular EMI shielding requirements. See ref. 2.4. The cable shall be constructed to the routing diagram, ref. 2.8.

3.2 Characteristics

The IFC shall meet all requirements defined in the following subparagraphs after exposure to the non-operating environments defined in Section 3.2.7.1 and while being exposed to the Operating Environments defined in Section 3.2.7.2.

3.2.1 Performance

3.2.1.1 Thermal characteristics

The IFCBB shall have the thermal characteristics as defined in the following subparagraphs.

3.2.1.1.1 Heat Capacity

The estimated thermal heat capacity of the IFCBB is approx. **570** J/K.

3.2.1.1.2 Thermal control & monitor

3.2.1.1.2.1 Cavity Brightness Temperature

The expected normal operational temperature range for the black body cavity is between 278 K [+5 C] and 298 K [+25 C]. Additionally, the IFC, in conjunction with commands from the IPU, shall be capable of controlling the IFCBB cavity temperature to 318 Kelvin [+45 C] (ITS §4.6.7.1) in vacuum. This is for occasional mirror emissivity calibration purposes.

3.2.1.1.2.2 Radiometric Temperature Sensors

The IFC shall contain two redundant sets of three temperature sensors on the IFCBB, each set shall consist of two on the base and one on the side.

3.2.1.1.2.2.1 Type

The IFC Radiometric Temperature sensors shall be Rosemount 118MK500A platinum resistance.

3.2.1.1.2.2.2 Temperature Sense Circuit

The BEU temperature sensing circuit is an A.C. bridge running at 125 Hz.

3.2.1.1.2.2.3 Sensor Power Dissipation

The power dissipation in any one PRT shall be less than or equal to 250 μW.

3.2.1.1.2.2.4 Sensor Resolution

The IFC shall be capable of monitoring the Blackbody temperature with a resolution of 0.005 K or less **.**

3.2.1.1.2.2.5 Sensor Absolute Accuracy

The IFC shall be capable of monitoring the Blackbody temperature with an absolute accuracy of ±0.04 K over the black body temperature range 278 K to 298 K and BEU range 283 K to 308 K, and ±0.07 K over the BB range 273 to 318 K for the same BEU temperatures, over the lifetime of the instrument defined in 3.2.9, (ITS §4.6.7.2) and meets these requirements after exposure to survival environments applied for up to 24 hours.

3.2.1.1.2.2.6 Sensor Thermal Conditioning

The temperature range over which the IFCBB sensors will be conditioned is determined by the expected temperature range to which the IFCBB is likely to be exposed at any time following the initial calibration at subsystem level. This temperature range is –40 C to +65 C.

3.2.1.1.2.3 Housekeeping Temperature Sensors

The IFCBB front plate shall incorporate redundant AD590 temperature sensors.

3.2.1.1.2.4 Reference Resistors

The BEU incorporates a Vishay precision reference resistor mounted in its own capsule.

3.2.1.1.2.5 Black Body Temperature Uniformity & Stability

The requirement on the uniformity of the IFCBB emission over the aperture is that the maximum unsigned difference in brightness temperature between any two points in the aperture shall be less that 0.001 K. This uniformity may be influenced if there are time varying temperatures within the cavity. The cavity is designed to minimise these gradients.

The IFC black body effective aperture temperature shall not change by more than 20 mK per minute during normal operation in Mission Mode ref. ITS §4.6.5.4. By design the IFCBB has a long thermal time constant relative to the sampling period and is thermally isolated from its thermal environment.

3.2.1.1.2.6 Black Body Heater & Heater Power

The IFC shall incorporate two identical redundant heaters on the IFCBB each capable of producing 0.9 ± 0.1 Watts of heat into the Blackbody cavity.

3.2.1.1.3 Optical & Radiometric Requirements

The principal optical interface to the IFCBB is to the calibration mirror of the TSS. The IFC shall conform to the optical and radiometric requirements defined in the following subparagraphs. Note that there is a requirement on the knowledge of the IFC calibration mirror temperature (ITS 4.6.7.2).

3.2.1.1.3.1 Black Body Aperture

The IFCBB aperture shall be 15.0 mm square and clocked as defined in the TSS/IFC ICD (ref. 2.3).

3.2.1.1.3.2 Black Body Cavity Emissivity

The IFC BB cavity shall have an effective emissivity of not less than 0.997 (ITS § 4.6.4) over the lifetime of the instrument defined in 3.2.9.

3.2.1.1.3.3 Black Body Spectral Range

The IFC emissivity defined in 3.2.1.1.3.2 shall apply over the spectral range of 6-18 microns.

3.2.1.1.3.4 Black Body Cavity to Aperture Plate Temperature Difference

The contrast between the clear aperture of the cavity and the outer cover shall be capable of attaining >1K, to permit checking of the LOS alignment with respect to the aperture during operation in the instrument.

3.2.1.1.3.5 Emissivity of Black Body External Surfaces

The external surface of the IFCBB including the front plate shall be of low and diffuse reflectivity.

3.2.1.1.4 <reserved>

3.2.1.1.5 <reserved>

3.2.2 IFC States of Operation

The IFC shall have the operational states defined in reference 2.10. These are summarised in the following subparagraphs for information.

3.2.2.1 Power off

No power applied to the IFC, no output signals, undetermined temperature.

3.2.2.2 Warm up/Cool down

Power is applied, and the IFC is on, control and telemetry is activated, the BB heater is activated, the calibration resistor oven is activated. Steady state thermal conditions have not been achieved following power-up or a change in temperature set-point or power level setting.

3.2.2.3 Operational

The IFC BB temperature has reached its set point and is stable, the calibration resistor temperature is stable, all functions valid.

3.2.2.4 IFC states to instrument mode correlation

Instrument Mode	IFC state
Off	Power off
Survival	Power off
Idle	Power off

Low power	Power off
Standby 1	Undefined
Standby 2	Warming
Mission mode	Operational

3.2.3 Interfaces

The functional, physical, and test interfaces are specified in the following subparagraphs.

