SPIRE Beam Steering Mirror Subsystem Specification Document V 2.0

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DISTRIBUTION LIST

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1. Scope

This specification defines the requirements applied to the performance, design and qualification of the Beam Steering Mechanism for the SPIRE photometer. It includes a brief description of the proposed design to meet these requirements. The complete design description is found in RD1.

The Beam Steering Mechanism forms a sub-system of the SPIRE instrument. This specification is applicable to the CQM, the PFM and the FS.

2. Documents and Glossary

2.1 Applicable documents

	Title	Author	Reference	Date
AD1	Instrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Issue 0.30	May 2000
AD2	Structure - BSM ICD		SPIRE/ICD/1.1-1.5.1	
AD3	Deleted			
AD4	Optics - BSM ICD		SPIRE/ICD/1.2-1.5.1	
AD5	Baffles - BSM ICD		SPIRE/ICD/1.2.2-1.5.1	
AD6	Photometer Bolometer Arrays - BSM ICD		SPIRE/ICD/1.4.1-1.5.1	
AD7	Spectrometer Bolometer Arrays - BSM ICD		SPIRE/ICD/1.4.2-1.5.1	
AD8	Photometer Calibration Source - BSM ICD		SPIRE/ICD/1.5.1-1.6.1	
AD9	Deleted			
AD10	On Board Software - BSM ICD		SPIRE/ICD/1.5.1-2.6	
AD11	Analogue Simulator - BSM ICD		SPIRE/ICD/1.5.1-3.1	
AD12	Instrument Simulator - BSM ICD		SPIRE/ICD/1.5.1-3.3	
AD13	Current Optical Configuration		PHT 126 I	
AD14	Operating Modes for the SPIRE Instrument	B.M.Swinyard	SPIRE-RAL_PRJ 000320 issue 2.2	
AD15	BSM Sub-system Development Plan		SPIRE-ATC-PRJ-003	latest
AD16	IID-A	FIRST/Planck Project Team	SCI-PT-IIDA-04624 rev 1/0	01/09/2000
AD17	IID-B	ESA FIRST/Planck Project Team	SCI-PT-IIDB/SPIRE-02124 rev 1/0	01/09/2000
AD18	SPIRE mirrors specification	K.Dohlen and D.Pouliquen	LAM.PJT.SPI.SPT.200007 Ind 1	6.Jun.00
AD19	MCU-BSM ICD		TBD	
AD20	SPIRE Product Assurance plan	RAL	SPIRE-RAL-PRJ-00017	5.Feb.98

2.2 Reference documents

	Title	Author	Reference	Date
RD1	SPIRE BSM Design Description Document	I.Pain	SPIRE-ATC-PRJ-002	latest
RD2	FIRST Telescope Specification		PT-RQ-04761 Issue 1/A SPIRE-ESA-DOC-000195	January 1998

2.3 Glossary

AD	Applicable Document	QMW	Queen Mary & Westfield College
ATC	UK Astronomy Technology Centre	RAL	Rutherford Appleton Laboratory
BSM	Beam Steering Mirror	RD	Reference Document
CQM	Cryogenic Qualification Model	RMS	Root Mean Square
DPU	Digital Processing Unit	SMEC	Spectrometer Mechanism
DSP	Digital Signal Processor	TBD	To Be Decided
FEA	Finite Element Analysis	TBC	To Be Confirmed
FS	Flight Spare	LAM	Laboratoire Astronomique de Marseille
ICD	Interface Control Document		
PID	Proportional – Integral - Derivative		
PFM	Proto-Flight Model		
MAC	Multi Axis Controller		

3. Subsystem description

3.1 Outline Description of the Beam Steering mirror mechanism subsystem

The Beam Steering Mirror mechanism subsystem (BSM) is a critical part of the SPIRE Instrument. It is used to steer the beam of the telescope on the photometer and spectrometer arrays in 2 orthogonal directions, for purposes of fully sampling the image, fine-pointing and signal modulation.

The BSM comprises 4 main deliverables :

- The cryogenic mechanism (BSMm).
- The structural interface (BSMs).
- The warm electronics (BSMe)
- Mass and optical alignment dummies as required for SPIRE system level integration, (BSMd)

The position of the BSMm & BSMs are indicated in Figure 1.

