SPIRE BSM SUBSYSTEM TEST PLAN

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DOCUMENT APPROVAL

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Date	Index	Remarks
22/3/02	1.4	Catalogued in Qpulse
24/1/03	2.1	Updated by David McNeill
27/06/03	2.4	Update by D. McNeill (not added to Qpulse). Update of Model Testing Flow Plans, spec call-up from SSSD (AD 3) and some procedures updated.
01/07/03	3.0	Section on Design Verification Tests removed and made into separate document.
09/10/03	3.2.6	Re-order of Tests and Update.
26/10/03	3.2.9	Addition of separate resolution test: 4.8.
05/11/03	4.0	Issue for sign–off.

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Change order below.

1 APPLICABLE AND REFERENCE DOCUMENTS

1.1 Applicable documents

Applicable documents are project specific and may be assumed to apply fully to the BSM, unless stated otherwise

Ref	Title	Author	Reference	Ver	Date
AD 1	SPIRE Instruments Requirements Document (Section 3.5.7, Beam Steering Mechanism)	B. Swinyard, K. King.	SPIRE-RAL-PRJ-000034	1.1	02. Jan. 02
AD 3	SPIRE Beam Steering Mirror Subsystem Specification Document	P. Parr-Burman.	SPIRE-BSM-PRJ-0460	TBD	
AD 5	SPIRE Instrument AIV Plan	B. Swinyard.	SPIRE-RAL-DOC-000410	TBD	
AD 7	SPIRE BSM Development Plan		SPIRE-BSM-PRJ-466	TBD	
AD 9	BSM Axes Definition		TBD		
AD 6	SPIRE BSM Subsystem Development Test Plan	D. McNeill	TBD		

1.2 Reference documents

Reference documents are generic and may only apply in part to the project, or may be for information or reference only.

Ref	Title	Author	Reference	Ver	Date
RD 1	BSM Inspection Record		TBD		
IRD 2	Operating Modes for the SPIRE Instrument	B. Swinyard, M. Griffin.	SPIRE-RAL-PRJ-000320	3.0	04. Jan. 03
RD 3	Test and Calibration Results Document		TBD		
RD 4	Calibration Mirror Tilt Measurement		TBD		

1.3 Glossary of Acronyms and Abbreviations

Abbreviation	Definition	Abbreviation	Definition
AD	Applicable Document	LAM	Laboratoire d'Astrophysique de Marseille
ADP	Acceptance Data Package	LAT	Lot Acceptance Tests
ARB	The Acceptance Review Board	MAPTIS	Materials and Processes Technical Information Service
BSM	Beam Steering Mirror	MSFC	Marshall Space Flight Center
BSMe	Beam Steering Mirror electronics	MCU	Mechanism Control Unit
CAE	Computer Aided Engineering	MIP	Mandatory Inspection Point
CDR	Critical Design Review	MGSE	Mechanical Ground Support Equipment
CoG	Centre of Gravity	MPIA	Max Planck Institute for Astronomy
CIL	Critical Items List	MSSL	Mullard Space Science Laboratory
CQM	Cryogenic Qualification Model	NASA	National Aeronautical Space Agency
CTD	Change to Drawing/Document	NA	Not Applicable
DCL	Declared Components List	NCR	Non Conformance Report
DDR	Detailed Design Review	NCRP	Non Conformance Review Panel
DM	Development Model	OGSE	Optical Ground Support Equipment
DML	Declared Materials List	PA	Product Assurance
DPA	Destructive Physical Analysis	PAD	Part Approval Document
ECSS	European Cooperation for Space Standardisation	PFM	Proto Flight Model
EGSE	Electrical Ground Support Equipment	PPARC	Particle Physics and Astronomy Research Council
ESA	European Space Agency	PI	Principal Investigator
FMEA	Failure Modes and Effects Analysis	QA	Quality Assurance
FMECA	Failure Modes, Effects and Criticality Analysis	RAL	Rutherford Appleton Laboratory
FPGA	Field Programmable Gate Array	RAL SSD	RAL Space Science Department
FPU	Focal Plane Unit	RD	Reference Document
FSM	Flight Spare model	SMEC	Spectrometer Mechanism

GSFC	Goddard Space Flight Center	SPIRE	Spectral and Photometric Imaging REceiver
GSE	Ground Support Equipment	TBC	To Be Confirmed
HoS	Head of Specialism	TBD	To Be Defined
Herschel	ESA Mission name (formerly FIRST)	TBW	To Be Written
IBDR	Instrument Baseline Design Review	UK ATC	United Kingdom Astronomy Technology Centre
KIP	Key Inspection Point	UK SPO	UK SPIRE Project Office
		WE	Warm Electronics

See http://www.roe.ac.uk/atc/projects/spire/SPIRE_BSM_Glossary.html for most up to date version.