3.2.3.1 Electrical Interfaces

The IFC shall be designed with two fully redundant sides. One being cold spared during operation. The "A" side of the IFC shall interface with the "A" side of the IPU and the "B" side of the IFC shall interface with the "B" side of the IPU. The IFC shall conform to all electrical interfaces defined in the IFC/IPS ICD (ref. #2.5) and the BEU/IFCBB ICD (ref. #2.4). Further, the IFC shall conform to the command formats defined in section 2.6 of the C&TH (ref. #2.10).

3.2.3.1.1 Electrical Power Interfaces

The IFC shall operate within specification when supplied with ±15V and+5V by the IPU as defined in section 3.2.2 of the IFC/IPS ICD (ref. #2.5).

3.2.3.1.1.1 Power Consumption

The IFC power consumption shall not be greater than:

Supply rail		+5	+15	-15	Volts
IFC power		0.30	2.35	1.90	Watts

3.2.3.1.1.2 Impedances

The IFC impedances shall be as defined in section 3.2.2 of the IFC/IPS ICD (ref. #2.5)

3.2.3.1.1.3 Supply Tolerance

The IFC shall function within specification during application of voltage on all supply rails over the maximum range of values specified in the IFC/IPS ICD (ref. #2.5) for an indefinite period.

3.2.3.1.1.4 Abnormal supply

The IFC is not protected against the application of power of reverse polarity.

Unannounced removal of power does not cause any failures in the IFC nor leave it in an unstable state. However, the IFC requires the ±15V and +5V supplies to be applied simultaneously in order for the power-on reset to function correctly.

3.2.3.1.1.5 Transients

The IFC is part of the load on the IPU, there is therefore no GIRD requirement for turn on/off transients to be applied to the IFC.

3.2.3.1.1.6 Secondary Power Isolation & Bonding

The IFC structure shall not be used to carry power nor signal returns. The isolation of the power and signal ground and structure shall be at least 1 MΩ and less than 1 μF when the circuit ground connection is removed.

The bonding method will achieve an RF impedance of less than 500 mΩ at 1 MHz. The IFCBB and BEU shall provide ground bonding as specified in the ICDs (ref. 2.5 and 2.3).

Connector back-shells shall provide bonding to chassis as specified in the ICDs (ref. 2.5 and 2.3).

3.2.3.1.2 Electrical Control Interfaces

The control and data interface shall consist of three TIA/EIA-422B circuits, as defined in section 3.2.3 of the IFC/IPS ICD (ref. #2.5).

The control lines from the IPU to the IFC are the clock (IFC_CLOCK) at 20 kHz, the control (IFC_CONTROL) for serial data, the activation (IFC_ENVELOPE) to define the type of data to be transferred. A control word transmitted to the IFC by the IPU provides up to 256 set points in the operating range of the heater controller.

In addition there is a synchronisation signal from the chopper control unit called (IFC_SYNC) at 500 Hz for locking the PWM and a.c. resistance bridge supply. This sync. will also be supplied on the TIA/EIA 422 interface.

3.2.3.1.2.1 Telemetry

The IFC shall have a serial telemetry line (IFC_DATA) for confirmation of receipt by the BEU of the control word, and status transfer to the IPU. Specifications for the data line shall be as defined in section 3.2.3 of the IFC/IPS ICD (ref.#2.5).

3.2.3.1.2.1.1 Telemetry Timing

The IFC shall conform to the telemetry timing diagrams defined in section 3.2.3.5 of the IFC/IPS ICD (ref. #2.5).

3.2.3.1.2.2 Digital data word

The IFC shall produce a single 24 bit word upon demand from the IPU at the IPU clock rate.

3.2.3.1.3 Connectors & Harnesses

The IFC design shall conform to the connector types and function/pin locations defined in section 3.2.5 of the IFC/IPS ICD (ref. # 2.5) and the IFCBB/BEU ICD (ref. #2.4)

For reference this information is provided below.
One harness (U15) is used for electrical interface connection between the IFC and IPU to carry the A and B sides of the BEU, signal and power. There are two connectors on the IFC supplied by the harness; the J631P for A-side power and communications and J633S for B-side power and communications. These are specified in the IFC to IPS ICD ref. 2.5.

There is a separate single harness (U25) used to interface the BEU and the IFCBB with a connector on the BEU and connector on the IFCBB. The harness connects to both sets of the redundant heater and sensors on the IFCBB.

3.2.3.1.4 Floating Conductors

There shall be no floating conductors that are not enclosed in a conducting enclosure in the IFC subsystem. There shall be no unused wires or conductors and all printed wiring boards shall be free of loose, ungrounded conductors in the IFC.

3.2.3.2 Mechanical Interfaces

The IFC subsystem shall conform to the envelope specifications defined in the STH/IFC ICD (ref. #2.2) and the IFC/TSS ICD (ref. #2.3)

3.2.3.2.1 IFC to STH Mechanical Interface

The IFC subsystem shall conform to all mechanical interfaces defined in the IFC/STH ICD (ref. #2.2).

3.2.3.2.2 IFC to TSS Mechanical Interfaces

The IFC subsystem shall conform to all mechanical interfaces defined in the IFC/TSS ICD (ref. #2.3)

3.2.3.3 Thermal Interfaces

The IFC subsystem shall conform to the thermal interface specified in SP-HIR-111 (ref. #2.1).

3.2.3.3.1 IFCBB to TSS Thermal Interface

The IFCBB cavity shall be thermally isolated from the OBA as specified in the IFC/TSS ICD ref. 2.3. Thermal energy is transferred to the instrument cavity radiatively through the cavity aperture. The remainder of the external surfaces have a conductive path to the TSS mounting face and a radiative path to the enclosure and run at a temperature close to ambient.

3.2.3.3.2 BEU to STH Thermal Interface

The BEU shall be thermally coupled to the STH by conduction through the mounting feet. The external faces of the BEU box shall be gold plated.

3.2.3.4 Venting

The BEU shall vent through its base and through the STH panel, see ref. 2.2.
The IFCBB cavity will vent through the cavity aperture, the rest of the structure will vent through its base, see ref. 2.3.