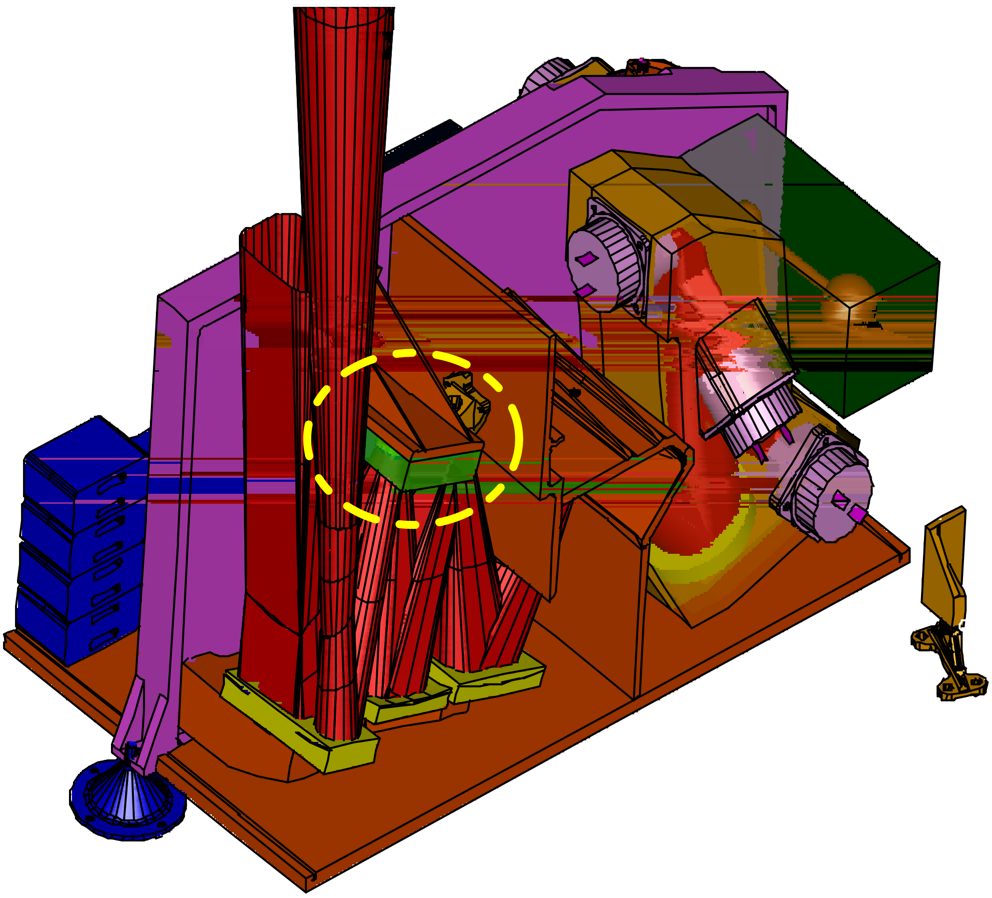

Figure 1 Photometer Layout, BSM in green, highlighted with yellow oval

The BSMs consists of an aluminium alloy mirror, nominal diameter 30mm, machined as part of the chop axis. This is mounted orthogonally within a gimbal-type frame which provides for jiggle axis motion. The axes are suspended by flex-pivot mounts.

The BSMm is a cryogenic device with nominal temperature 4K. Nominally, the chop axis provides 2.5 ° of mirror motion at 2 Hz and the jiggle axis provides 0.5° of motion at 1 Hz.

The BSM also provides an aperture through which the Photometer Calibration Source is directed towards the detector arrays.

The BSMs provides location of the BSMm on the SPIRE optical bench, and will also provide for a light tight enclosure and structural support for harnessing and thermometry. The BSMs integrates to the SPIRE Photometer Calibration Source (QMW), a baffle (RAL…TBC) and the SPIRE optical bench (MSSL). The BSMs is a cryogenic structure with nominal temperature 4K.

