Herschel SPIRE

Detector Subsystem
Specification Document

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Issue: 3.2

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Document Status Sheet:

Document Title: Herschel SPIRE Detector Subsystem Specification Document			
Issue	**Revision**	**Date**	**Reason for Change**
1.1		16 June 2000	
1.2	Made into spec for all units of detector subsystem and compatible with IRD	4 July 2000	
1.3	Combine comments from Bruce and Jamie, redefine terminology.	10 July 2000	
1.4	Further finessing.	17 July 2000	
1.5	Include CRR RFA.	2 August 2000	
1.6	Change wording in section 3.1.	3 August 2000	
1.7	Changes to DRCU specifications in response to detector meeting.	1 March 2001	
1.8	Change to DRCU specifications, detector specifications sections.	2 April 2001	
1.9	Add section 2.4	17 April 2001	
2.0	Moved Rec/Dels (section 2.4) to BA. DRCU specs revised with CEA input. Updated ADs and RDs.	20 June 2001	
3.0	Various minor revisions and additions to requirements. Feedhorn and bolometer specifications updated. Vibration level specifications updated.	6 Sept. 2001	Comprehensive update prior to NASA CDR and start of CQM hardware manufacture.
3.1	Added reference to technical note on detector arrangements Electronics specifications reviewed by CEA/JPL/RAL at detector closeout meeting on 6 November 2001 Changes to specification as detailed in change sheet	19 Feb 2002	Tidying up sections edited at closeout meeting on 6 November 2001 This version will be issued for the IBDR
3.2	Updated as per HR-SP-RAL-ECR-042 and HR-SP-RAL-043	7 January 2003	See ECRs and change notice below

This document is now under configuration and change control. The following is a list of TBCs in Issue 3.0 which are to be closed out before manufacture of the relevant parts of the BDA hardware.

BDA-WIR-01	Harness definition document compatibility
BDA-STR-01	BDA interface plate movement compensation
BDA-STR-05	Maximum movement of BDA under mechanical failure
BDA-ITR-02	300-mK filter interface
Section 3.4.1	Feedhorn waveguide diameters
Section 3.4.2	Array pixel layout

Issue 3.1 closed all TBCs above.

Document Major Change Record:

Document Title: Herschel SPIRE Detector Subsystem Specification Document	
Document Reference Number: SPIRE-JPL-PRJ-000456	
Document Issue/Revision Number: 3.1	
Section	**Reason For Change**
3.3.2.6	DRCU requirements table updated to incorporate changes agreed at Nov. 2001 Detector Summit meeting
3.4.1	Detailed changes to feedhorn specifications in change request HR-SP-JPL-ECR-001
1.3.2	Replace technical note in RD9 with controlled ICD
3.1.1	JFET-PER-01 – Change from minimum performance of 10 to 15 nV/rt(Hz)
3.1.3	JFET-TEC-05 - Clarification of compliance – only at noise given by JFET-PER-01 minimum performance

Document Title: Herschel SPIRE Detector Subsystem Specification Document	
Document Reference Number: SPIRE-JPL-PRJ-000456	
Document Issue/Revision Number: 3.2	
Section	**Reason For Change**
3.1.1	Detailed changes to noise values to reflect double side band de-modulation BDA-PER-02 and Table 3-1-1 – see HR-SP-RAL-043
3.1.1	Detailed changes to optical efficiency numbers (BDA-PER-03; BDA-PER-04 and BDA-PER-05) to reflect latest measurements. – see HR-SP-RAL-042
3.1.2	Move BDA-FUN-04 to section 3.1.1 to reflect status as performance requirement.
3.1.3	Add note on temperature at which JFETS will be optimised
3.2.1	BDA-SAF-06 is deleted
3.3.2.5	Temperature sensitivities in table 3-3-4 updated to reflect increased white noise as per HR-SP-RAL-043
3.3.2.6	Add new requirement on DC offset BDA-DRCU-27
3.3.5	Add two new requirements BDA-ISY-03 and 04 to reflect number of thermal cycles andneed for inspection on receipt of hardware
3.4	Note on waiver against vibration levels added
3.4.1	Detailed changes to backshort distances

1 Introduction

1.1 Purpose of the document

This specification defines the requirements applied to the performance, design, qualification, and interfaces of the SPIRE detector subsystem. It is applicable to the STM, the CQM, the PFM and the FS as described in this document.

1.2 Acronyms and Abbreviations

1.2.1 Acronyms

Acronym	Meaning
AD	Architectural Design
ATP	Acceptance Test Plan
AVM	Avionic Model
BDA	Bolometric Detector Assembly
CPP	Common parts Procurement
CQM	Cryogenic Qualification Model
DCU	Detector Control Unit
DDD	Detailed Design Document
DQE	Detective Quantum Efficiency
DRCU	Detector Control and Readout Unit
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
ESA	European Space Agency
FIRST	Far InfraRed and Submillimeter Telescope
FPS	Focal Plane Structure (mechanical housing)
FPU	Focal Plane Unit
FS	Flight Spare
IBDR	Instrument Baseline Design Review
ICD	Interface Control Document
ICDR	Instrument Critical Design Review
IRD	Instrument Requirements Document
ISVR	Instrument Science Verification Review
JFET	Junction Field Effect Transistor
JPL	Jet Propulsion Laboratory
NA	Not Applicable
NEP	Noise Equivalent Power
LIA	Lock-In Amplifier
PA	Product Assurance
PFM	Proto Flight Model
SPIRE	Spectral and Photometric Imaging REceiver
STM	Structural Thermal Model
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written

1.3 References

1.3.1 Applicable Documents

Document Reference	Name	Number/version/date
AD1	SPIRE Instrument Requirements Document	SPIRE-RAL-PRJ-000034 Issue 1.0, 23 Nov. 2000
AD2	ICD Structure – Mechanical I/F	SPIRE-MSS-PRJ-000617 Issue 1 April 2001

1.3.2 Reference Documents

Document Reference	Name	Number/version/date
RD1	SPIRE A Bolometer Instrument for FIRST (The SPIRE proposal to ESA) *The SPIRE Consortium*	SPIRE-RAL-PRJ-000020
RD2	SPIRE Harness Definition Document	SPIRE-RAL-PRJ-000608
RD3	JPL Environmental Requirements Document	JPL-D-19155
RD4	JPL Test Plan	JPL-D-20549
RD5	Detector Subsystem Interface Control Document	JPL-D-21995
RD6	Herschel-SPIRE Business Agreement: *Provision of Hardware for the Detector Subsystem of Herschel-SPIRE*	SPIRE-UCF-PRJ-000822 September 6 2001
RD7	BDA, JFET, and RF Module Shipping, Handling and Integration Procedures	JPL-D-***** (TBD by JPL)
RD8	SPIRE Filter Specifications Document	SPIRE-CDF-PRJ-000454
RD9	BDA Mechanical Interface Drawing	Drawing No. 10209721

2 Subsystem Description

The SPIRE instrument is designed to observe astronomical sources in the 200 to 670 μm waveband. To accomplish this it will use bolometric detector arrays based on silicon nitride "spider web" absorbers with NTD germanium thermistors. The detectors will have feedhorn focal plane optics to efficiently couple the radiation from the SPIRE optics onto the bolometers.

The detector sub-system for SPIRE contains five Bolometric Detector Assemblies (BDAs) – three for the SPIRE photometer and two for the spectrometer:

P/LW – Long wavelength photometer array
P/MW – Medium wavelength photometer array
P/SW – Short wavelength photometer array
S/LW – Long wavelength spectrometer array
S/SW – Short wavelength spectrometer array

These arrays are cooled to an operating temperature of close to 300 mK by means of thermal straps to a ^{3}He sorption cooler. Electrical cables connect the BDAs to the JFET readout modules. As the JFET box is located outside of the 4 K structure, the cables must be routed through the 2 K and 4 K structure and out to the JFET modules. A mechanical interface defines the mounting of JFET modules into the JFET housing. The electrical outputs from the JFET modules connect to a wiring harness that leads from the optical bench to hermetic connectors at the wall of the Herschel cryostat, and then to the SPIRE warm electronics units. Electrical signals from the JFETs are amplified and conditioned by the Detector Control Unit (DCU), which is a sub-unit of the Detector Readout and Control Unit (DRCU). A block diagram of the SPIRE detector sub-system is shown in Figure 2.1, indicating those units which are the subject of this specification document. A block diagram of the SPIRE instrument is shown in figure 2.2 to indicate the relationship between the detector subsystem and the other sub-systems within the instrument. A description of the detector technology may be found in Turner *et al*., 2001, *Applied Optics*, **40**, 4291, 2001.