3.2.4 Physical Characteristics

3.2.4.1 Mass

The Mass of the IFC shall be no greater than:

IFCBB	0.7 kg
BEU	2.4 kg
Cables	0.4 kg
Total Mass (Cable included)	3.5 kg

3.2.4.2 <reserved>

3.2.4.3 Structural Design Requirements

The Structural design of the IFC shall conform to the interface design limit loads requirements of the ITS section 3.6.3.2 .

3.2.4.4 Strength of Materials

The IFC shall be designed to withstand qualification acceleration levels defined in sp-hir-188 (ref. 2.20) without experiencing any rupture, buckling, material failures or permanent deformation. Calculations shall be based on the minimum material condition.

3.2.4.5 Storage

Storage environments shall be considered in the design of the IFC. The IFC shall not be required to withstand environments more severe than the non-operating environments as specified in section 3.2.7.1.

3.2.4.6 <reserved>

3.2.4.7 Health and Safety

The IFC shall be designed in accordance with the safety restrictions of the Oxford PAIP (ref. #2.7).

3.2.5 Reliability

The IFC shall have a reliability factor of >0.990 for a 5 year mission, (ref. 2.6, ITS table 5.1-3). This reliability shall not be degraded because of the shelf life requirements specified in 3.2.9.1 or the verification test requirements specified in section 4.

The reliability shall be determined by analysis and shall include failure modes and effects, identification of critical items per the MAR section 7.2.1, in addition a parts stress analysis with appropriate de-rating verification will be undertaken. Test data will be used to support reliability assessment where appropriate.

There are no mechanically operating nor limited life items in the IFC.

Materials that are used in the IFC or for its development with limited shelf life will be identified and controlled in accordance with the manufacturer's specifications.

3.2.6 Maintainability

The IFC shall not require maintenance and/or adjustments.

3.2.7 Environmental Conditions

The IFC shall perform as specified herein after exposure to all natural and induced environments experienced during manufacture, test, transportation, handling, storage and during pre-launch, ascent, and on-orbit operations.

3.2.7.1 Non-operating/Survival Conditions

The IFC shall perform as specified herein after exposure to the non-operating/survival environments listed in the following subparagraphs.

3.2.7.1.1 Random & Sine Vibration

The IFC shall perform to the requirements in this document after exposure to the specified random and sine vibration levels as specified in sp-hir-188 (ref. 2.20).

3.2.7.1.2 Shock

The IFC shall perform to the requirements in this document after exposure to the specified shock level as documented in ref. 2.20. The shock requirement as specified in GIRD 10.4 is induced external to the instrument.

3.2.7.1.2 Thermal

The IFC shall perform as specified herein after exposure to non-operating and survival temperatures defined in section 4.3 of this document.

3.2.7.1.3 Humidity

The IFC shall perform as specified herein after exposure to specified relative humidity conditions of transportation and ELV launch in the range 0 % to 65 % R.H.

3.2.7.1.4 Launch Pressure Decay

The IFC assemblies shall survive without degradation the launch pressure profile specified in the GIRD ref. 2.16 of 1.0 kPa/s. Enclosed volumes shall be vented, see section 3.2.3.4.

3.2.7.2 Mission Operating Environments

The IFC shall be capable of performing as specified herein while being subjected to the on-orbit operational environments defined in the following subparagraphs.

3.2.7.2.1 <reserved>

3.2.7.2.2 On-Orbit Acceleration (On Orbit)

The IFC shall be capable of performance as specified in §3.2 and subparagraphs during exposure to the manoeuvring accelerations of 0.015 g as specified in GIRD section 10.3.

3.2.7.2.3 On-Orbit Vibrational Environment

The IFC shall be capable of performance as specified in §3.2 during exposure to on-orbit vibrations as specified in. Low level vibrations do not affect the performance of the IFC.

3.2.7.2.4 On-Orbit Thermal Environment

The IFC shall perform as specified herein during exposure to operational temperatures between 0 degrees C and +30 degrees C. This range includes the required +/- 10 C test margins.

3.2.7.2.5 Total Ionizing Dose and High Energy Radiation

The IFC shall operate to specification in the radiation environment specified in ref. 2.18 (GIRD) **with the given amount of shielding afforded by the structure**. The BEU shall not be susceptible to latch-up in the specified ionising radiation environment.

3.2.7.2.6 Atomic Oxygen

The IFC shall meet all performance requirements during exposure to the atomic oxygen environment specified in GIRD Section 10.10

3.2.7.3 Ground Operations & Test Environment

3.2.7.3.1 Pressure

The IFC shall be capable of full operation during exposure to standard laboratory atmospheric pressures.

3.2.7.3.2 Temperature

The IFC shall be capable of full operation during exposure to BEU box temperatures up to +45 C.

3.2.7.3.3 Relative Humidity

The IFC shall be capable of full operation during exposure to relative humidity ranging from 0% to 65%.

3.2.8 Cleanliness

The IFC shall meet particulate and condensable emission requirements described in the Oxford PAIP and the CCP (ref. 2.7).

3.2.8.1 Particulate Levels

The external surfaces of the IFC shall meet the following particulate cleanliness levels per paragraph of the HIRDLS Contamination Control Plan (PA-HIR-006) at delivery to the Instrument Integrator:

IFCBB	Mil-Std 1246C Level 250
BEU	Mil-Std 1246C Level 300
Cable	Mil-Std 1246C Level 300

3.2.8.2 Non-volatile Residue

The IFC shall be Mil-Std 1246 Level A at delivery to the Instrument Integrator.

3.2.9 Useful Life

3.2.9.1 Shelf Life

The IFC shall have a shelf/storage life of not less than one (1) year when stored in sealed bags with a desiccant (ref. ITS §3.13.3).

3.2.9.2 Operating Life

After receipt at the HIRDLS instrument integration and test facility, the IFC shall have a lifetime of not less then seven (7) years of operation without performance degradation (ref. ITS §3.13.2). Two years are allocated for integration, test, calibration and spacecraft integration, and 5 years for mission life.