2 INTRODUCTION

This document describes the proposed tests used to verify the performance of the SPIRE Beam Steering Mirror (these tests are essentially the system acceptance tests). Test procedures in this document are composed to test the required specifications set forth in the Subsystem Specification Document (AD 3) and as selected in The Development Plan (AD 4). AD 3 is derived from the SPIRE System requirements in AD 1.

The BSM is a two axis position controlled device, working at 3.5 - 6 degrees K. The mirror is supported on flexible rotating joints, and uses linear motors and magnetoresistive position sensors.

The BSM System comprises the BSM mechanism, the Warm Electronics and the Control Software. The BSM Warm Electronics and Control Software will be built by Laboratoire d'Astrophysique de Marseille (LAM) in France, to UKATC specifications.

There are two main test areas for the SPIRE Beam Steering Mirror based on the requirements for the testing: design and performance verification. This document is concerned with Performance Verification. The test details and required system hardware for deliveries are outlined in AD 7.

There are several models used for development and to verify levels of performance, and then the flight and flight spare are tested against Specification for performance. –

Prototype Model(s) - for proof of concept work

DM-1, DM-2 - Development Models
Used for detailed engineering development, performance verification, and survivability qualification. Used at ATC.

STM - Structural and Thermal Model
Used for vibration and thermal tests at ATC and RAL

PFM - Proto-Flight Model
Flight Hardware delivered to RAL and ESA

FS - Flight spare.

3 TEST SEQUENCE

Figure 1and Figure 2 show the test sequences for each model as defined in AD 7.
The specific tests relating to qualification and performance and necessary supporting tests are outlined in this document.

Figure 1: BSM Tests and Models Overview.