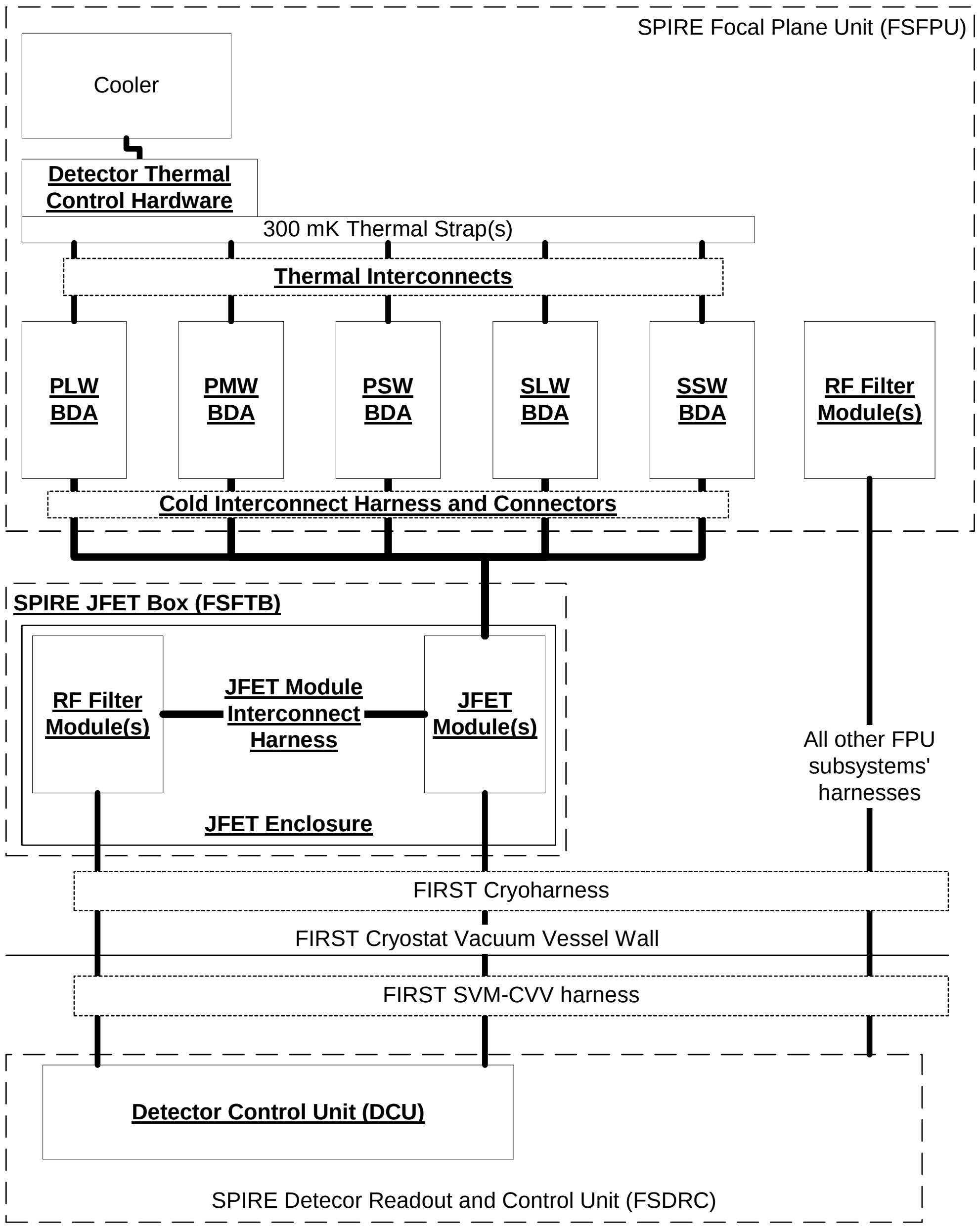


Figure 2-1: Block diagram of the SPIRE detector sub-system. The units that are indicated in underlined bold text belong to the detector subsystem and are the subject of this specification document.

2.1 Design

2.1.1 Bolometer Detector Assembly

The BDA is designed to accommodate a focal plane array of bolometric detectors operating at a temperature of close to 300 mK. The detectors couple to the cold optics of the SPIRE instrument via an array of feedhorns mounted in front of the detector array. The feedhorns concentrate sub-millimeter radiation onto the detectors, and define the detector field of view. A band-defining sub-millimeter filter is located over the feedhorn apertures at 300 mK. The focal plane array is mechanically supported and thermally isolated from the 2-K environment by a low-conductivity kevlar suspension system. The kevlar suspension must meet the tight thermal and mechanical requirements of the SPIRE instrument. The focal plane arrays are cooled to close to 300 mK by means of thermal straps to the ^{3}He sorption cooler which attach to the BDAs at a defined location. A flange at 2 K provides the mechanical interface for the BDA to mount onto the 2-K structure.

The bolometric detectors are addressed by cryogenic readout cables, routed from the 300 mK focal plane array to the bottom 2-K surface. The 2-K surface serves to enclose the back end of the focal plane array from straylight. Connectors will be located at the 2-K surface to allow for ready integration into the instrument.

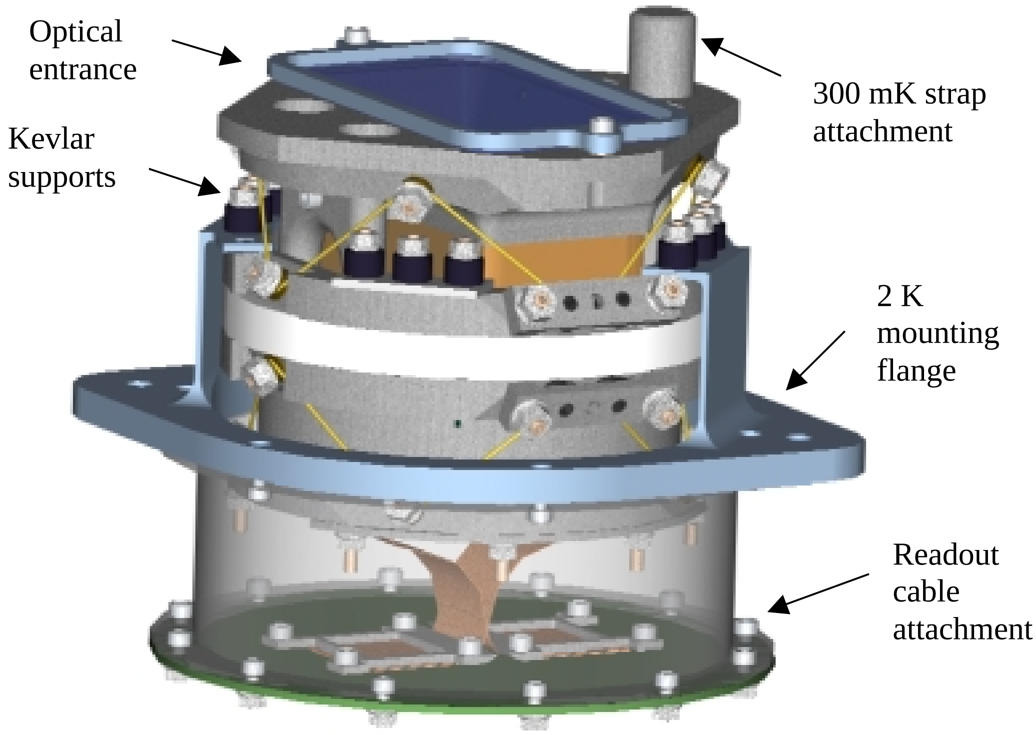


Figure 2-2: Schematic BDA Mechanical Design
(Note: this diagram is somewhat out of date but representative of the essential features of the BDA.)

2.1.2 JFET Amplifier Modules

The detector signals are power amplified by cryogenic JFET modules located at the Herschel cryostat Level-2 temperature – nominally between 9 and 15 K. These modules house 24 dual JFETs that meet the tight thermal dissipation and noise specifications of the SPIRE instrument. The JFET modules are mounted into a housing at a mechanical interface defined by a mounting flange and connector interface. The JFET module is designed to attenuate thermal radiation from the 120-K JFETs by means of a light wall. Passive RF filter components located on circuit boards inside the module housing provide RF attenuation coming from the output cables. Output connectors interface to the cryogenic wiring harness going to the CVV connectors and then the warm electronics.

2.1.3 RF Filter Modules

In addition to the JFET modules there will also need to be passive RF filter modules present on all power; bias and heater lines entering the JFET Box. These will be housed in modules similar in design to the JFET modules but with only passive components. All subsystem wiring entering the FPU enclosure will also require RF filtering. These modules will be identical to those used in the JFET box and will be provided as part of the Detector Subsystem.

2.1.4 JFET Box Mechanical Enclosure

The JFET modules and RF filter modules will be mounted on the Herschel optical bench in a mechanical enclosure close to the SPIRE FPU structure. This enclosure will interface to directly to the Herschel cryostat Level-2 temperature stage – at about 10 K – and will also provide a mechanical interface between the SPIRE FPU structure and the JFET modules through which the cold interconnect harness can be supported.

2.1.5 JFET Box Interconnect Harness

Any connections between the RF filter modules and the JFET modules in the JFET box will be made by use of a dedicated internal harness. This harness will be isothermal and can therefore be implemented in standard copper wire technology.

2.1.6 Cold Interconnect Harness and Connectors

Readout wires for each detector are fanned out at the focal plane array and wire bonded to a load resistor module located inside the BDA at 300 mK. The signal lines then connect to lithographed kapton cables connected to an alumina fanout located at the 2-K surface at the bottom of the BDA. Connectors located at the 2-K surface allow for ready mounting and demounting of the BDA. Low-conductivity cables connect the outputs of the BDA to the JFET modules, and run from the 2-K structure to the 4-K structure to the JFET modules. Intervening connectors are required to allow for integration of the cables into the instrument. The outputs of the JFET modules pass through RF filters and connect to the wiring harness. Detector bias, JFET power, and JFET heater power pass through separate, redundant RF filters and connect on a backplane connector into each JFET module. Separating these lines simplifies the wiring harness and reduces electrical cross talk.