The BSMe provides electrical actuators used to provide motion of the mirror. Electrical transducers are used to measure the mirror position to allow control of the mirror position. The BSMe baseline design makes use of cryogenic motors and magneto-resistive sensors used in ISOPHOT. Each axis houses a rare-earth (e.g. Cobalt-Samarium) magnet moving pole piece and is driven by a motor coil fixed to the mechanism housing/structure.

The cryogenic electronics are connected to the analogue power and amplifier electronics on the Warm Electronics (WE) by a cryogenic harness which will also feed out signal cables from thermocouples on the BSMs. The BSM operates under control of the Detector Readout and Control (FSDRC) sub-system (LAM). The BSMe will be specified and designed by the UK ATC, then manufactured by LAM in conjunction with the SMEC electronics. Integration and test will be at LAM, with support from ATC.

The BSMd may comprise several actual dummies, with at least (1) an optical dummy for initial alignment work and (2) a mass-representative model for structural vibration tests. Designs for mass and optical alignment dummies will not be specified in detail until the BSMs/BSMm design is largely complete.

3.2 Subsystem Description

The BSM subsystem consists of the following parts.

BSMs - BSM structural support	This forms the support for the BSM cryogenic mechanism, and attaches the cryogenic mechanism to the optical bench. It also serves as a mounting point for a baffle, light tight enclosure and the photometer calibrator.
BSMm - BSM cryogenic mechanism	The cryogenic mechanism comprises the mirror, chop and jiggle stages, pivots, mirror structure, motors, position sensors and thermometers.
BSMe - BSM warm electronics	The warm electronics provide drive signals for the motors and read the signals from the position sensors.
BSMd – BSM mass and alignment dummy	This is a model of the cryogenic mechanism with the correct mass and a non-moving mirror. It is used for vibration testing and optical alignment