3.3 Parts and Materials

3.3.1 Parts and Materials Selection

All parts, materials, processes and fabrication methods shall conform to the PA requirements as specified in the Oxford PAIP (ref. 2.7).

The specifications and standards for the procurement of materials and parts, the processing, assembly and the control of parts and assemblies will be as described in the Oxford PAIP and references therein and include traceability and certification of raw materials, stress corrosion resistance, vacuum out-gassing, flammability. Custom devices in the IFC include the inductive voltage dividers which will be fabricated in accordance with MIL-STD-981 or GSFC 311-INST-001 as appropriate.

The EEE parts will be used in accordance with the derating guidelines of the PPL and will have the appropriate radiation tolerance required for their application in the specified ionising environment. Extra screening, DPA or verification will only be implemented where agreed with the PCB.All parts, materials and processes will be declared to the Project Office.

Fasteners and lubricants will be selected for their suitability of application in the IFC for space use. There are no lubricants used in the IFC.

3.3.2 Acceptance Screening of Non-metallic

All non-metallic materials used in the IFC shall be shown to meet, as a minimum, the requirements of Total Mass Loss (TML) <1.0% and Collected Volatile Condensable Material (CVCM) <0.1% when tested in accordance with ASTM E595.

3.3.3 Outgassing

At delivery to the Instrument Integrator, the IFC shall have an outgassing rate $<1\times10^{-11}$ g/cm^2*sec **(TBV)** from all surfaces onto a Thermal-electrically Controlled Quartz Crystal Microbalance (TQCM) or equivalent.

3.3.4 Flammable materials

There are no flammable materials used in the IFC.

3.4 Electromagnetic Compatibility

The design of the IFC shall be compliant with the levels of conducted and radiated electromagnetic disturbances follows:.

3.4.1 Conducted Susceptibility

The power supply to the IFC is supplied from the IPU, therefore the IFC conducted susceptibility on the power leads will comply with the specified IPU supply characteristics. The IFC shall be tested in accordance with MIL-STD-462 CS02.

3.4.2 Radiated Emissions

The IFC will conform to the requirements for radiated electric field emissions for the instrument per MIL-STD-462 RE02 respectively.

3.4.3 Radiated Susceptibility

The IFC will conform to the requirements for radiated magnetic and electric field susceptibility for the instrument per MIL-STD-462 RS01 and RS03 respectively.

3.4.4 EMI/EMC & Grounding & Shielding

Grounding and shielding will be implemented to comply with the instrument subsystem grounding & shielding requirements (ref. 2.19). The EMI shield will be continuous from the IFCBB through the harness and back-shells to the BEU.

Connector shells shall be at mechanical ground and electrically bonded to the box. Cable shields shall be bonded to the cable shells at both ends of the cable.

3.5 Storage Containers

Storage containers shall meet requirements of GSFC 424-11-13-01, Mission Assurance Requirements for the HIRDLS Instrument.

3.6 Identification and Markings

The individual Units of the IFC (IFCBB, BEU, Cable) shall be permanently marked in a conspicuous area with the part number, serial number, configuration identifier and the drawing number, as a minimum. The connector plugs and receptacle shall be clearly labelled with the identifications specified in the ICDs. Marking and identification for traceability shall be in accordance with the EOS MAR Section 8.4. Materials used for marking and identification shall comply with the contamination control requirements of this specification.

3.7 Use of Metric Components

All interface hardware used in the IFC, including threaded fasteners, shall conform to standard ISO metric sizes and specifications. In the event of the unavailability of appropriate metric hardware, exceptions to this requirement will be considered on a case-by-case basis.

3.8 Use of Système International (SI) Units

All deliverable documentation pertaining to the IFC interface details, including, but not limited to, drawings, analysis and trade-off reports, handbooks, procedures, test plans, test results, operating manuals, and math model outputs, shall present all technical data, parameters, dimensions, and equations in SI units per ISO 1000.

4.0 Quality Assurance Provisions

4.1 General

Quality Assurance provisions shall be as specified herein and in accordance with the MAR (ref. #2.19) and the Oxford PAIP (ref. #2.7). Certain quality assurances are required to support the reliability of the IFC operating for an extended time in a space environment. Qualification and acceptance testing of the IFC shall be combined into a single test program entitled Protoflight Tests (4.3). The IFC shall be considered ready for flight upon successful completion of inspection, analysis, and tests, as specified in this section, which verifies conformance to the requirements specified in Section 3.

It is not a requirement that Oxford implement an accredited ANSI Q9001 system of quality management, however, the QA system used at Oxford will, where practical, be of a comparable level as the same.

4.1.1 Responsibility for Tests.

Unless otherwise specified, testing shall be conducted at the IFC RO's facility in accordance with an approved Test and/or Verification Plan and Acceptance Procedures as defined in section 6.4.1 of the Performance Verification Plan (ref. #2.8). The IFC RO shall be responsible for designing and performing all qualification tests of the IFC.

4.1.2 Special Tests and Examinations.

4.1.2.1 Components and Subsystems.

Prior to assembly, all active components, subassemblies, and assemblies shall be inspected, tested, and accepted in accordance with their respective specifications or drawings. Selection of any new parts or components shall also necessitate inspection and acceptance in accordance with their specifications and drawings.

4.1.2.2 Environmental Stress Screening.

The purpose of Environmental Stress Screening is to stress the hardware to identify failed and weak parts and workmanship defects. Environmental stress screening shall be performed in accordance with Oxford PAIP (ref #2.7) at the component, module and subassembly level as deemed appropriate and with the approval of the HIRDLS program office.

4.1.2.3 Engineering Development Tests and Evaluations

Measurements, tests and evaluations shall be used for obtaining design parameters and for confirming that the IFC subassemblies will meet the performance and safety requirements specified herein before protoflight testing.