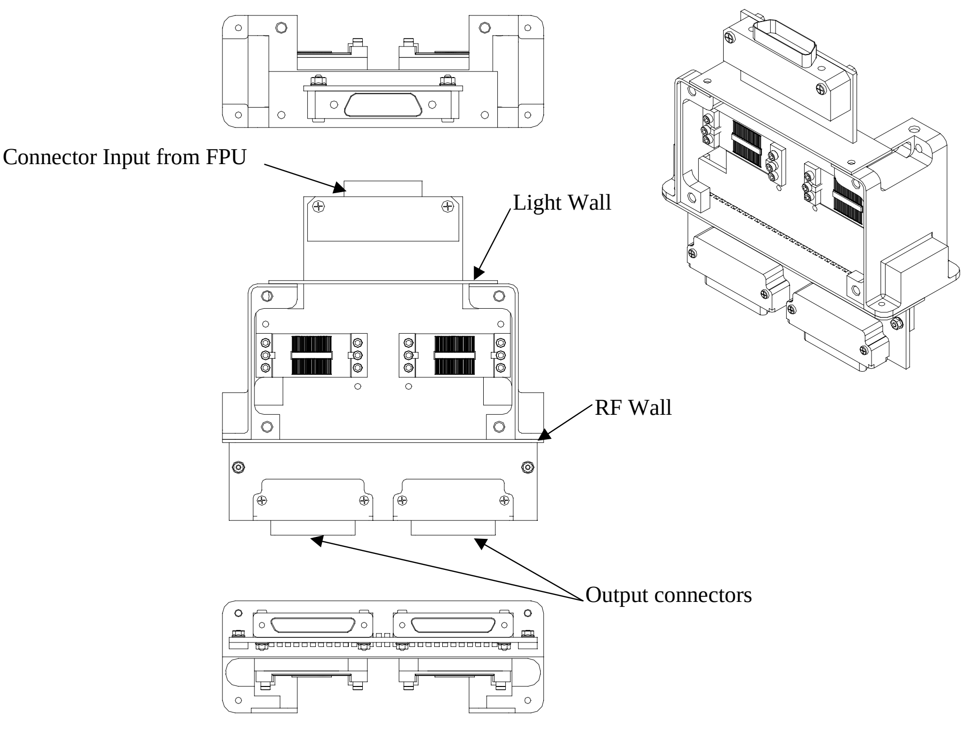


Figure 2-3: Schematic mechanical design of 2 JFET modules

2.1.7 Detector Readout

The BDA arrays are read out using an AC bias and demodulation supplied by the warm DRCU (see Fig. 2-4). The AC bias modulates the signal at 50 – 300 Hz, above the 1/f knee of the JFET amplifiers and readout electronics. This relaxes the noise requirements on the JFETs, which could not be met at the audio frequencies of the detectors at the power dissipations allowed. Each BDA receives an independent bias. The warm electronics also supply power and heater lines for the JFET modules. Because the bias and JFET power lines represent single-point failures for many detectors, they are designed to be redundant.

2.1.8 Thermal Interconnects

The BDAs are mounted on the 2-K instrument structure up to 50 cm from the cold tip of the ^{3}He cooler. This necessitates the use of thermal straps between the cooler and the BDAs. These are considered part of the SPIRE structure for the purposes of subsystem definition. However, there does need to be a connection made between the thermal straps and the BDAs. The hardware associated with this connection (a copper mounting point) is part of the detector sub-system.

2.1.9 Thermal Control Hardware

If the ^{3}He cooler can meet the requirements placed on it in this document, there should be no need to have active control of the detector temperature. However, if, following the development phase of the instrument, there is a requirement for active control of the detector temperature, then the cold hardware for this will be provided as part of the detector sub-system. The cold hardware will consist of NTD germanium thermistors in a bridge arrangement and resistive heaters.

2.1.10 Cold Detector Simulator

The cryoharness to be provided by ESA for the Herschel cryostat, and the one to be provided for the AIV cryostat, will need to be tested to ensure that they are compatible with the requirements of the detector subsystem. To allow this, a cold detector simulator will be built that will have the same electrical (noise, impedance etc.) characteristics as the detector subsystems as seen by the cryoharness. This will most likely consist of resistors in one or more JFET module housing(s) that will have the same noise and impedance characteristics when cold and the same interface to the cryoharness. The Structural Thermal Model of the JFET modules may be used for this unit.

2.2 Mission Profile

The proto-flight model of the detector subsystem units will be designed to permit 2 years of storage on ground at room temperature in the appropriate environmental conditions (as specified in RD3), 3 years use (in vacuo, cold) on the ground, and 4.5 years in orbit.

2.3 Product Tree

The instrument models define the functionality of the hardware delivered by JPL. The STM model of the instrument will be used to characterise the thermal and mechanical performance, and to verify the electrical properties of the cold harnesses. The hardware required must therefore be thermally and mechanically representative. In addition, a full electrical harness is required, and the BDAs and JFETs must provide electrical equivalents for verification of the cryo-harnesses. JPL will supply one suspended BDA for testing in the STM FPU.

The CQM instrument is used to verify the optical and electrical performance of the instrument, and to determine potential problems with interference of various sub-systems. One operational photometer BDA with associated JFETs is deemed sufficient to characterise operation of the photometer, and two spectrometer BDAs with associated JFETs are deemed sufficient to characterise operation of the spectrometer. Temperature control will not be implemented in the CQM instrument, although data collected may indicate the need to implement temperature control in the PFM and FS instruments.

The PFM and FS instruments are to be fully operational. The FS instrument will incorporate CQM hardware delivered by JPL. A full tabulation of the delivered and received hardware and documentation is found in the Business Agreement.

3 Specification

3.1 Functional

The functional requirements on the arrays are divided into three categories: minimum performance, achieved performance to date, and design value.

Minimum performance values are quoted for information, and are based on achieved or design values with margin. Performance levels that have been achieved to date are also indicated for information. The design values approach, and are generally compliant with, the performance levels defined in the Instrument Requirements Document. For this issue of the specification document there is insufficient data on whether the design values will be met in the course of the flight model build programme. A margin will be held on all mass, thermal and power budgets at the level of the instrument as a system. If any of the required performances are not met by the flight model units the consequences will be evaluated against the impact on the performance of the instrument as a whole and extra resources allocated or the instrument specification adjusted to reflect the new situation.

3.1.1 Performance Specification

Specification ID	Description	Requirement Reference	Minimum Performance	Achieved to Date	Design Value
BDA-PER-01	Maximum number of bad detectors in each BDA	IRD-DETP-R04 IRD-DETS-R04	11 (P/LW) 22 (P/MW) 35 (P/SW) 5 (S/LW) 9 (S/SW)	10 % on array only	4 (P/LW) 9 (P/MW) 14 (P/SW) 2 (S/LW) 4 (S/SW)
BDA-PER-02	The ratio of photon NEP due to radiation absorbed by the detector and total NEP, given as $(NEPphoton/NEPtotal)^2$ NEP includes all sources of noise at 1 Hz, measured at 300 mK, assuming a total readout noise of 10 nV/√Hz and the values in Table 3-1-2.	IRD-DETP-R01	0.46 P/LW 0.53 P/MW 0.59 P/SW 0.50 S/LW 0.59 S/SW	- 0.70 (P/MW) - - - (10 nV/√Hz amplifier noise).	0.55 P/LW 0.63 P/MW 0.70 P/SW 0.60 S/LW 0.71 S/SW
BDA-PER-03	The optical efficiency of the BDA horn and bolometer assembly for the photometer arrays at the centre of the bandpass assuming λ^2 throughput and a beam filling source	IRD-DETP-R01	0.65	0.8±0.1	0.85
BDA-PER-04	The optical efficiency of the short wavelength spectrometer horn arrays and bolometer assembly at 250 µm assuming	IRD-DETS-R01 IRD-DETS-R08	-	-	0.7