3.3 Block Diagram

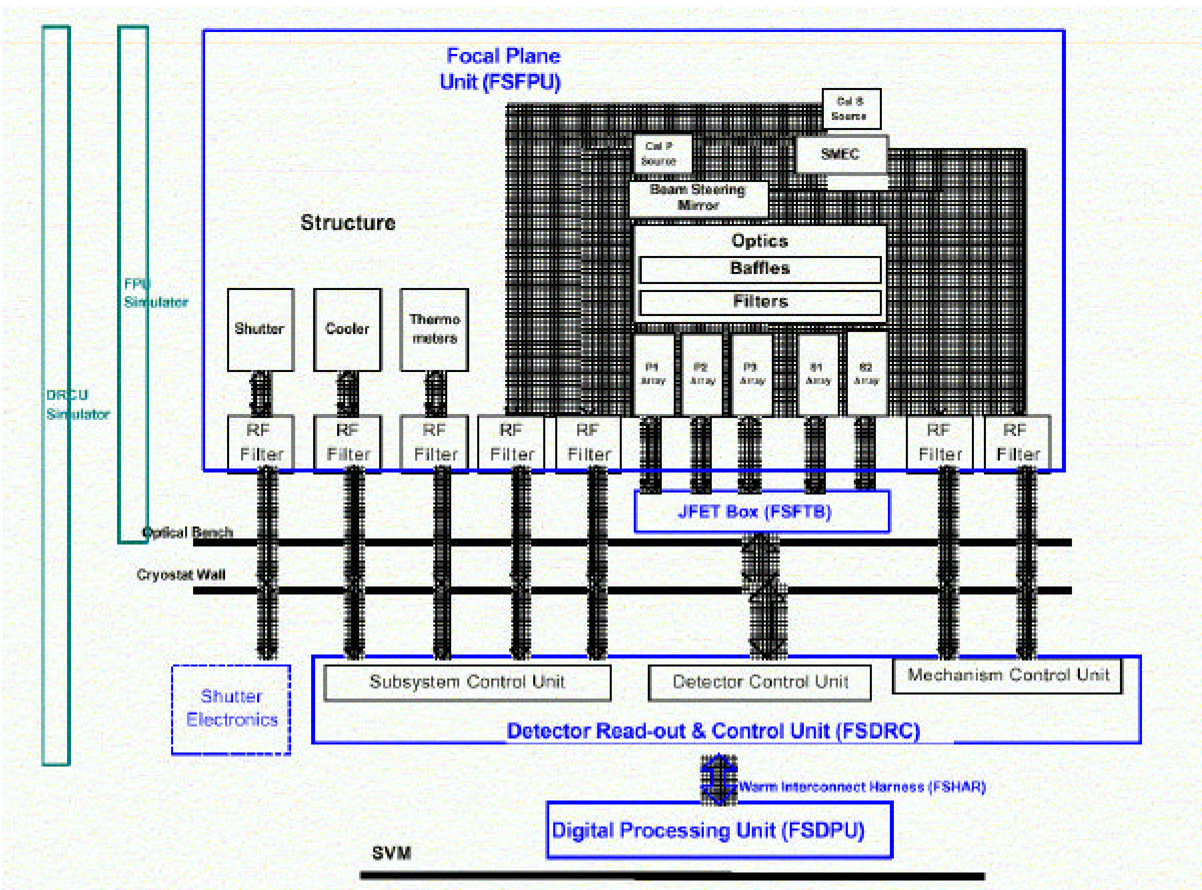

Figure 2 SPIRE Block Diagram showing BSM, SMEC and FSFPU

3.4 Mission profile

TBD

3.5 Design Assumptions

3.5.1 Optical Scaling Factor

A scaling factor between the movement of the mirror and movement of the beam on the sky of 1° (at the mirror) per 50 arcsec (on the sky) is assumed. This value is derived from the SPIRE optical design (AD13).

3.5.2 Definition of Axes

The FIRST spacecraft axes are defined in AD1, as follows:

- The X axis is the spacecraft boresight
- The Y axis is away from the HIFI instrument
- The Z axis is towards the sun shield.

The BSM is positioned in the SPIRE optical system such that the two rotation axes of the mirror produce nominal movements of the beam in the XY plane (around the Z axis) and in the XZ plane (around the Y axis) respectively.

The rotation axes of the BSM mirror shall be referred to as follows:

- Rotation producing a movement of the beam around the spacecraft Z axis - Chop axis
- Rotation producing a movement of the beam around the spacecraft Y axis - Jiggle axis

The mirror orientation is defined by two angles - the chop angle and the jiggle angle (θ_c,θ_j). The nominal zero position ((θ_c,θ_j) = (0,0)) is defined as the orientation such that the centre of the photometer detector arrays are aligned along the nominal SPIRE boresight.

4. Functional Requirements

4.1 Performance requirements

These requirements are not dependent on the particular design of the BSM.

4.1.1 Angular Travel - Chop Axis

The BSM shall allow angular movement of the mirror surface through an angle of ±2.4° in the mirror chop axis. (see assumption 3.5 for corresponding on-sky motion).	IRD-BSMP-R01 IRD-B SRD-R9
The minimum available chop throw shall be +/- 0.1° (see assumption 3.5 for corresponding on-sky motion).	IRD-B SRD-R9

4.1.2 Angular Travel - Jiggle Axis

The BSM shall allow angular movement of the mirror surface through an angle of ±0.6° (TBC) in the mirror jiggle axis. (see assumption 3.5 for corresponding on-sky motion).	IRD-BSMP-R02

4.1.3 Minimum Step Size

The BSM shall allow movements of the mirror surface in both chop and jiggle axes in minimum increments of 0.04°. (see assumption 3.5 for corresponding on-sky motion).	IRD-BSMP-R03

4.1.4 Chop Frequency

The BSM shall allow movements of the mirror in the chop axis at any frequency up to 2Hz.	IRD-BSMP-R04
As a goal, the BSM shall allow movements of the mirror in the chop axis at any frequency up to 5Hz. At frequencies above 2Hz, a degradation in power dissipation performance and settling time of the BSM is acceptable.	IRD-BSMP-R04

4.1.5 Jiggle Frequency

The BSM shall allow movements of the mirror in the jiggle axis at any frequency up to 0.5Hz.	IRD-B SMP-R05
As a goal, the BSM shall allow movements of the mirror in the jiggle axis at any frequency up to 1Hz. At frequencies above 0.5Hz, a degradation in power dissipation performance and settling time of the BSM is acceptable.	IRD-B SMP-R05