4.2 Quality Conformance

4.2.1 Methods of Verification

The requirements of Section 3 of this specification shall be verified by the methods defined below and as itemised in Table 4.2.1. Formal verification testing (protoflight tests) shall be performed in accordance with section 4.2.

4.2.1.1 Inspection (I)

This method involves examining an item against the applicable documentation to confirm compliance with the requirements. This method also involves physically examining the article to ensure conformance with envelope, mass, and electrical grounding requirements.

4.2.1.2 Analysis (A)

This method consists of interpreting or interpolating/extrapolating analytical or empirical data with reference to defined conditions or analytical procedures to ascertain theoretical compliance with stated requirements.

4.2.1.3 Test (T)

This method entails performance of a functional operation under specific conditions. Instrumentation and special test equipment, or both, shall be used to generate, acquire, and record data. This method shall also include analysis of test data.

4.2.1.4 Demonstration (D)

This method of verification involves performance of a functional operation under specific conditions in a Pass/Fail scenario. Instrumentation and special test equipment, or both may be used to generate, acquire, and record data which will be used to determine if the instrument performance lies within the required range.

4.2.1.5 Not Applicable (N)

Use of the term “not applicable” shall be limited to those paragraphs/paragraph headings for which there is no method of verification or where verification is specified in subparagraphs.

4.2.1.6 Similarity (S)

Verification is achieved by substantiated argument that the item is sufficiently similar to another one already having been verified and approved for use in a comparable environment and comparable application as the one intended, otherwise of appropriate heritage.

4.2.2 Verification Tests

This section describes which tests and verifications are required for the delivered IFC in the various phases of the program. Unless otherwise specified, the tests shall be conducted in the order given. Details of the verification methods are given in section 4.3.

4.2.2.1 Component Verifications

Prior to assembly of the IFC, the components shall be tested for compliance with the requirements as defined in their respective specifications or drawings.

4.2.2.2 Instrument Level Pre-test Inspection

Before testing, the IFC shall be inspected for compliance with the requirements listed in Table 4.2.1 under Method of Verification: Inspection. The following physical properties as defined in section 4.2.4.1.1 of the Performance Verification Specification (ref. # 2.18) shall be verified:

a. Mass Properties: The mass of each of the IFC Units shall be measured. The allowable tolerance on the sum total masses in excess of those specified in Section 3.2.2.1 is +/- 0.02 Kg or +/-1.0%, whichever is greater.

b. Center of Mass: The canter-of-mass locations of each of the IFC Units shall be determined either by test or analysis. The allowably tolerance shall be +/- 0.30 cm in each of three orthogonal axes.

c. Geometry: The geometry of each of the IFC Units, including size, shape, and volume shall be verified by inspection to comply with the drawings specified in Section 3.1.5.2.

d. Mechanical Interface: The mechanical interface of each of the IFC Units shall be verified for compliance with the envelope drawings specified in Section 3.1.5.2.

4.2.2.3 Design Verification

A set of activities will be identified to provide the means to demonstrate that the IFC design will comply with the requirement described in this document. These activities will include design and flight acceptance for the expected specified structural loads, vibro-acoustic vibration and shock. The design levels will be applied at 1.25 times the levels for flight acceptance as specified in section 3.2.7.1 of this document.

There are no mechanisms in the IFC requiring functional test and qualification.

4.2.2.4 Reporting

The requirements that are verified by analysis shall be documented by Analysis Reports; the reports shall be available prior to the start of the environmental tests.

All tests and test results will be reported by means of logbooks or documented reports as appropriate.

4.3 Proto-Flight Tests

The IFC shall be subjected to the protoflight tests specified herein. The test sequences shall be as shown in Figure 4.3. Prior to the start of the environmental testing, the IFC shall have satisfied the inspection and analysis requirements of section 4.2.1 and the complete functional test requirements of Section 4.3.1.

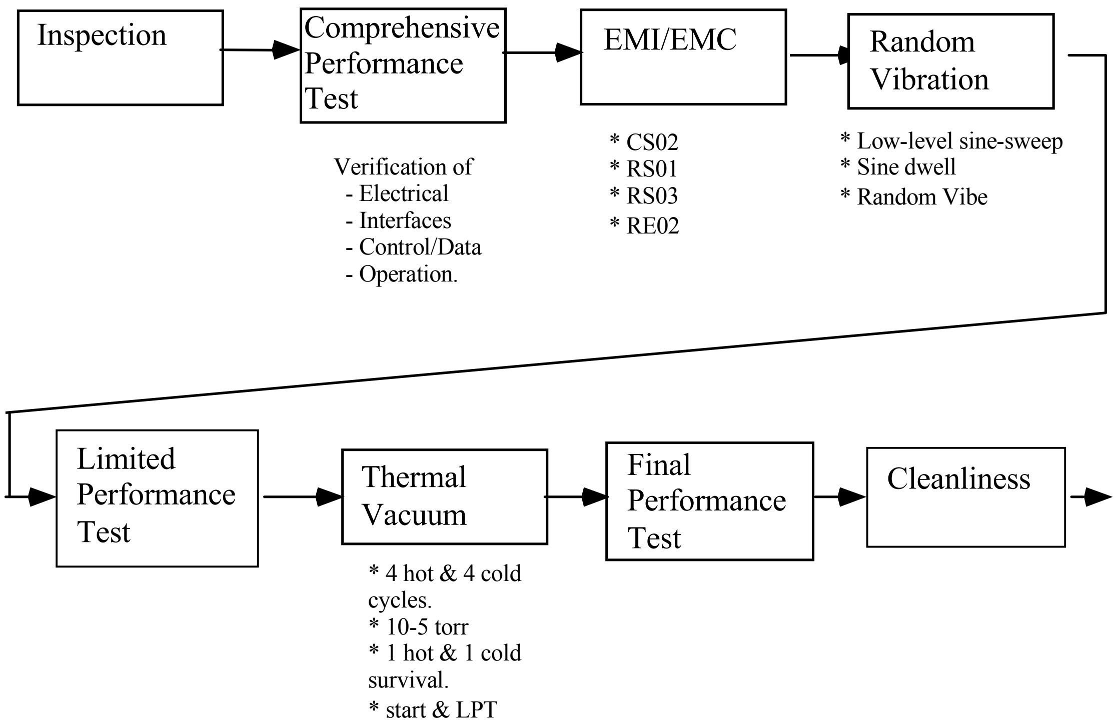

Figure 4.3
IFC Test Sequence

4.3.1 Demonstrations and Functional Tests

The following demonstrations and functional tests shall be performed on the IFC to verify the functional performance requirements of section 3.