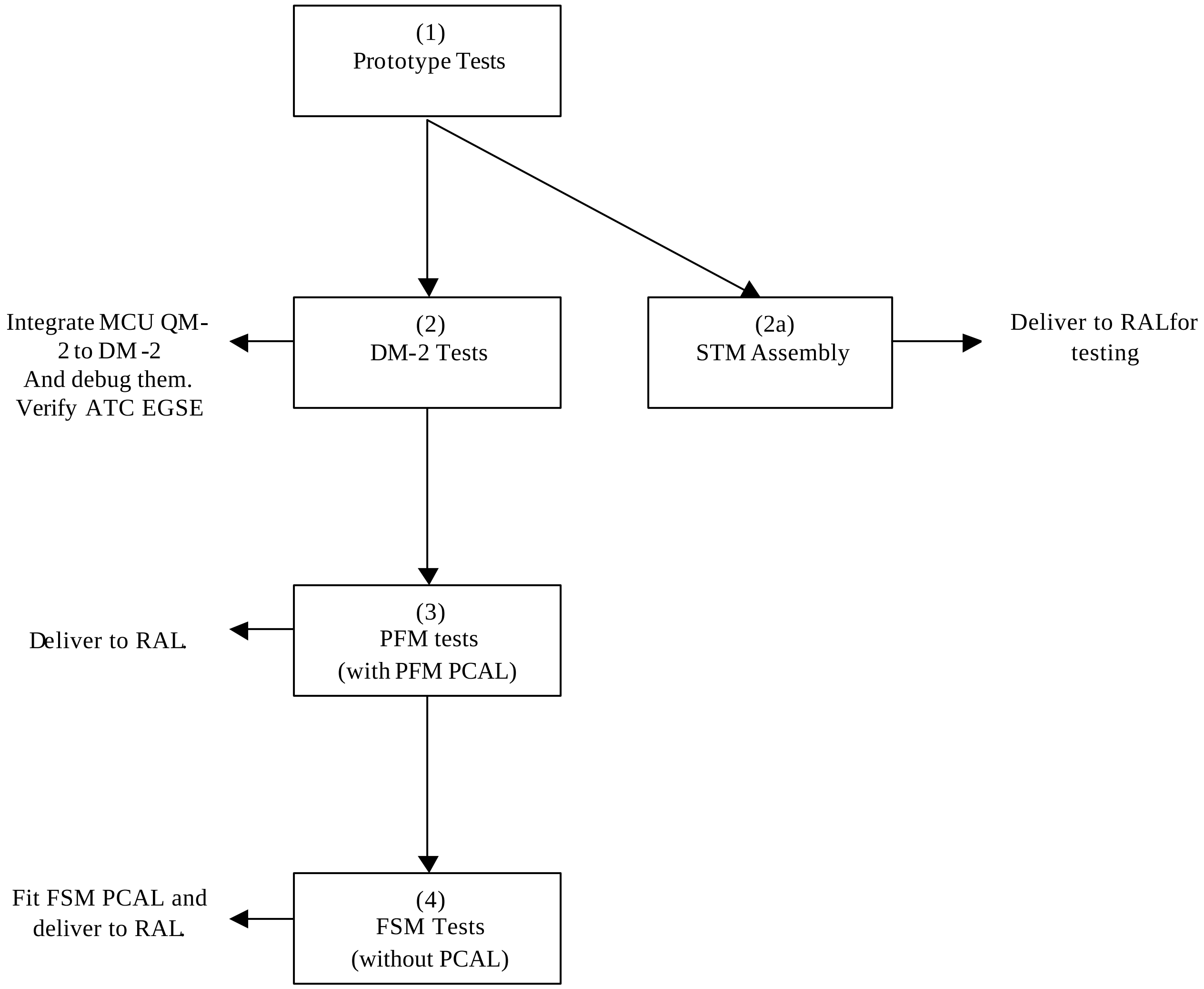
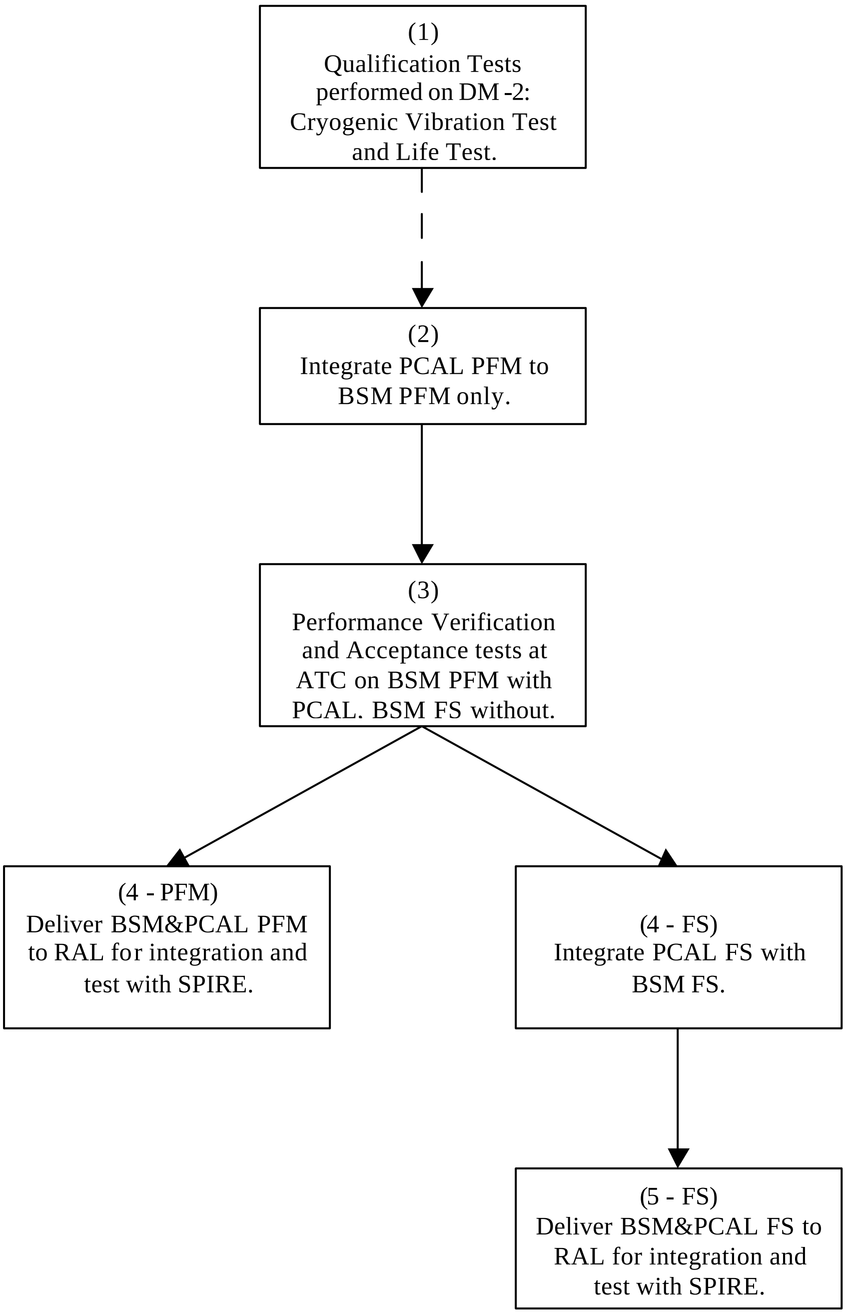