4.1.6 Holding position/ Drift Constraint

The BSM shall be capable of moving to, and holding at, any commanded position within its range of movement, to within TBD° (RMS), for periods of up to 4 hours (TBC). Note that until this requirement is more firmly defined it is assumed that the best predictions of BSM stability will suffice – see 4.1.7	IRD-BSMP-R06

4.1.7 Stability

After settling, the mirror position shall remain within 0.004° (RMS) of the mean steady state position, in the frequency range 0.03 - 25Hz.	IRD-BSMP-R07
As a goal, after settling, the mirror position shall remain within 0.002° (RMS) of the mean steady state position, in the frequency range 0.03 - 25Hz.	IRD-BSMP-R07

4.1.8 Position Measurement

The BSM shall provide measurements of the angular orientation of the mirror surface in both chop and jiggle axes to a resolution of <0.002° (TBC), at a rate of TBD Hz.	IRD-BSMP-R08

4.1.9 Settling Time

The angular position of the mirror surface shall be within 0.02° of the mean steady state position in less than 0.025 sec from the application of a demand in the chop axis.	IRD-BSMP-R09
The angular position of the mirror surface shall be within 0.02° of the mean steady state position in less than 0.100 sec from the application of a demand in the jiggle axis.	IRD-BSMP-R09
As a goal, the angular position of the mirror surface shall be within 0.02° of the mean steady state position in less than 0.050 sec from the application of a demand in the jiggle axis.	IRD-BSMP-R09

4.1.10 Chop repeatability

The steady state repeatability between successive chop cycles shall be less than 0.004° (RMS).	IRD-BSMP-R10

4.2 Technical Specifications

4.2.1 Mechanical Dimensions

The BSM shall fit within a volume of 130x130x30 mm (excluding mounting structure).	IRD-BSMP-R09
The BSM mounting structure footprint is as defined in MSSL Interface drg. A2-5264-907	AD2

4.2.2 Operating Temperature

The operational temperature of the BSM shall be at Thermal Interface Level 1 per the AD16 : nominally 4K, but in the range 3.5-6.0K .	IRD-BSMP-R10 AD16 (5.7.7.1)
The BSM shall be capable of operation (with reduced performance) at temperatures up to 300K.	IRD-BSMP-R10

4.2.3 Thermal Isolation

No part of the BSM visible to the optical path shall rise by no more than 1K from the nominal operating temperature of the surrounding structure after 1 hour of operation in any mode	IRD-BSMP-R11

4.2.4 Cold Power Dissipation

The average power dissipation of the BSM Cryogenic Mechanism (BSMm) and the BSM Support Structure (BSMs) shall be less than 4mW in any operating mode, when operating at the temperature defined in section 0	IRD-BSMP-R12

4.2.5 Warm Electronics Power Dissipation

The average power dissipation of the BSM Warm Electronics (BSMe) shall be less than TBD Watts when chopping at 2Hz in any operating mode.	IRD-BSMP-R13

4.2.6 Mirror Surface Dimensions

The mirror clear diameter shall be greater than 32mm (TBC).	AD13
The mirror shall include a central hole of no greater than 2mm diameter (TBC) to allow the Photometer Calibrator to be seen by the detectors.	AD13

4.2.7 Mirror Surface Finish

The mirror surface of the BSM shall be flat to <2µm (RMS) (TBC) and shall have a surface roughness of <10nm (RMS).	AD13, AD18

***See also* 4.5.4.1.**

4.2.8 Mirror Surface Reflectivity

The reflectivity of the mirror surface of the BSM shall be >99% in the wavelength range 200 - 670 µm.	AD13, AD18

See also 4.5.4.2.

4.2.9 Mirror Surface Emissivity

The emissivity of the mirror surface of the BSM shall be <1% in the wavelength range 200 - 670µm.	AD13, AD18

4.2.10 Position of Rotation Axes

TBD	TBD

4.2.11 Orthogonality of Rotation Axes

TBD	TBD

4.2.12 Fail Safe (No Drive Signal) Position

When no drive signals are applied to the BSM, the mirror shall take up a position such that the mirror surface is perpendicular to the nominal (0,0) mirror position to within ±0.18°. For information, this is intended to place the BSM within 50% of the beam FWHM.	???