	$2\lambda^2$ throughputand a beam filling source and measured using an optical filter with a width of 15% of the central wavelength				
BDA-PER-05	The optical efficiency of the long wavelength spectrometer horn arrays and bolometer assembly at 350 µm assuming $3\lambda^2$ throughputand a beam filling source and measured using an optical filter with a width of 15% of the central wavelength	IRD-DETS-R01 IRD-DETS-R08	-	0.7±0.1	0.7
BDA-PER-06	The photometer detector time constant (based on a maximum modulation frequency of 2 Hz)	IRD-DETP-R02	32 ms	(C_{300mK} = 1pJ/K)	18 ms (P/LW) 13 ms (P/MW) 11 ms (P/SW)
BDA-PER-07	The spectrometer detector time constant (based on a maximum signal frequency of 20 Hz).	IRD-DETS-R02	14 ms (S/LW) 8 ms (S/SW)	(C_{300mK} = 1 pJ/K)	4.2 ms (S/LW) 4.2 ms (S/SW)
BDA-PER-08	The uniformity of the calibrated responsivity.	IRD-DETP-R03 IRD-DETS-R03	0.99	0.99	0.99
BDA-PER-09	Detector cross-talk.	IRD-DETP-R05 IRD-DETP-R06 IRD-DETS-R05 IRD-DETS-R06	< 5 % nearest neighbors	< 1 % nearest neighbors < 0.1 % non-nearest neighbors	1 % nearest neighbors 0.1% non-nearest neighbors
BDA-PER-10	The 1/f knee frequency (frequency at which total noise is $\sqrt{2}$ larger than white level).		0.1 Hz	0.03 Hz	0.03 Hz
BDA-PER-11	The detectors shall be designed for optimal performance under the following levels of absorbed power (pW).	JPL			2.5 (P/LW) 3.3 (P/MW) 4.1 (P/SW) 10.6 (S/LW) 10.8 (S/SW)
BDA-PER-12	The detectors and readout electronics shall be designed to function under a radiation background a factor of two lower or a factor of 5 higher than the nominal values assumed in BDA-PER-11				
BDA-PER-13	The positional repeatability of the focal plane structure shall be < 125 µm orthogonal to the optical axis, and < 500 µm along the optical axis. The rotational repeatability around the optical axis shall be < 0.5 deg.	RAL	-	-	<125 µm orthogonal <500 µm along axis <0.5 degree rotation

Specification ID	Description	Requirement Reference	Minimum Performance	Achieved To Date	Design Value
JFET-PER-01	Median noise of JFET module over 100 – 300 Hz (nV/$\sqrt{Hz}$)	IRD-FTB-R01	15	7.0	7.0

JFET-PER-02	Maximum number of bad JFET pairs corresponding to each BDA	IRD-DETP-R04 IRD-DETS-R04	11 (P/LW) 22 (P/MW) 35 (P/SW) 5 (S/LW) 9 (S/SW)		4 (P/LW) 9 (P/MW) 14 (P/SW) 2 (S/LW) 4 (S/SW)

Notes:

BDA-PER-01: A "bad detector" is here defined as one that does not achieve, at the BDA output, performance compatible with the minimum performance values for BDA-PER-2 to 10.

JFET-PER-02: A "bad JFET pair" is here defined as one that does not achieve, at the JFET output, a noise level of less than the minimum performance level.

BDA-PER-01 and JFET-PER-02: The minimum performance requirement on yield are quoted individually above for both the BDAs and JFETs. This is designed to ensure an overall yield of at least 0.75 for the system at the JFET outputs. As long as this is achieved, the JFET and BDA yield do not *both* need to be at or above their minimum performance yields.

BDA-PER-02: The bolometer performance estimation assumes the following nominal photon NEPs (W/√Hz) referred to power absorbed at the detector:

P/LW: 4.6×10^{-17}
P/MW: 6.3×10^{-17}
P/SW: 8.2×10^{-17}
S/LW: 10.5×10^{-17}
S/SW: 13.6×10^{-17}

BDA-PER-02 and BDA-PER-11: The optical loading and photon NEP assume the following nominal optical efficiencies of the bolometer and feedhorn combinations:

P/LW 0.65
P/MW 0.65
P/SW 0.65
S/LW 0.65
S/SW 0.70

BDA-PER-11: The values of optical loading are based on the SPIRE instrument sensitivity models, and incorporate the following assumptions:
(i) the thermal background from the telescope corresponds to a temperature of 80 K and an emissivity of 4%;
(ii) the total power loading on the detectors is dominated by the telescope, with a negligible contribution from the instrument itself;
(iii) the spectral passbands are defined by a combination of BDA waveguide cut-off and submillimetre filters resulting in a negligible contribution to the background and the NEP from out-of band radiation.

The second two assumptions are seen as reliable, but the first is not, because of large uncertainties in the telescope background. Should the actual power levels on the detectors be different to the nominal values, the all detector specifications might not be met simultaneously (for instance, speed of response and sensitivity).

Table 3-1-1 Summary of Detector Design Values

Quantity	Units	P/LW	P/MW	P/SW	S/LW	S/SW
Q	pW	2.5	3.3	4.1	10.6	10.8
NEP_{blip}	E-17 W/√Hz	4.6	6.3	8.2	10.5	13.6
NEP_{tot}	E-17 W/√Hz	6.2	7.9	9.8	13.6	16.1
τ	ms	18	13	11	4.2	4.2
G_0	pW/K	40	53	66	170	170
V_{bol}	mV_{rms}	3.3	3.8	4.3	6.8	6.8
S_{dc}	E8 V/W	4.7	4.1	3.6	2.3	2.2

Table 3-1-2 Summary of Common Detector Design Values

Quantity	Value	Units
R_0	180	Ω
Δ	41.8	K
T_{bol}	0.39	K
R_{bol}	5.8	MΩ
Z/R	0.4	

3.1.2 Functional Specification

Specification ID	Description	Requirement Reference	Compliant
BDA-FUN-01	The photometer angular response shall be defined by a straight-walled conical feedhorn.	IRD-DETP-R07	Yes
BDA-FUN-02	The spectrometer angular response shall be defined by a multi-mode feedhorn.	IRD-DETS-R07	Yes
BDA-FUN-03	The spectral long-wavelength cutoff determined by the feedhorn output waveguide aperture will be 670 µm.	IRD-DETP-R08 IRD-DETS-R08	Yes
BDA-FUN-04	*Deleted v3.2 – moved to performance requirement BDA-PER-13*		

Specification ID	Description	Requirement Reference	Compliant
JFET-FUN-01	The JFET module will mount to the Herschel optical bench, dissipating power at the Level-2 stage of the cryostat.	IRD-FTB-R07 IRD-FTB-R05	Yes
JFET-FUN-02	The RF filters will operate without power dissipation	IRD-RFM-R03	Yes
JFET-FUN-03	The JFET modules must be capable of functioning, without necessarily meeting noise specifications, over a temperature range from 4 K to 300 K	IRD-FTB-R06	Yes
JFET-FUN-04	The JFET module and RF filters will operate from a base temperature between 4 – 20 K.	IRD-FTB-R08	Yes

3.1.3 Technical Specification

Note: For all budgetary resource values (mass; thermal dissipation; temperature) the instrument will hold a margin against the design value – 20% unless indicated otherwise. Where the minimum performance value is below the margin (BDA-TEC-06, JFET-TEC-05), a system level analysis will be conducted to investigate the effect of increasing the resource allocations to the minimum performance values indicated here. A future release of this document will reflect updated resource allocations and minimum performance levels.

Specification ID	Description	Requirement Reference	Compliant
BDA-TEC-01	The BDA shall accommodate a defined mechanical interface to the 2 K structure.	IRD-DETS-R08 IRD-DETP-R14 IRD-STRP-R01	Yes
BDA-TEC-02	The BDA shall provide an attachment point and/or a thermal interconnect to a 300 mK thermal strap.	IRD-STRP-R01	Yes
BDA-TEC-03	The BDA mass will have a design value of 600 gm averaged over 5 detector arrays, including output connectors.	IRD-SUBS-03	Yes
BDA-TEC-04	The first resonant frequency of the BDA will be > 200 Hz, with a goal of > 250 Hz.	IRD-DETP-R15 IRD-DETS-R16	Yes
BDA-TEC-05	The mechanical envelope of the BDA will be described by the *Detector Subsystem Interface Control Document* [RD5].	IRD-DETP-R12 IRD-DETS-R13	N/A
BDA-TEC-06	The total power load on the 300 mK cooler from the BDAs will be < 15 µW (minimum performance); < 8 µW (design value). This assumes the focal plane mount is held at 1.7 K.	IRD-DETP-R13	Minimum Value not compliant. Design Value is compliant.

BDA-TEC-07	The power allocated for temperature control of the ^{3}He stage is 2 μW.		N/A

Specification ID	Description	Requirement Reference	Compliant
JFET-TEC-01	The 48-channel JFET modules will have a mass less than 305 g each.	IRD-SUBS-R03	Yes
JFET-TEC-02	The mechanical envelope of the JFETs and RF filters will be described by the *BDA Interface Control Document* [RD5].	IRD-FTB-R04	N/A
JFET-TEC-03	The RF filters are to provide –40 dB attenuation from 500 MHz to 3 GHz (minimum), -60 dB attenuation from 500 MHz to 10 GHz (goal).	IRD-FTB-R02 IRD-RFM-R01	Yes
JFET-TEC-04	The first resonant frequency of a JFET module will be > 200 Hz, with a goal of > 250 Hz.	IRD-FTB-R09	Yes
JFET-TEC-05	The maximum allowed total JFET power dissipation for photometer mode (all three arrays operating) is 42 mW. The design value for JFET module dissipation is 7 mW per 48-channel module. Some JFET modules for the 250 μm array may be switched off in operation if necessary to keep within the maximum allowed power limit. The 250 μm array layout and wiring will be configured to allow contiguous portions of the array to be switched off 24 detectors at a time. Notes: The design of JFET rack and cryoharness are to be examined to see if base temperature of the rack can be increased above that of the optical bench, reducing the dissipation for a given JFET temperature. CQM and PFM JFET units will be optimised for operation at a JFET temperature T ~ 120 K. Thermal dissipation of fully functional CQM JFET units may be as large as 11 mW per module to meet minimum noise performance specification	IRD-FTB-R05	Yes at 15 nV/rt(Hz)
JFET-TEC-06	The RF filter modules will have a mass less than 165 g each.	IRD-SUBS-R03	Yes