Figure 2: BSM Proto-Flight Model (PFM) and Flight Spare (FS) Tests And Qualification Tests on DM-2



Note: This is the baseline, but it is possible that both models of the BSM may be tested and delivered without PCAL.

4 PERFORMANCE VERIFICATION TESTS

Performance Verification tests are on the two models: the Proto-Flight Model and the Flight Spare. The tests are also to be carried out on both the Prime and Redundant circuitry of both models, except where marked.

All tests (except where marked) are at <80 deg.K, and most at 3.5 – 6K. A temperature shall be recorded during every test [See AD 3 Spec. Requirement BSM-SSSD-R82]. The Warm Electronics is at room temperature.

The following tests comply with the Verification Requirements of AD 3 section 4.8.

4.1 Mirror Surface Flatness

Mirror Surface Flatness

This test is performed on the mirrors before they are assembled into the main structure of their respective BSMs.

Set up the cryostat and interferometer in a place in which the set-up can remain undisturbed.

Access to the cryostat should be possible without disturbing the setup (in particular the relative positions of the cryostat and interferometer). This is achieved by mounting the cryostat on a three-point mount accurately positioned relative to the interferometer. The cryostat can be removed and repeatably replaced in the same position.

The mirror is tested as follows:

1) Calibrate interferometer with reference flat.

2) Cryostat containing mirror to be tested is then aligned with the interferometer.

3) Flatness of mirror is tested warm at atmospheric pressure.

4) The cryostat can now be evacuated and the flatness measurement repeated to determine the change in interferogram caused by the bow of the dewar window.

5) The cryostat can now be cooled to 77K and the flatness measurement repeated to determine the change in surface form of the mirror.

6) As the cryostat is allowed to warm up further measurements can be taken.

Note than during cooling the tilt of the mirror relative to the interferometer is likely to change and appropriate adjustments will be required to maintain fringes.

Specification:
The flatness of the mirror over the 32mm clear diameter of the mirror shall be <1µm rms (<2µm rms wavefront error) when cold.
[See AD 2 Spec. Requirement BSM-SSSD-R28]

4.2 Fail Safe (No drive signal) Position

This test is performed first out of all the Performance Verification tests after the units are assembled. This test is to be performed at 77K

Upon full assembly of the BSM, but before integration of PCAL unit, assemble the 3-point mounted alignment mirror (part SPI-BSM-022-007) onto the PCAL mount giving a reference nominal (0,0) position. The BSM mirror is measured with respect to this mirror, ensuring correct orientation. (See RD 4 'Calibration Mirror Tilt Measurement' for measurement of calibration mirror's accuracy)
The measurement is to be conducted using a laser directed through the PCAL hole in the centre of the BSM mirror. The beam is to return along the same path, so that the returning spot falls through the aperture of the laser. The laser beam is therefore normal to the alignment mirror. Once so positioned, the BSM is to be mounted so that it will not be moved for the duration of the test. The distance between the laser and the BSM mirror is known. The laser will be solidly fixed onto an assembly which will allow repeatable movement of the laser, sliding perpendicularly to the beam. This is so that the laser can be reflected off the alignment mirror through the hole in the BSM, then moved to reflect off the BSM mirror, and thus obtain a true measurement of out-of-alignment.