4.2.13 Fail Safe (Mechanical Failure) Position

In the event of mechanical failure on launch, the mirror shall take up a position such that the beam remains useable by the spectrometer instrument, i.e. That the mirror surface is perpendicular to the nominal (0,0) mirror position to within ±1.0°.	???

4.2.14 Mass

The BSM cryogenic mechanism (BSMm) and the BSM support (BSMs) shall have a combined mass of less than 1100g.	???

4.2.15 Cool-down time

Upon integration to the SPIRE optical bench, the BSM shall reach a temperature of 4K within 15 hours of the commencement of cooldown. This assumes a maximum average cooldown rate of 20K/hour.	???

4.3 Operational Specification

4.3.1 Operational Safety

The BSM shall operate safely in any normal operating mode.	???

4.3.2 Lifetime

The BSM shall be capable of operation in any normal mode for periods in excess of 1/6 of the nominal mission lifetime.	AD1
Lifetime tests of the chop/jiggle mode will use a multiplier of 1.25x	RD16
Lifetime tests of items operating <100000 times will use factors as specified in RD 16	RD16

Life time breakdown				
#	Parameter	IRD	Value	Note
OL1	Ground Storage lifetime		2 years	A guess
OL2	Ground Integrated lifetime		4 years	A guess
OL3	Ground operational lifetime		1.5 years TBC	6 months for subsystem acceptance 6 months for SPIRE acceptance 6 months for FIRST acceptance
OL4	On orbit operational (chop & jiggle mode) lifetime		Minimum 8.5 months cumulative time	Operating during 1/6 of the mission duration (4.25 years)
OL5	On orbit de-powered operational lifetime		Up to 3.5 years cumulative time	TBD
OL6	On Orbit powered but not chopping (servo control only)		Up to 3.5 years cumulative time	TBD May be required if self-damping inadequate in face of micro-vibration environment

4.3.3 Operating modes

AD14 defines the required modes of operation in detail. There are 14 (TBC) operational modes, but from the point of view of the BSM motion they fall into three categories :

Jiggle	AD14
Chopping	AD14
Scan mapping	AD14

Additionally holding the 'stare' position may require active servo control.

4.3.4 Jiggle Mode

Jiggle Mode is used to optimize the sampling of the detector arrays. In this mode, the mirror is stepped in small angular increments.

Jiggling may be done in any angular orientation (i.e. jiggling is not confined to the jiggle axis, and will usually be a combination of movements in the chop and jiggle axes).

Jiggle movements may be demanded in both chop and jiggle axes simultaneously.
The fine pointing mode is executed as a jiggle pattern, and the difference lies in the processing/use of the data.

Jiggle mode will be used with both the photometer and the FTS. When the FTS is in use no chop will be required. During a photometer jiggle operation the BSM is also required to chop. i.e. at each jiggle position a number of chop cycles will be executed.

4.3.5 Chopping Mode

Chopping Mode is used to provide removal of 1/f noise in the photometer detectors. The mirror is used to move the source of interest between two separate detectors.

Chopping is only required in one axis (the chop axis), and will only be used when the photometer is in use, not with the FTS

4.3.6 Scan mapping

Scan mapping with chopping may be required. The jiggle and chop axes are used to execute chopping either parallel to or perpendicular to the scan direction, with the frequency of chop set by the jiggle axis frequency limit.

4.3.7 Stare or 'holding' mode

Dependent on spacecraft vibration levels, the BSM may require active servo control in order to maintain the nominal 'power-off' hold position within adequate accuracy. This is TBD.

4.3.8 Combinations of Modes

The following combinations of the basic modes are required.

1. Chopping and Jiggling
2. Removal of optical or mechanical cross coupling during Chop-only or Jiggle-only operations.

4.4 Interface requirements

4.4.1 Data Outputs

The following data is provided by the BSM.