4.3.1.1 Electrical Interface Tests

The IFC shall be subjected to a series of electrical interface tests in accordance with the Performance Verification Specification (ref. #2.18). These tests shall be conducted to verify that all interface signals meet the requirements defined in the ICDs and are within acceptable limits of the applicable performance specifications. The electrical harness shall be tested to verify proper routing of electrical signals, continuity and High Potential (High-Pot) isolation.

4.3.1.2 Comprehensive Performance Test

The comprehensive performance tests of the IFC shall include sufficient tests in order to verify all performance characteristics of section 3.2.1 of this document over the range of interface conditions detailed in section 3.2.3. The test details are given in the IFC Test Plan; ref. 2.9.

4.3.1.3 Limited Performance Test

The limited performance tests of the IFC shall include sufficient tests in order to verify a sub-set of the performance characteristics of section 3.2.1 of this document at a prescribed point in the operating range. The test details are given in the IFC Test Plan; ref. 2.9 but include the following items:

Verify the heater control function; verify the temperature measurement function; Check the control and data interface.

4.3.1.4 Final Performance Test

The final performance tests of the IFC shall include sufficient tests to verify a sub-set of the performance characteristics detailed in section 3.2 of this document for the purposes of checking the sub-system before and after a period such as storage or shipping. The test details are given in the IFC Test Plan; ref. 2.9.

4.3.2 Environmental Testing.

The IFC shall be subjected to the sequence of environmental tests specified in Figure 4.3 (IFC Test Sequence). The following subparagraphs describe the individual environmental tests.

4.3.2.1 Random Vibration Test.

The IFC shall undergo Random Vibration testing as defined in section 4.2.4.1.3.1 of the Performance Verification Specification (ref. #2.18). This testing shall be as follows.

The random vibration input levels for the IFCBB and BEU shall be as specified in the HIRDLS Subsystem Environmental Requirements document (SP-HIR-188). Testing shall be conducted with the subsystem, or unit, secured at its mounting locations to the shaker armature using a test fixture or fixture combination. Random vibration shall be applied to the subsystem, or unit, for a duration of 1 minute in each of three mutually orthogonal axes. Vibration shall be measured and controlled with an accelerometer mounted on the vibration test fixture near one of the instrument mounting points. At the completion of the test, the instrument shall be visually examined for evidence of damage or permanent deformation.

4.3.2.2 Thermal Balance Test

The validity of the IFC thermal design and Thermal Model shall be demonstrated by subjecting it to a thermal balance test in accordance with the Performance Verification Plan (ref. #2.8). During this test the IFC shall be configured and operating in its “Operational State” as defined in section 3.1.4.3. This test shall occur at 3 (TBV) temperatures and may be combined with the Thermal-Vacuum Test.

4.3.2.3 Thermal-Vacuum Test

The IFC shall undergo Thermal-Vacuum testing in accordance with the Performance Verification Specification (ref. #2.18) This testing shall be as follows.

The IFC shall be subjected to a 4 1/2 cycle thermal-vacuum test. The test shall commence with a “hot” cycle and shall conclude with a “hot” cycle. The temperature levels required for verification of the IFC, shall be as specified in the HIRDLS Subsystem Environmental Requirements document (SP-HIR-188). The test profile is depicted in Figure 4.3.2.3. The pressure shall be $5x10^{-6}$ Torr ($6.64x10^{-4}$ Pascal’s) or less. The IFC shall be configured and operating in its “Operational Mode” except during periods of Hot and Cold survival temperatures. The cycling test environment shall be initiated by a high temperature soak. Each cycle shall include a 4-hour soak at the high and low-temperature levels. Limited Performance tests shall be conducted for each subsystem at the extremes of the operating temperature range during the first and last thermal cycles, following the Hot and Cold starts, and during one Hot-to-Cold and one Cold-to-Hot transition. The transition between extreme temperature levels shall be made at a maximum rate of 20.0 deg. C per hour. The last three cycles shall be failure free.

4.3.2.3 Outgassing Verification

The IFC shall undergo Outgassing verification in accordance with the Performance Verification Specification (ref. #2.18) This verification shall be as follows.

Verification of the IFC outgassing rate defined in paragraph 3.3.3 shall occur by test at vacuum with the IFC at its highest operational temperature +10C in accordance with the requirements defined in the HIRDLS Contamination Control Plan (PA-HIR-006). This verification can be included as part of the subsystem Thermal-vacuum testing as shown in Figure 4. 3.2.3The subsystem Outgassing test shall incorporate a quartz crystal microbalance (QCM) and cold finger during outgassing testing as defined in paragraph 9.4 of the MAR (GSFC 424-11-13-01) or an equivalent method. During Outgassing testing the TQCM shall be held at 10°C below the minimum on-orbit operating temperature of the Unit under test.

4.3.2.3.1 Vacuum Chamber Requirements:

At a minimum, vacuum chambers used for Thermal Vacuum Testing of the IFC shall meet the requirements of §4.3.2.3.7.1.

4.3.2.3.2 Control of Molecular Contamination:

At a minimum, test conditions in §4.3.2.3.7.2 shall be observed to minimise the re-distribution of contamination during vacuum testing of IFC hardware.

4.3.2.3.3 Control of Particle Contamination:

At a minimum, test conditions in §4.3.2.3.7.3 shall be observed to minimise the re-distribution of contamination during vacuum test operations involving IFC hardware.

4.3.2.4 EMI/EMC Test

The IFC shall undergo EMI/EMC testing for radiated emissions, conducted emissions, and conducted susceptibility in accordance with the Performance Verification Plan (ref. #2.8).