The distance (measured at the laser) between the aperture and the returning spot after reflection off the BSM mirror shall be such that the angle subtended is less than or equal to 0.30 degrees. Since there is a factor of two due to mirror reflection, this mirror reflection angle of 0.30 relates to the mirrors being out of alignment by no more than 0.15 degrees. Record this actual angular position of the mirror with respect to the alignment mirror.

Take sensor readings (voltages) of the mirror position when it is correctly aligned and driven to zero (this need only be performed on one circuit of the BSM – prime or redundant, not both). Define this as the Alignment Zero of sensors for further tests, e.g. test 4.5 Angular Travel.
[See AD 2 Spec. Requirement BSM-SSSD-R41]

4.3 Mass of Unit

Place the complete BSM unit (without any external wires connected to the BSM) on scales graduated to the nearest gram. Read and record mass. Do this with and without PCal (if PCal available).
(Previous to weighing, the scales will be tested with calibration weights.)

4.4 Operating Temperature

When at room temperature (300K) plug in the BSM and make sure that the motors operate and the sensors function by inputting reduced angle throw commands to both axes. Observe mirror movement and sensor feedback traces on the dSPACE programme, and record position sensor information and motor currents using dSPACE's signal capturing ability. (Note that the normal operating calibration does not apply, as the scale factors of sensors and motor ability changes drastically from room temperature to 4K.)
The BSM shall be capable of (reduced performance) operation at temperatures up to 300K.
[See AD 3 Spec. Requirement BSM-SSSD-R21]

4.5 Angular Travel

These tests are to verify that the BSM can move through the full angle required by specification.

4.5.1 Minimum Chop Throw

Input a square wave of +/- 0.08deg and frequency 0.5Hz, and record the mirror angular position using the external optical equipment.
The minimum chop throw shall be <= +/ -0.09 deg.
[See AD 3 Spec. Requirement BSM-SSSD-R2]

4.5.2 Combined Jiggle and Chop

Test performed at 4 – 6K.

Using DSpace Test Software Module 'bsm_verification.mdl', perform and record angles for combinations as in table:

	+ Jiggle	0 Jiggle	- Jiggle
+ Chop	Max chop and max Jiggle combined.	Max Chop for zero deg jiggle.	Max chop and min jiggle combined.
0 Chop	Max jiggle for zero deg chop.	Fail safe position. (See Note (a) below.)	Min jiggle for zero deg chop.
- Chop	Min chop and max jiggle combined.	Min chop for zero deg jiggle.	Min chop and min jiggle combined.

Whilst performing these tests, note sensor voltages for +/- 2.53 degrees chop and +/- 0.573 degrees jiggle. These will be used during test 4.7 Position Measurement.

Maximum chop angles shall all be >= +2.60 degrees, minimum chop angles shall all be <= -2.60 degrees. Maximum jiggle angles shall be >= +0.60 degrees, minimum jiggle angles shall all be <= -0.60 degrees.

Angles shall be measured using external optical equipment.
Note (a): The zero shall be the Alignment Zero defined in test 4.2 Fail Safe (No Drive Signal) Position.
[See AD 3 Spec. Requirement BSM-SSSD-R1, R3, R4]

4.6 Minimum Step Size

4.6.1 Chop

Using DSpace Test Software Module 'Bsm_verification.mdl' and measuring using the external optical equipment, apply a 2 Hz square wave command at an amplitude of <=0.030 deg peak to trough to the Chop axis. Record the amplitudes.
Verify that the measured Chop angle is <= 0.030 deg peak to trough.
[See AD 3 Spec. Requirement BSM-SSSD-R5]

4.6.2 Jiggle

Using DSpace Test Software Module 'Bsm_verification.mdl' and measuring using the external optical equipment, apply a 0.5 Hz square wave command at an amplitude of <= 0.030 deg peak to trough to the Jiggle axis. Record the amplitudes.
Verify that the measured Jiggle angle is <=0.030 deg peak to trough.
[See AD 3 Spec. Requirement BSM-SSSD-R5]

4.7 Position Measurement

4.7.1 Chop

This test and 4.7.2 are used to ensure that the BSM movements are accurate i.e. actual movement compared to commanded signal.