Data	**Rate**	**Reference**
Chop axis position	TBD	
Jiggle axis position	TBD	
Thermometer data	1Hz (TBC)	
Motor voltage (or current, TBD)	TBD	

4.4.2 Data Inputs

The following inputs are required to operate the BSM.

Data	**Rate**	**Reference**
Chop axis demand position	On Demand, max. 5Hz	AD19
Jiggle axis demand position	On Demand, max. 1Hz	AD19
Control system parameters (PID terms)	TBD, but slow	AD19
Trajectory parameters (3 for each axis)	TBD, but slow	AD19
Unlatch signal, if required	One-off	AD19

4.4.3 Self induced vibration

The BSM will produce vibration in the region 0-5 Hz, with TBD harmonics and TBD amplitude.

4.4.4 Stray Magnetic fields

To prevent spurious signal generation, magnetic field strength at the BSM position sensors should not exceed TBD

4.4.5 Electro-Magnetic Compatibility

TBD - Grounding, Radiated emissions, etc…

4.4.6 ICD's

The BSM interfaces with the following other subsystems in the SPIRE instrument. The interface to each sub-system is specified in the relevant Interface Control Document.

Sub-System	**ICD Reference**
Structure – BSM	AD2
Optics – BSM	AD4
Baffles – BSM	AD5
Photometer Bolometer Arrays - BSM	AD6
Spectrometer Bolometer Arrays - BSM	AD7
Photometer Calibration Source - BSM	AD8
On Board Software - BSM	AD10
FPU Simulator - BSM	AD11
Instrument Simulator - BSM	AD12
MCU-BSM	AD19

4.5 Design, manufacture and test requirements

This section details additional requirements which are placed on the sub-system which are not necessary to meet the functional or operational requirements, but are necessary to enable the sub-system to be designed, manufactured or tested.

4.5.1 Design requirements

UK Astronomy Technology Centre design procedures shall be adopted as applicable.

4.5.2 Electronics Card Format

All electronics associated with the BSM shall be mounted on double eurocards.

4.5.3 Product Assurance Plan

The BSM deliverables will comply with the Spire Product Assurance Plan, AD20.

4.5.4 Manufacturing and testing requirements

4.5.4.1 Mirror Flatness

To facilitate optical laboratory testing, the mirror surface shall have a flatness of <100nm (P-V).

4.5.4.2 Mirror Reflectivity

To facilitate optical testing laboratory testing, the mirror surface shall have a reflectivity of >80% at 633nm.

4.5.5 Parts, Material and Processes

4.5.5.1 General

The workmanship and materials used shall be, or shall be shown to be compatible in any future build, of a standard consistent with flight hardware. The number of materials, mechanical parts types, and processes shall be minimized. Materials and mechanical parts that have been successfully used in similar space applications shall be preferred. Standard processes or known processes previously used in space applications shall be preferred. Material justification shall prove the hardware structural integrity during the design life.

4.5.5.2 Materials, Processes and Mechanical parts (MPM) approval and listing

All MPM meeting the requirements of this document shall be approved by submitting to TBD the Declared Materials List. If these requirements are not met, a RFA shall be submitted to TBD. A Declared Materials List (DML) shall be drawn up, according to the requirements of ECSS-Q- 70 § 3.1.3. The format of PSS-01-700, issue 2, Annex B, is a suitable example. Materials with limited-life characteristics and non-metallic materials shall be highlighted. Mechanical parts shall be included in the DML as a separate group. Process details shall also be included in the DML for the appropriate material. Critical processes shall be highlighted.

4.5.5.3 Cleanliness

The BSM shall be class 100 compatible

4.5.5.4 Finish

Surface finish shall prevent deterioration from exposure to the environment. Aluminium surfaces shall be treated for corrosion protection coating. Mechanical parts made of stainless steel shall be passivated.

4.5.5.5 Outgassing

PSS-01-702 shall be used as a guideline.

4.5.5.6 Material selection

In addition to ESA guidelines noted elsewhere in the applicable documents, the following guidelines will be observed.

Structures will be a 6082 grade aluminium alloy to UK standards, and will be selected in consultation with the optical bench design body (MSSL). The BSM mirror may be specified in grade 6061-T6/T651 to ensure adequate thermal stability based on ATC practice.