4.3.2.5 Failure-free Operation

At the conclusion of the performance the IFC shall have demonstrated failure-free performance testing for at least the last 100 hours of operation as required by section 4.2.4.1.3.4 of the Performance Verification Specification (ref. #2.18). Failure-free operation during the subsystem thermal-vacuum test exposure is included as part of the demonstration. Major hardware changes during or after the verification program shall invalidate previous demonstration.

4.3.2.6 Environmental Test Equipment Tolerance.

Unless otherwise specified, test apparatus shall be capable of controlling test conditions within the following tolerances of specified or equivalent units

a. **Temperature:** ± 2 °C or ± 5 % of difference from 21 °C, whichever is greater.
b. **Pressure:** ±200Pa or ±5%, which ever is greater, greater than 1 atm, + 10 Pa for less than 1 atm.
c. **Relative humidity:** 5 %
d. **Vibration frequency (hz):** ±2% or ±1 Hz, whichever is greater.
e. **Time period:** ±5%.
f. **Random vibration acceleration (g, RMS):** ±10%
g. **Acceleration spectral density (g^2/Hz):** ±3 dB.
h. **Heat flux (W/m-s):** ±10% or ±0.5 W/m^2-s, whichever is greater.
i. **Controlled rate of re-pressurization** □ 1 torr/minute.

4.3.2.7 Variation of Data During Environmental Tests.

To establish whether the IFC performance has degraded, data shall be taken in all states before and after exposure to environmental tests. The initial data taken prior to the environmental tests are to be used as baseline values to which those data taken after environment testing will be compared. The subsequent data set(s) shall not vary from the baseline values by more than a statistically significant amount. This variation is to account for variability in tests results due to ground support equipment.

4.4 General Test Requirements

The following subparagraphs shall apply to the test activity.

4.4.1 Test Equipment Accuracy's

The test equipment shall be calibrated in accordance with MIL-STD-45662. Unless otherwise noted, the test equipment inaccuracies shall contribute no greater than 10 percent of the tolerance of the parameter being measured.

4.4.2 Electro-Static Discharge

During test, development and handling the electronics of the IFC full electrostatic discharge control and prevention procedures will be implemented.

4.4.3 Performance Test Procedures

The verification testing to be performed on the IFC as described above will be arranged and documented in a procedure which includes the sequence of events and method of exercise.

5.0 Preparation for Delivery, Shipping, Handling & Storage

5.1 Safety & Hazards

Packing, shipping and handling procedures will include appropriate hazard identification and safety management.

There are no hazardous materials, equipment or procedures associated with the IFC development programme.

5.2 Delivery

There will be a pre delivery review and acceptance data package which shall contain sufficient data to allow the recipient to check for survival of shipping.

5.3 Shipping, Storage & Handling and Procedures

The subsystem shall be cleaned in accordance with the Oxford PAIP ref. 2.7 prior to packing. The first level of packing will be a sealed clean-compatible bag and box.

Electrical connectors shall be capped, harnesses and other movable/flexible parts supported, apertures closed with caps/covers. Physical contact with other sensitive surfaces shall be minimised.

The shipping container shall conform to the requirements of the Oxford PAIP ref. 2.7. It will provide sufficient rigidity, bracing, cushioning to support and protect the sub-system during normal transit conditions. It shall provide for purging and sealing against exposure to water or other volatile contaminants.

The inner bag/box shall be mounted so that it can easily be manually extracted from the shipping container.

Procedures for removing packing and undertaking initial visual inspection shall be provided.

All procedures will be approved in advance of exercising by the responsible engineer as described in the Oxford PAIP.

The shipping box shall be appropriately marked and labelled.

Appendix 1 - Acronyms and Definitions

AIT	Assembly integration & test.
BEU	(IFC) black body electronics unit.
BMU	(IFC) blackbody mechanical unit (= IFCBB)
BOL	beginning of life
CCB	Configuration control board.
CCP	(Oxford) Contamination Control Plan
EMC/EMI	Electromagnetic compatibility/interference
EOL	end of life
ESD	electrostatic discharge
GIRD	General Interface Requirements Document
ICD	interface control drawing/document
IFC	in-flight calibrator (subsystem)
IPS	instrument processor subsystem
IPU	Instrument processor unit.
ITS	instrument technical specification
LOS	line of sight
LSB	Least significant bit.
MSB	Most significant bit.
OBA	optical bench assembly
PAIP	product assurance implementation plan
PRT	platinum resistance thermometer
PSS	Power subsystem.
SE	System engineer
SEE	Single event effect
SEU	Single event upset
SSD	subsystem specification document
TBC/D/V	to be confirmed/decided/ verified
TCR	Temperature coefficient of resistance.
TM	Technical manager
TSS	telescope subsystem

Appendix 2 - Verification Cross Reference matrix

The following abbreviations are used in the Requirements/Verification Cross-Reference Matrix (VCRM). Header sections marked by “ --“.

Column 3, “Method”, specifies verification method as follows:

Notation	Meaning	Defined in section
I	inspection	4.2.1.1
A	analysis	4.2.1.2
T	test	4.2.1.4
D	demonstration	4.2.1.3
N/A	not applicable	4.2.1.5
S	similarity	4.2.1.6

Column 4, “Item”, specifies the level of assembly at which the verification is performed, as follows:

Notation	Meaning
SS	Applied to complete IFC sub-system
A	Assembly: IFCBB, BEU or U25.
SA	Sub-Assembly or functional block
C	Component or part