3.2 Operational Specification

3.2.1 Operational Safety

Specification ID	Description	Requirement Reference	Compliant
BDA-SAF-01	Failure of a BDA or JFET module, or one of its components, as tabulated in BDA-SAF-03 to 06, shall not affect the health of any other subsystem, the instrument, or the interface with the satellite.	IRD-SAFE-R07	Yes
BDA-SAF-02	Any on-ground failure of a component of a BDA or JFET module will result in the entire module being removed and either replaced or refurbished at JPL at module level.	IRD-SAFE-R08	Yes
BDA-SAF-03	Separate sets of 2 x 3 overlapping photometer pixels that are to		Yes

	be used for chopped point source observations shall not be served by the same 24-channel JFET membrane. The particular pixel set to be designated as the redundant set will be specified by the SPIRE Project.		
BDA-SAF-04	Any in-flight failure of any component of a BDA or JFET module shall not damage any redundant or backup component designed to replace that component. The only redundant hardware related to the BDA are bias and power wiring, RF filter modules, and back-up modules for the warm electronics.		Yes
BDA-SAF-05	The power supplies to each individual JFET 24-channel membrane shall be commandable ON/OFF (see BDA-DRCU-06)	IRD-SAFE-R07	Yes
BDA-SAF-06	*Deleted v3.2 – reflects removal of snubbers from design*		

3.2.2 Reliability

Specification ID	Description	Requirement Reference	Compliant
BDA-REL-01	Failure of a BDA and a JFET module shall not lead to the total loss of instrument operations, as tabulated in BDA-SAF-03 to 04.	IRD-REL-R01	Yes
BDA-REL-02	Observations can continue in degraded mode in the event of failure of the cold beam steering mirror.	IRD-REL-R02	Yes
BDA-REL-03	Point source observations can continue in degraded mode in the event of misalignment of the photometer or spectrometer BDAs.	IRD-REL-R02	Yes
BDA-REL-04	Single-point failures in the detector and JFET wiring (detector bias, JFET power) are to be duplicated. The RF filter modules on these lines will also be redundant.	IRD-REL-R03	Yes
BDA-REL-05	BDA temperature stabilisation shall be implemented by an interruptible software-driven control loop.	IRD-REL-R04 IRD-REL-R05	Yes

3.3 Interface Requirements

3.3.1 ^{3}He Cooler

Requirement ID	Description	Reference	Compliant
BDA-HCO-01	Design values of detector performance requires a temperature < 290 mK at the point of contact to the BDA. Design value sensitivities assume 300 mK at the detector.	IRD-COOL-R01 BDA-PER-02	Yes Design compliant. To be confirmed by instrument-level testing of the CQM.
BDA-HCO-02	Design values of detector performance require temperature stability at the point of thermal control (near the evaporator) of 10 μK/√Hz from 0.1 – 10 Hz. This assumes that the BDA acts as a 100-s thermal low-pass filter.	IRD-COOL-R05 BDA-PER-10	Compliance to be verified by instrument-level testing of the CQM.
BDA-HCO-03	Maximum allowed thermal drift at the point of thermal control (near the evaporator) is 1 mK/hr. This assumes that the BDA acts as a 100 s thermal low-pass filter.	IRD-COOL-R04 BDA-PER-10 BDA-HCO-02	Compliance to be verified by instrument-level testing of the CQM.

Notes:

Performance of the ^3He cooler will be measured with the detectors during CQM-level testing. If the thermal performance does not satisfy BDA-PER-10, temperature control of the evaporator stage must be implemented on the PFM and FS instrument models.

3.3.2 Wiring Harness

Requirement ID	Description	Reference	Compliant
BDA-WIR-01	The wiring harnesses supplied by JPL shall meet the specifications described in the *SPIRE Harness Definition Document* (RD2).	RD2	Yes
BDA-WIR-02	The signal-wire-to-signal-wire capacitance of the cables running from the BDA to the JFET modules (including connector contribution) will be < 50 pF, after mounting.	IRD-FPHR-R01	Yes

3.3.3 FPU Structure Specifications

Requirement ID	Description	Reference	Compliant
BDA-STR-01	The structure interface shall provide compensation of the position and rotation of the BDA by up to ± 0.5 mm in x, y, and z, and ± 1 degrees	IRD-STRP-R03 IRD-STRS-R03	Yes
BDA-STR-02	The JFET modules will be housed in a JFET enclosure with a defined mechanical interface.	JPL	Yes
BDA-STR-03	The BDAs and JFETs shall be housed in an RF-tight shield. The JFET modules form part of this RF shield. All electrical, and thermal penetrations into the shield will be RF blocked or attenuated. The instrument optical aperture shall be designed to be compatible with the inclusion of a wire mesh RF filter should it prove necessary to minimise RF disturbance at the detectors. It shall be possible to electrically isolate the RF shield from the Herschel optical bench. The defining point for electrical ground of the RF shield shall be at the BDAs (either at the 2-K or 300-mK level, TBD).	BDA-ISY-01	Compliance to be verified by CQM instrument-level testing.
BDA-STR-04	The wiring harness shall have a mechanical resonant frequency greater than 1 kHz when secured in the FPU.	JPL	Design: TBC by JPL and MSSL.
BDA-STR-05	The structure in the vicinity of the BDAs shall make allowance for possible movement of the 300-mK suspended mass under mechanical failure of the BDA as follows: 1.5 mm in any direction.	BDA-SAF-06	Yes

3.3.4 SPIRE Instrument Transmission Specification

Requirement ID	Description	Reference	Compliant
BDA-ITR-01	The filter stack shall provide definition of the short wavelength cutoff as described in Table 3-4-1.	JPL	Yes
BDA-ITR-02	The filters incorporated into the BDAs shall conform to the mechanical envelope described in RD5. Filters delivered to JPL shall have been subjected to thermal cycle tests and bakeout at qualification levels.	JPL	Yes
BDA-ITR-03	Filters in the SPIRE FPU, in combination with the waveguide filters within the BDAs, shall attenuate out-of-band radiation such that out-of-band power and photon noise are insignificant (< 10%) in comparison to in-band power and photon noise. Here “out-of-band” is taken to mean more than 10% outside the relevant edge (defined at 10% transmission as in RD 8).	JPL	Yes
BDA-ITR-04	In band radiation incident on the detectors from the SPIRE instrument over the 200 - 670 μm range shall be < 10% of that from the telescope.	JPL	Yes TBC by instrument level testing
BDA-ITR-05	The optical efficiency of the SPIRE instrument shall be consistent with the requirements defined in AD1.		Yes TBC by instrument level testing

3.3.5 SPIRE Instrument System Specifications

Requirement ID	Description	Reference	Compliant
BDA-ISY-01	The dissipated RF power at the detectors, arising from external sources on the spacecraft that propagate to the bolometers by radiation (EMI) or conduction, shall contribute < 1E-17 W/√Hz noise to the bolometers (< 5 nV/√Hz equivalent detector noise post-demodulation). EMI-induced current at the bolometers shall be < 1 pA rms	JPL	TBC by instrument -level testing
BDA-ISY-02	The signal from microphonics (including both voltage and thermal response), arising from external sources on the spacecraft, shall contribute < 1E-17 W/√Hz noise to the bolometers (< 5 nV/√Hz over a > 25-Hz band around a chosen bias frequency within the allowed range of 50 and 300 Hz). For the third and fifth harmonics of the bias frequency, the noise specification is higher by factors of 3 and 5, respectively). Note: a system study is to be carried out to verify the need for this requirement on the harmonics.	JPL	TBC by instrument -level testing
BDA-ISY-03	The nominal number of thermal cycles of the JPL hardware in the PFM instrument is 7 and the total number of cycles in the PFM instrument shall not exceed 15.	JPL	TBC
BDA-ISY-04	An agreed inspection of JPL hardware shall be carried out upon receipt in Europe. JPL will provide	JPL	Yes

	this procedure		

Notes:

BDA-ISY-01 and BDA-ISY-02: These are requirements which must be met to ensure that the inherent sensitivity of the bolometers is not degraded by exrtaneous sources of noise. They apply to the complete system, including the BDA units themselves and the JPL-supplied wiring harness. It is recognised that achieving them will require joint effort by the JPL and SPIRE Project teams.

3.3.6 DRCU

3.3.2.1 Functional description

The DRCU provides amplification and digitization of the bolometer signals. Starting from the bolometer end of the signal chain, the detector is AC-biased by the DRCU in series with 2 x 10 MΩ cryogenic load resistors. The differential AC bias provides stabilization of the JFETs and amplifiers by modulating the signal above the electronics 1/f knee. The AC bias also reduces the 1/f noise requirements on the JFET amplifiers, allowing them to operate at the small power dissipation required by the Herschel cryogenic system. The differential bolometer signals pass to low-noise Si JFET amplifiers mounted on the Herschel optical bench. The JFETs provide power amplification by reducing the output impedance for ~ 5 MΩ to ~5 kΩ. Electrical power for the JFETs is provided by the DRCU, in addition to a controllable heater for JFET startup and noise optimization. The differential output signals pass through the cryo-harness to the LIA input stage of the DRCU. The LIA stage amplifies the bolometer signals and performs synchronous demodulation with the bias reference. An offset signal is removed from the output of the LIA so that the signals can be digitized with a 16-bit A/D converter, and the signals are muiltiplexed.