Fasteners will be cryogenic grade stainless steel. Where practicable they will be of a self locking type. Fasteners may include UNS thread types where required on the grounds of availability in small sizes, or as required by ICD, otherwise will be metric thread. In cases where a self locking fastener is not available, Stycast or Scotchweld 1838 will be used in visible applications under fastener heads.

4.5.5.7 Processes

The use of existing ESA documents shall be maximized. In particular the following documents shall be consulted:

- PSS-01-708 for soldering
- PSS-01-726 for crimping

Critical processes shall be identified and reported to TBD through a critical process list or the DML.

4.6 Logistic requirements

4.6.1 Storage

The BSM shall not suffer any performance degradation following storage in a dry nitrogen atmosphere for a period of up to 5 years.

Storage temperatures shall be in the range +5°C to +30°C.

4.6.2 Handling

TBD.

4.6.3 Transportation

TBD

4.6.4 ESD precautions

TBD

4.7 Environmental requirements

These requirements describe the environment the subsystem will encounter during its life.

4.7.1 Operating environment

This section defines the environment for the BSM during operation. The BSM must meet all of the functional and operational requirements specified in section 4 when operating under this environment.

4.7.1.1 Shock

TBD. As a working figure 50g static acceleration loads in all three axes are assumed.

4.7.1.2 Vibration

TBD	

4.7.1.3 Vacuum Level

Less than 10-4 Pa TBC	

4.7.1.4 Vacuum Outgassing

Less than TBC	

4.7.1.5 Temperature

The BSM shall perform within specification at the operational temperature cited in 4.2.2. In addition, the BSM will operate with reduced performance at temperatures from 4-300K.	

4.7.1.6 Magnetic Fields

To prevent spurious position signal input, stray magnetic fields must not exceed TBD at the chop and jiggle position sensors.	

4.7.1.7 Survival Temperature

The BSM shall remain fully operational following exposure to temperatures of 80°C for periods of up to 72 hours.	

4.7.1.8 Radiation environment

The integrated dose for silicon behind 2 mm of aluminium is estimated at 12 kRad and behind 5 mm of aluminium as 3.5 kRad. These figures will be taken as the radiation tolerance for components in the warm electronics boxes and inside the cryostat respectively (TBC).	RD2

4.8 Verification requirements

The BSM Development Plan (AD15) contains more detail on the actual tests to be carried out on the BSM. The table below shows how each of the functional and operational requirements in this document is to be demonstrated, for each of the BSM models.

Test T
Measurement M
Analysis A
Inspection I

4.8.1 Performance Requirements

Reference	Requirement	CQM	PFM	FS
4.1.1	Angular Travel - Chop Axis	T	T	T
4.1.2	Angular Travel - Jiggle Axis	T	T	T
4.1.3	Minimum Step Size	T	T	T
4.1.4	Chop Frequency	T	T	T
4.1.5	Jiggle Frequency	T	T	T
4.1.6	Holding position	T	T	T
4.1.7	Stability	T	T	T
4.1.8	Position Measurement	T	T	T
4.1.9	Settling Time	T	T	T
4.1.10	Chop repeatability	T	T	T

4.8.2 System Requirements

Reference	Requirement	CQM	PFM	FS
4.2.1	Mechanical Dimensions	M	M	M
4.2.2	Operating Temperature	T	T	T
4.2.3	Thermal Isolation	T	T	T
4.2.4	Cold Power Dissipation	T	T	T
4.2.5	Warm Electronics Power Dissipation	T	T	T
4.2.6	Mirror Surface Dimensions	M	M	M
4.2.7	Mirror Surface Finish	I	I	I
4.2.104.2.8	Mirror Surface Reflectivity	A	A	A

4.2.9	Mirror Surface Emissivity	A	A	A
4.2.10	Position of Rotation Axes	I	I	I
4.2.11	Orthogonality of Rotation Axes	T	T	T
4.2.12	Fail Safe (No Drive Signal) Position	T	T	T
4.2.13	Fail Safe (Mechanical Failure) Position	TBD		
4.2.14	Mass	M	M	M
4.2.15	Cool-down time	T	T	T

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