IFC SSD para.	Paragraph Heading	Method	Item
3.1	SUB-SYSTEM DEFINITION	--	--
3.1.1	IFC Black Body Definition	I	A
3.1.2	Blackbody Electronics Unit Definition	I	A
3.1.3	The IFCBB-BEU Cable Definition	I	A
3.2	CHARACTERISTICS	--	--
3.2.1	Performance	--	--
3.2.1.1	Thermal characteristics	--	--
3.2.1.1.1	Heat Capacity	A	A
3.2.1.1.2	Thermal control & monitor	--	--
3.2.1.1.2.1	Cavity Brightness Temperature	A/T	A
3.2.1.1.2.2	Radiometric Temperature Sensors	I	SA
3.2.1.1.2.2.1	Sensor Type	I	C
3.2.1.1.2.2.2	Temperature Sense Circuit	--	
3.2.1.1.2.2.3	Sensor Power Dissipation	T	A
3.2.1.1.2.2.4	Sensor Resolution	A/T	SS
3.2.1.1.2.2.5	Sensor Absolute Accuracy	T	SS
3.2.1.1.2.3	Housekeeping Temperature Sensors	I	C
3.2.1.1.2.4	Reference Resistors	--	--
3.2.1.1.2.5	Black Body Temperature Uniformity & Stability	A/T	A
3.2.1.1.2.6	Black Body Heater & Heater Power	T	SS
3.2.1.1.3	Optical & Radiometric Requirements	--	--
3.2.1.1.3.1	Black Body Aperture	I	A
3.2.1.1.3.2	Black Body Cavity Emissivity	A/T	A
3.2.1.1.3.3	Black Body Spectral Range	A/T	C
3.2.1.1.3.4	Black Body Cavity to Aperture Plate Temperature Difference	A	A
3.2.1.1.3.5	Emissivity of Black Body External Surfaces	I	A
3.2.1.1.5	Emitted Disturbances	D	SS
3.2.2	IFC States of Operation	D	SS
3.2.2.1	Power off	D	SS
3.2.2.2	Warm up/Cool down	D	SS
3.2.2.3	Operational	D	SS
3.2.2.4	IFC states to instrument mode correlation	--	--

3.2.3	Interfaces	--	--
3.2.3.1	Electrical Interfaces	I/T	SS
3.2.3.1.1	Electrical Power Interfaces	T	SS
3.2.3.1.1.1	Power Consumption	T	SS
3.2.3.1.1.2	Impedances	T	SS
3.2.3.1.1.3	Supply Tolerance	T	SS
3.2.3.1.1.4	Abnormal supply	D/T	SS
3.2.3.1.1.5	Transients	T	SS
3.2.3.1.1.6	Secondary Power Isolation & Bonding	T	A
3.2.3.1.2	Electrical Control Interfaces	T	SS
3.2.3.1.2.1	Telemetry	T	SS
3.2.3.1.2.2	Digital data rate	T	A
3.2.3.1.3	Connectors & Harnesses	I/T	A
3.2.3.1.4	Floating Conductors	I	A
3.2.3.2	Mechanical Interfaces	I	A
3.2.3.2.1	IFC to STH Mechanical Interface	I	A
3.2.3.2.2	IFC to TSS Mechanical Interfaces	I	A
3.2.3.3	Thermal Interfaces	I	A
3.2.3.3.1	IFCBB to TSS Thermal Interface	A/I	A
3.2.3.3.2	BEU to STH Thermal Interface	A/I	A
3.2.3.4	Venting	I	A
3.2.4	Physical Characteristics	--	--
3.2.4.1	Mass	I	A
3.2.4.2	Center of Mass	A/I	A
3.2.4.3	Structural Design Requirements	A/T	A
3.2.4.4	Strength of Materials	A/D	C
3.2.4.5	Storage	I/D	--
3.2.4.7	Health and Safety	D	SS
3.2.5	Reliability	A/S	SS
3.2.6	Maintainability	I	SS
3.2.7	Environmental Conditions	D/T	A
3.2.7.1	Non-operating/Survival Conditions	--	--
3.2.7.1.1	Random Vibration	T	A
3.2.7.1.2	Shock	T	A
3.2.7.1.2	Thermal	T	A
3.2.7.1.3	Humidity	D/T	A/C
3.2.7.1.4	Launch Pressure Decay	A	A
3.2.7.2	Mission Operating Environments	A/T	A
3.2.7.2.2	On-Orbit Acceleration (On Orbit)	A/T	A
3.2.7.2.3	On-Orbit Vibrational Environment	A/T	A
3.2.7.2.4	On-Orbit Thermal Environment	A/T	A
3.2.7.2.5	Total Ionising Dose and High Energy Radiation	A/T	A/C
3.2.7.2.6	Atomic Oxygen	D	A
3.2.7.3	Ground Operations & Test Environment	D	A
3.2.7.3.1	Pressure	D	A
3.2.7.3.2	Temperature	D	A
3.2.7.3.3	Relative Humidity	D	A
3.2.8	Cleanliness	--	--
3.2.8.1	Particulate Levels	I/T	A
3.2.8.2	Non-volatile Residue	T	A
3.2.9	Useful Life	--	--
3.2.9.1	Shelf Life	D	SS
3.2.9.2	Operating Life	D	SS
3.3	PARTS AND MATERIALS	--	--
3.3.1	Parts and Materials Selection	I	C
3.3.2	Acceptance Screening of Non-metallic	I	C
3.3.3	Out-gassing	D	C
3.3.4	Flammable materials	I	C
3.4	ELECTROMAGNETIC COMPATABILITY	--	--
3.4.1	Conducted Susceptibility	T	SS

3.4.2	Radiated Emissions	**T**	**SS**
3.4.3	Radiated Susceptibility	**T**	**SS**
3.4.4	EMI/EMC & Grounding & Shielding	**T**	**SS**
3.5	STORAGE CONTAINERS	**I**	**--**
3.6	IDENTIFICATION AND MARKINGS	**I**	**--**
3.7	USE OF METRIC COMPONENTS	**I**	**--**
3.8	USE OF SYSTÈME INTERNATIONAL (SI) UNITS	**I**	**--**
5.0	PREPARATION FOR DELIVERY, SHIPPING, HANDLING & STORAGE	**--**	**--**
5.1	SAFETY & HAZARDS	**I**	**SS**
5.2	DELIVERY	**I**	**SS**
5.3	SHIPPING, STORAGE & HANDLING AND PROCEDURES	**I**	**SS**