The bias generator, LIA signal outputs, and power supplies interface with a digital second stage. The digital second stage commands the amplitude and frequency of the bias, and sets the voltages for the JFET power supplies. The signals from the LIA stage are digitized by the second stage synchonously with the bias. The digitized signals then pass to the DPU for digital processing and storage for telemetry.

The design of the DRCU is modular so that the instrument may be run in photometer or spectrometer mode, operating only the spectrometer or photometer pixels. In addition, in photometer mode the DRCU is capable of amplifying 3 thermometers for thermal control of the 300 mK stage. A control signal can be generated to control the 300 mK stage temperature by means of a heater at the stage or elsewhere in the refrigerator.

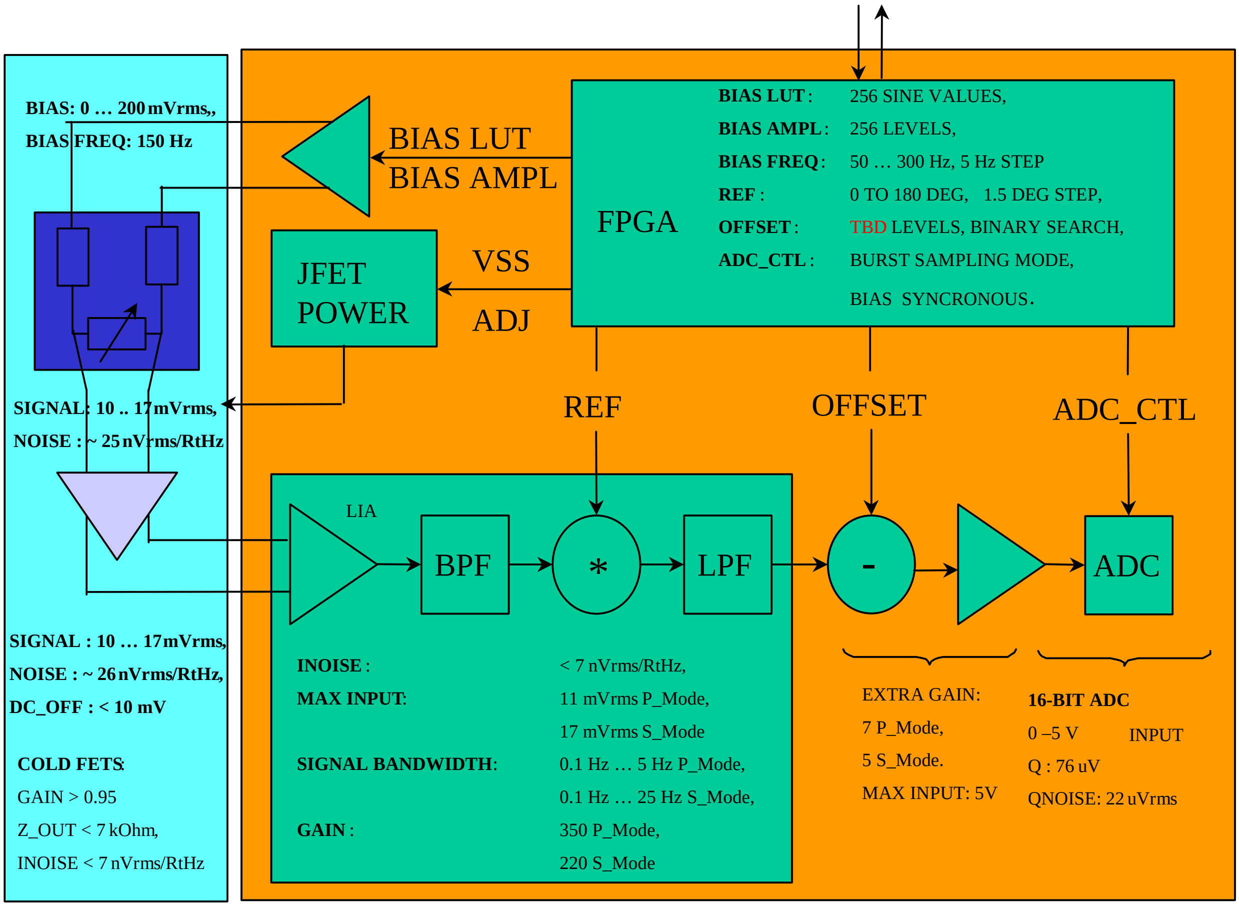
3.3.2.2 DRCU channel description

The detector subsystem requires the following channels:

Table 3-3-1 BDA Channel Description

Array	Opt. Pixels	Dark Pixels	Thermistors	5 MΩ Resistors
P/LW	43	2	2	1
P/MW	88	2	2	1
P/SW	139	2	2	1
S/LW	19	2	2	1
S/SW	37	2	2	1
T/C	0	0	3	0

3.3.2.3 Signal flow diagram



The design nominal and (peak of the load curve) signals are as follows:

Table 3-3-2 BDA Nominal Voltages (in mV rms)

Array	Opt. Pixels	Dark Pixels	Thermistors	Resistors	Bias Amp.
P/LW	3.3 (4.1)	4.8 (5.0)	3.0	3.0	15
P/MW	3.8 (4.7)	5.5 (5.8)	3.4	3.4	17
P/SW	4.3 (5.3)	6.1 (6.4)	3.8	3.8	19
S/LW	7.6 (9.4)	10.9 (11.4)	6.5	6.5	33
S/SW	6.3 (7.8)	9.1 (9.5)	5.5	5.5	28
T/C			100.0		500

3.3.2.4 Noise budget

The design noise budget is as follows

Table 3-3-3 Nominal Noise* Budget (in nV/√Hz)

	P/LW	P/MW	P/SW	S/LW	S/SW
Photon	21	26	30	24	30
Phonon	9	9	9	9	9
Johnson	7	7	7	7	7
Load resistor	2	2	2	2	2
JFET	7	7	7	7	7
LIA	6	6	6	6	6
A/D	4	4	4	3	3
Quad. Subtotal	26	30	33	28	34
Thermal+	< 6	< 6	< 7	< 11	< 11
EMI/EMC	< 5	< 5	< 5	< 5	< 5
Microphonic	< 5	< 5	< 5	< 5	< 5
Bias lines	< 4	< 4	< 4	< 4	< 4
Quad. Total	< 28	< 32	< 35	< 31	< 37

*Referred to the detector at DC and prior to demodulation.

+T_n < 300 nK/√Hz at the detector.

3.3.2.5 Thermistor channels

The temperature sensitivity to base plate temperature of the thermistors is given by $T_n = V_n\,(dT/dV)$, where $dV/dT = (-\alpha V/T)*(2R_L/(R_B+2R_L))$, and $V_n^2 = V_{n,amp}^2 + 4kTR_B(1 + R_B/2R_L)$ The equivalent temperature sensitivity of a detector is given as $T_n = NEP/G_0$, where NEP includes all noise sources.

Table 3-3-4 Nominal Temperature Sensitivities in nK $Hz^{-1/2}$

Array	Thermistor T_n	Detector T_n
P/LW	510	1550
P/MW	440	1490
P/SW	400	1480
S/LW	235	800
S/SW	275	950

3.3.2.6 DRCU Requirements

Requirement ID	Description	Reference	Compliant
BDA-DRCU-01	The DRCU signal processing electronics shall have less than 7 nV/√Hz as seen post demodulation, after digitzation. Noise is referred to the input over the frequency range 0.05 to 25 Hz. This performance must be accomplished with a bias input signal to the DRCU of 10 mVrms AC, 5 mV DC, 1 V DC	JPL	Yes