These results are to be acquired using the TMA (Tilt Measurement Apparatus), using an external laser. A pellicle beam splitter (at approximately 45 degrees to the mirror) directs the reflected beam from the mirror on to the TMA sensor (The TMA sensor is sitting at approximately 90 degrees to the mirror). The TMA is mounted on a translation stage, allowing for accurate movement of the TMA so that full chop throw can be measured.

Using DSpace test module "bsm_verification.mdl", scan the Chop axis -in enough increments to fill the linearisation look-up table for sensors- between +2.53 (+0.1, -0)° and –2.53 (+0, -0.1)°. At the same time, record the measured mirror Chop position using the TMA.
Note: When linearisation of the sensors is complete, the zero position of the system (i.e. the corrected readings from the sensors) is to be the same as the Alignment Zero position as defined during test 4.2 Fail Safe (No Drive Signal) Position (was also used during test 4.5 Angular Travel). Also note that the +/- 2.53 degrees linearisation-table figures are to be defined using the sensor voltages noted in test 4.5.2 for these angles. This calibrates the TMA for the rest of the linearisation.
Note that for chop, the large +/-2.53 deg throw means that there have to be several position windows when using the TMA.

Analyse the stored control input and corresponding angles. Construct a look-up table that linearises the actual position with respect to the demanded position. Insert the table parameters into the dSPACE model and repeat the above test. The difference between the demand and the measured angle after linearisation shall be <= 0.0035° rms for the range +2.53 (+0.1, -0)° to –2.53 (+0.1, -0)°. Record these comparisons throughout the range.
[See AD 3 Spec. Requirement BSM-SSSD-R12]

4.7.2 Jiggle

These results are to be acquired using the TMA, using an external laser. A pellicle beam splitter (at approximately 45 degrees to the mirror) directs the reflected beam from the mirror on to the TMA sensor (The TMA sensor is sitting at approximately 90 degrees to the mirror). The TMA should not have to be moved to obtain full movement.

Using DSpace test module "bsm_verification.mdl", scan the Jiggle axis -in enough increments to fill the sensor linearisation look-up table- between +0.573 (+0.1/-0)° and –0.573 (+0/-0.1)°. At the same time, record the measured mirror Jiggle position using the TMA.

Note: When linearisation of the sensors is complete, the zero position of the system (i.e. the corrected readings from the sensors) is to be the same as the Alignment Zero position as defined during test 4.2 Fail Safe (No Drive Signal) Position (was also used during test 4.5 Angular Travel). Also note that the +/-0.573 degrees linearisation-table figures are to be defined using the sensor voltages noted in test 4.5.2 for these angles. This calibrates the TMA for the rest of the linearisation.

For jiggle, one position window should be sufficient to measure full throw at approximately 130mm.

Analyse the stored control input and corresponding angles. Construct a look-up table that linearises the actual position with respect to the demanded position. Insert the table parameters into the dSPACE model and repeat the above test. The difference between the demand and the measured angle after linearisation

shall be <= 0.0035° rms for the range +0.573 (+0.1/-0)° to –0.573 (+0/-0.1)°. Record these comparisons throughout the range.
[See AD 3 Spec. Requirement BSM-SSSD-R12]

4.8 Resolution

4.8.1 Chop

Using DSpace test module "bsm_verification.mdl", move axis from 0.80 degrees to 0.85 degrees at a rate slow enough to measure resolution- approximately 0.01 degrees per second. For this time, record the sensor output using dSPACE's signal capturing capability. Confirm that the resolution (measured as the incremental step size) of the measured angle is <= 0.0004°. Record a figure for the actual resolution.
[See AD 3 Spec. Requirement BSM-SSSD-R12]

4.8.2 Jiggle

Using DSpace test module "bsm_verification.mdl", move axis from 0.30 degrees to 0.35 degrees at a rate slow enough to measure resolution- approximately 0.01 degrees per second. For this time, record the sensor output using dSPACE's signal capturing capability. Confirm that the resolution (measured as the incremental step size) of the measured angle is <= 0.0004°. Record a figure for the actual resolution.
[See AD 3 Spec. Requirement BSM-SSSD-R12]