	common-mode offset, with an input load of 7 kΩ. Thermal requirements on bias stability are implicit in this requirement.		
BDA-DRCU-02	Requirement deleted	JPL	
BDA-DRCU-03	Input capacitance to be less than 100 pF, measured from the DRCU DxMA connector pins without the harness.	JPL	Yes (may be verified by design)
BDA-DRCU-04	Input impedance to be ≥ 1 MΩ from 50 – 300 Hz.	JPL	Yes (may be verified by design)
BDA-DRCU-05	The DRCU shall provide 5 BDA bias signals, adjustable from 0 to 200 mV_{rms}, and 1 bias signal for temperature readout, adjustable from 0 to 500 mV_{rms}. The temperature readout biases are to be divided from a common oscillator. Each bias shall be adjustable with 8-bit precision. The frequency of each bias shall be adjustable between 50 and 300 Hz, with a precision of 5 Hz. Voltage noise on the bias lines, within the modulated band (50 – 300 Hz), measured at the DRCU DxMA connector, shall be < 20 nV/√Hz	JPL	Yes TBC by SAp
BDA-DRCU-06	The DRCU shall provide 15 commandable JFET source voltages with 256 levels. The range of Vss is from 0 V to –5 V.	JPL	Yes
BDA-DRCU-07	Vdd shall be adjustable from 1.5 to 4 V.	JPL	Yes
BDA-DRCU-08	Vdd and Vss lines individually must source 1 mA to 5 mA. Noise on Vss < 1 μV/√Hz, and noise on Vdd < 0.3 μV/√Hz within modulated band (50 – 300 Hz), measured at the DRCU DxMA connector.	JPL	Yes
BDA-DRCU-09	Each of the 15 Vdd and Vss supplies must be commandable ON/OFF for spectrometer and photometer independently, without overshoot. Each Vdd and Vss pair are turned on and off together.	JPL	Yes
BDA-DRCU-10	The DRCU will provide 2 double-wired JFET heater lines with adjustable amplitude and duration. The supplies must be able to provide 5 V and 25 mA (photometer), 3 V and 10 mA (spectrometer). Each heater line is commandable ON/OFF, with a minimum duration of 10 s.	JPL	Yes
BDA-DRCU-11	The common-mode rejection ratio shall be better than –60 dB (50 – 300 Hz).	JPL	Yes
BDA-DRCU-12	The DRCU shall provide a dynamic range at the ADC sufficient to maintain the noise performance of the detectors under maximal signal conditions as defined below in BDA-DRCU-22.	JPL	Yes
BDA-DRCU-13	The signal bandwidth of the photometer channels shall be 0.03 Hz to 5 Hz. The 5 Hz cutoff should have a precision of 1 %.	JPL	Yes
BDA-DRCU-14	The signal bandwidth of the spectrometer channels shall be DC to 25 Hz. The 25 Hz cutoff shall have a precision of 1 % or better.	JPL	Yes
BDA-DRCU-15	The sampling of the photometer channels shall be synchronised with the bias, at a rate selectable between $\nu_{bias}/2$ to $\nu_{bias}/256$.	JPL	Yes
BDA-DRCU-16	The sampling of the spectrometer channels shall be synchronised with the bias, at a rate selectable between $\nu_{bias}/2$ to $\nu_{bias}/256$.	JPL	Yes
BDA-DRCU-17	The DRCU shall provide 2 adjustable power supplies for temperature control using a heater located at the 300 mK stage. This supply must provide a maximum of 300 mV and	JPL	TBD by SAp

	50 µA, to be adjustable with (TBD by JPL) precision, and have a stability of (TBD by JPL).		
BDA-DRCU-18	Noise performance BDA-DRCU-01 shall be maintained under bias range 100 – 300 Hz.	JPL	Yes
BDA-DRCU-19	DRCU noise performance (BDA-DRCU-01) to be maintained under a warm electronics thermal drift of 1 K/hour (TBC).	JPL	Yes
BDA-DRCU-20	*This requirement has been deleted and replaced by an appropriate note in BDA-DRCU-01*	N/A	N/A
BDA-DRCU-21	The requirement on JFET power supply voltage stability is dV/V < 500 ppm hr^{-1} for Vdd and Vss under a warm electronics thermal drift of 1 K hr^{-1} at the feet of the DCU box.	JPL BDA-DRCU-01	TBD by SAp
BDA-DRCU-22	The DRCU shall not saturate at an input voltage as large as 11 mV_{rms} at input (photometer), 17 mV_{rms} at input (spectrometer). DRCU channels shall remain functional if one input signal goes to Vbias.	JPL	Yes
BDA-DRCU-23	The conducted RF current on all lines connecting to the bolometers or JFETS, originating in the DRCU, shall be less than 0.1 nA rms (TBC by JPL/RAL/SAp) over a frequency range of 0 - 10 GHz. (This assumes an attenuation of 40 dB by the RF filters).	JPL BDA-ISY-01	To be verified by instrument test
BDA-DRCU-24	Bias, JFET power, and readout electronics for the spectrometer and photometer arrays are to run from separate dedicated power supplies, with independent, isolated grounds.	JPL	TBD by SAp/RAL
BDA-DRCU-25	The electrical cross-talk, over the detector signal frequency band, between channels in the DRCU shall be less than 0.05 %. The electrical cross-talk shall be verified by varying the input signal on one channel and measuring the response in other channels. The input signal level to each channel must be representative.	JPL	Yes
BDA-DRCU-26	Each signal input to the LIA module must be connected to ground by a diode. This provides both protection and allows the JFETs to turn on without the JFET heater.	JPL	Yes
BDA-DRCU-27	The maximum allowed JFET DC offset at operating temperature is to be 15 mV for CQM JFET modules, and 15 mV or 11 mV (TBD) for PFM and FS JFET modules. The design of the DCU shall accommodate these offsets	JPL	Yes

3.4 Design and Manufacture Specification

Specification ID	Description	Requirement Reference	Compliant
	BDA design		
BDA-DES-01	The P/SW array is to have 139 detectors operating over a band centred on 250 µm with $\lambda/\Delta\lambda$ = 3, in a close-packed array of 2Fλ feedhorns.	IRD-PHOT-R02 IRD-DETP-R07	Yes
BDA-DES-02	The P/MW array is to have 88 detectors operating over a band centred on 350 µm with $\lambda/\Delta\lambda$ = 3, in a close-packed array of 2Fλ feedhorns.	IRD-PHOT-R02 IRD-DETP-R07	Yes
BDA-DES-03	The P/LW array is to have 43 detectors operating over a band centred on 500 µm with $\lambda/\Delta\lambda$ = 3, in a close-packed array of 2Fλ feedhorns.	IRD-PHOT-R02 IRD-DETP-R07	Yes
BDA-DES-04	The S/SW array is to have 37 detectors for FTS spectroscopy between 200 and 325 µm in a close-packed array of feedhorns with dimensions as given in Table 3-4-1.	IRD-SPEC-R04 IRD-DETS-R07	Yes

BDA-DES-05	The S/LW array is to have 19 detectors for FTS spectroscopy between 315 µm and 670 µm in a close-packed array of feedhorns with dimensions as given in Table 3-4-1.	IRD-SPEC-R04 IRD-DETS-R07	Yes
BDA-DES-06	For all sets of detectors which are designed to overlap on the sky, the internal relative alignment of the corresponding feedhorn centres in the three photometer arrays or two spectrometer arrays shall be ± 40 µm (corresponding to a co-alignment accuracy of ±0.5" on the sky). "Internal relative alignment" here is defined as the alignment of the detectors wrt each other when the respective BDAs are optimally co-aligned at their mechanical interfaces in a manner consistent with BDA-STR-01.	RAL	Yes TBC by JPL
BDA-DES-07	The BDA will accommodate cryogenic load resistors for current bias.	JPL	Yes
BDA-DES-08	The BDA will provide electrical connector ports for ease of integration into the instrument.	JPL	Yes
BDA-DES-09	The BDA will incorporate a differential readout scheme and harness design to minimize EMI/EMC and microphonic susceptibility.	JPL	Yes
BDA-DES-10	The BDA assemblies shall be sine vibration tested at a temperature T < 90 K under the following qualification levels: a vibration input level at the base of 60 g between 5-100 Hz, or 11-mm amplitude at the base, whichever is less severe, at a sweep rate of 2 oct/min. Acceptance sweep rate is 4 oct/min. and acceptance amplitude is lower by 1.5. The BDA assemblies shall be random vibration tested at a temperature T < 90 K under the following qualification levels: The input spectrum for the BDA in any direction is: * 0.8 g^2/Hz between 100 and 300 Hz * Ramp-up between 20 and 100 Hz at +6 dB/oct * Ramp-down between 300 and 2000 Hz at -6 dB/oct The input to the BDA is allowed to be notched at resonance to a level equal in g rms to 100 g for the suspended mass, taking into account a 4-sigma variation of the measured rms signal, in order not to exceed a quasi-static equivalent loading of the BDA of 100 g. The notch width at full depth should not exceed 1/3 octave band-width, with a ramp-up and ramp down of 10 db per octave. If JPL experience major problems in maintaining the 100-g limit while keeping within the notching scheme as defined above, then the spectrum shall be revised by mutual agreement between JPL and the Project Team. Notes: 1. It is possible, but not certain, that the above levels may be relaxed in the future taking into account the responses of individual BDAs. 2. Acceptance levels are a factor of 2.25 (g^2/Hz) or 1.5 (g-rms) lower than qualification levels. Accordingly, for acceptance tests, the notched random vibration spectrum shall be such as not to exceed a quasi-static load of 100/(1.5) = 67 g.	AD2	Yes

	3. Duration of tests: 120 seconds per axis qualification; 60 seconds per axis acceptance.		
BDA-DES-11	The BDA and JFET assemblies shall not exceed a temperature of 80 C and duration longer than a combined 300 total hours during bakeout testing at component, instrument and spacecraft level. Note that a change in the maximum temperature in this requirement would result in a change in the duration.	JPL	Yes TBC by RAL
	JFET module design		
JFET-DES-01	JFET modules shall accommodate up to 48 differential channels.	JPL	Yes
JFET-DES-02	All JFET output lines will be RF filtered.	JPL	Yes
JFET-DES-03	Each JFET input connector will provide 2 detector bias signals.	JPL	Yes
JFET-DES-04	Each JFET module will accommodate cryogenic source resistors in order to minimize microphonics susceptibility.	JPL	Yes
JFET-DES-05	The JFET unit shall incorporate a differential design to minimise EMI/EMC and microphonic susceptibility.	JPL	Yes
JFET-DES-06	RF modules will be incorporated into the JFET enclosures to filter detector bias, JFET power, and JFET heater lines.	JPL	Yes
JFET-DES-07	The JFET assemblies shall be sine vibration tested at a temperature T < 90 K under the following qualification levels: X-axis: a vibration input level at the base of 20 g between 5-40 Hz, or 11-mm amplitude at the base, whichever is less severe, and 10 g between 40-100 Hz, at a sweep rate of 2 oct/min. Acceptance sweep rate is 4 oct/min. and acceptance amplitude is lower by 1.5. Y and Z-axes: a vibration input level at the base of 14 g between 5-100 Hz, or 11-mm amplitude at the base, whichever is less severe, at a sweep rate of 2 oct/min. Acceptance sweep rate is 4 oct/min. and acceptance amplitude is lower by 1.5. The JFET assemblies shall be random vibration tested at a temperature T < 90 K under the following qualification levels: The input spectrum for the JFET in any direction is: * 0.6 g^2/Hz between 200 and 600 Hz * Ramp-up between 20 and 200 Hz at +6 dB/oct * Ramp-down between 600 and 2000 Hz at -6 dB/oct Notes: 1. Acceptance levels are a factor of 2.25 (g^2/Hz) or 1.5 (g-rms) lower than qualification levels. 2. Duration of tests: 120 seconds qualification; 60 seconds acceptance. 3. Should the above specification pose major problems for the JFET module design, the spectrum and/or the JFET rack design will be revised by JPL and the SPIRE Project Team and approriate modifications devised by mutual agreement. If the JFET module itself is shown to be capable of surviving the qualification input vibration levels applicable to the optical bench, then re-design of the JFET module shall not be required.	AD2	Yes
	RF Filter module design		
RFF-DES-01	The RF filter module assemblies shall be sine vibration tested at a temperature T < 90 K under the following qualification levels:	AD2	Yes

	Sine vibration: the same levels as for the BDAs as specified in BDA-DES-10 above. Random vibration: the same levels as for the JFET modules as specified in JFET-DES-07 above.		

3.4.1 Feedhorn and Array Parameters

The tables below summarise the detailed specifications for the feedhorns and the detector backshort distances.

λ_o = Nominal band centre wavelength
λ_b = Wavelength for which bolometer backshort distance is optimised
λ_U = Nominal long-wavelength edge (defined by the waveguide diameter)
λ_L = Nominal short-wavelength edge (defined by edge filter in front of horn)
$\lambda_o/\Delta\lambda$ = Bandwidth assuming that an edge filter at exactly λ_L is in front of the horn
Defocus = Required position of focus with respect to the horn aperture. Note: this places a requirement on the position of the horn wrt the mechanical interface of the BDA, which is to be specified in the Interface Control Document, consistent with this table.

Tolerances quoted correspond to maximum and minimum values acceptable for any horn (not the rms of a set of horns).

Table 3-4-1 Feedhorn and filter specifications for the photometer

λ_b	**µm**	250			363			517		
Design $\lambda o/\Delta\lambda$		3.00			3.18			3.00		
λ_L (50% points)	**µm**	208.3	+/-	2.1	306.0	+/-	3.1	430.8	+/-	4.3
λ_U	**µm**	291.7	+/-	8.5	420.0	+/-	12.3	603.2	+/-	17.6
$\lambda/\Delta\lambda$		3.00	+/-	0.39	3.18	+/-	0.45	3.00	+/-	0.39
Horn length	**µm**	2368	+/-	200	3275	+/-	200	4636	+/-	200
Horn centre-centre distance	**µm**	2500	+/-	20	3330	+/-	20	5000	+/-	20
Horn internal aperture	**µm**	2400	+/-	5	3230	+/-	7	4900	+/-	10
Waveguide length	**µm**	500	to	550	700	to	750	1000	to	1050
Waveguide diameter	**µm**	171	+/-	5	246	+/-	7	353	+/-	10
Defocus	**µm**	1600	+/-	500	2500	+/-	500	4000	+/-	500
Backshort length	**µm**	62.5	+/-	6.3	90.8	+/-	9.1	129.3	+/-	12.9
Frontshort length	**µm**	88	+/-	60	127	+/-	44	180	+/-	60

Table 3-4-2 Feedhorn and filter specifications for the spectrometer

Number of horns		37			19		
λ_o	μm	258			487		
λ_b	μm	275			450		
λ_L (50% points)	μm	190	+/-	2	300	+/-	3
λ_L (90% trans. points)	μm	200	+/-	2	315	+/-	3
λ_U	μm	321	to	329	666	to	683
$\lambda/\Delta\lambda$ (50% points)		1.83	to	1.99	1.27	to	1.34
Horn length	μm	2368	+/-	200	4636	+/-	200
Horn centre-centre distance	μm	2250	+/-	20	3900	+/-	20
Horn internal aperture	μm	2150	+/-	5	3800	+/-	9
Waveguide length	μm	550	to	600	900	to	950
Waveguide diameter	μm	188	to	193	390	to	400
Defocus	μm	0	+/-	500	0	+/-	500
Backshort length	μm	69	+/-	7	113	+/-	11
Frontshort length	μm	96	+/-	33	158	+/-	54

3.4.2 Array Layout

See RD9

3.5 Logistic Requirements

The bolometer arrays will be delivered in suitable containers, compatible with the requirements specified in RD3 and RD7, for transportation and storage. Handling, cleanliness, and ESD procedures during installation of all JPL hardware will be specified in an Integration Procedures document to be supplied by JPL and agreed to by RAL (RD7). It is required that there be no need to disassemble any hardware once delivered to RAL, or that any necessary disassembly be carried out by JPL staff at RAL.

3.6 Environment Requirements

Environmental requirements are described in the JPL Environmental Requirements Document (RD3), and implemented in the JPL Test Plan (RD4).

3.7 Verification Requirements

Before delivery to RAL, the BDA, JFET modules and RF filter modules will undergo environmental and performance qualification and acceptance. Several of these tests (e.g. EMI/EMC, thermal stability and microphonics) can only provide useful information at a higher system level, and will not require component-level testing. The following table lists the environmental tests for model delivered. Verification implementation is described in the JPL Test Plan (RD4).

Test	CQM	PFM	FS
Vibration:	**Q**	**A**	**A**
Thermal cycle:	**D/Q**	**A**	**A**
Vacuum cycle	**D/Q**	**A**	**A**
Lifetime:	**D**	**-**	**-**
Soak/cycle:	**D**	**-**	**-**
Radiation tolerance:	**D**	**-**	**-**
Thermal range:	**D**	**-**	**-**
Thermal stability (Instrument Level):	**Q**	**A**	**A**
Microphonics (Instrument Level):	**Q**	**A**	**A**
Ionising radiation:	**D**	**-**	**-**
EMI (Instrument Level):	**Q**	**A**	**A**
EMC (Satellite Level):	**Q**	**A**	**A**

Table 3-7-1: Test matrix for the BDA and JFET modules. Q indicates a test carried out at qualification level for qualification times; A indicates a test carried out at acceptance level; D indicates a qualification test carried out by design, including unit-level testing and engineering analysis. An X indicates that this test is carried out and is a characterisation type test or the level is irrelevant. A dash indicates that no test will be done on this model/unit.

Verification ID	Description	Reference
BDA-VER-01	To carry out the tests on the BDA QM listed in Table 3-7-1.	IRD-VER-R01 IRD-VER-R03
BDA-VER-02	To carry out the tests on the BDA PFM listed in Table 3-7-1.	IRD-VER-R01 IRD-VER-R04
BDA-VER-03	To carry out the tests on the BDA FS listed in Table 3-7-1.	IRD-VER-R01 IRD-VER-R04

APPENDIX 1: QUALIFICATION TESTS DESCRIPTION

Vibration:	The QM BDA will be vibrated at levels appropriate to its location within the instrument, as defined in the *Detector Subsystem Specification Document.*
Thermal-Vacuum cycle:	The BDA and JFET modules will undergo thermal vacuum tests. According to standard JPL procedures, 3 times the number of lifetime thermal cycles will be imposed for qualification testing on representative units. For acceptance testing, the number of thermal cycles after delivery from JPL will be incurred.
Lifetime:	Lifetime tests to be carried out on all non-flight standard electrical components; novel materials and novel manufacturing processes. Details of tests to be determined on a case by case basis.
Soak/cycle:	Electrical soak test to be carried out on JFET modules at operating temperature followed by cycle to ambient temperature followed by soak test. Number of cycles and details of applied voltages etc to be defined.
Radiation tolerance:	Radiation tests will be to 20 krad TID. Components may be qualified by analysis or independent testing.
Thermal range:	Need to test to bakeout temperatures to ensure survival of the detector subsystem units when the Herschel satellite is baked out.
Thermal stability:	A test designed to ensure the verification of detector operation if the interface temperature varies during operation. This may only be applicable at instrument level.
Microphonics:	Test to be performed at the systems level.
Ionising radiation:	The effects on the detector performance of individual ionising radiation impacts must be evaluated by modelling or tested for. This is NOT the same test as radiation tolerance, which only implies a total integrated dose. It is desirable that a high energy (>100 MeV) proton beam line is employed to carry out this test with a representative the detector cold and active.
EMI:	Test to be performed at the systems level.
EMC:	Test to be performed at the systems level.
Materials conformance:	All materials used in the manufacture will be approved for space use by ESA.