4.9 Position Stability

This test need only be performed on the PFM, not on the FS. This is because holding position is affected by:
(1) Electronic Control – not included in BSM mechanism, so not tested here.
(2) Sensor Stability – Qualified by similarity with PFM.
(See verification summary in AD4: Development Plan)

4.9.1 Chop

Set up the TMA at a distance allowing for sufficient precision, and using dSPACE test software module 'bsm_verification.mdl' apply a nominal 0.0 chop and jiggle position command. For 60 seconds, record actual position measured by the TMA for at a sample rate of >= 500 Hz.. Verify that the noise on the measured Chop position (after low-pass filtering at 25 Hz) is <= 0.003° RMS. Record a figure for the RMS noise on chop over the 60 seconds of this test.
[See AD 3 Spec. Requirement BSM-SSSD-R11]

4.9.2 Jiggle

Using the data from the previous tests, verify that the noise on the measured Jiggle position (after low-pass filtering at 25 Hz) is <= 0.003° RMS. Record a figure for the RMS noise on jiggle for the 60 seconds of this test.
[See AD 3 Spec. Requirement BSM-SSSD-R11]

4.10 Holding Position

For these tests especially, make sure that the equipment has had sufficient time to 'warm up' and settle before testing begins. The chop and jiggle tests may be performed simultaneously.
The holding position test is to be performed on the PFM model only. This is because holding position is affected by:
(1) Electronic Control – not included in BSM mechanism, so not tested here.

(2) Sensor Stability – Qualified by similarity with PFM.
(See verification summary in AD4: Development Plan)

4.10.1 Chop

Using DSpace Test Software Module 'bsm_verification.mdl' and Quadrant detector apparatus at a distance from the mirror surface that allows for sufficient precision, apply a nominal target value of 0.0 deg Chop position command, and record the Chop axis angle output for a period of 4 hours. The system will monitor the position of the axis at a sample rate of >=100 Hz, however, the system will not record this data unless the position of the axis leaves the region of 0.0030 deg rms from the target value . In addition to this, the system will record one data point at least every minute regardless of the axis position.

Analyse the monitor record and verify that the deviation from the target value (after filtering at 25Hz if necessary) is <= 0.0035° rms. Calculate an rms figure from the recorded data and record this figure.
[See AD 3 Spec. Requirement BSM-SSSD-R10]

4.10.2 Jiggle

Using DSpace Test Software Module 'bsm_ verification.mdl' and Quadrant detector apparatus at a distance from the mirror surface that allows for sufficient precision, apply a nominal 0.0 deg Jiggle position command, and monitor and record the Jiggle axis angle output for a period of 4 hours as before (Test 4.10.1).

Analyse the monitor record and verify that the deviation from the target value after filtering at 25Hz is <= 0.0035° rms. Calculate an rms figure from the recorded data and record this figure.
[See AD 3 Spec. Requirement BSM-SSSD-R10]

4.11 Repeatability

This test is performed only once the 4.7 Position Measurement test has been completed, using linearised and calibrated sensor output.

4.11.1 Chop

Using DSpace test module 'bsm_verification.mdl', scan the Chop axis by commanding a square wave motion at 0.1 Hz between +1.5 (+/- 0.1) deg and –1.5 (+/- 0.1) deg.

The following programme is to be run, which compares the positive position sensor values with each other, and the negative position sensor values with each other. However, the programme will disregard motion for the time of the transition between positive and negative, and accompanying settling effects.

At the start of this 4 hour test, this programme will run constantly for one minute obtaining a standard value for the +ve and a standard for the –ve values.
During this test, several samples are taken each time the mirror has moved from the -1.5 deg to the positive angle and from the positive to the negative. These samples shall be recorded and compared with the previously recorded standard values of position: The positive peaks will be compared with the standard positive peak, and the negative peaks will be compared with the standard negative peak. This test shall run for four hours. The programme will automatically record the whole trace. Record a number for the rms repeatability.

For the four hours, the maximum deviation of the positive peaks will be <= 0.0035 deg rms from the mean value of the previously recorded positive peaks.
For the four hours, the maximum deviation of the negative peaks will be <= 0.0035 deg rms from the mean value of the previously recorded negative peaks.

[See AD 3 Spec. Requirement BSM-SSSD-R16]

4.11.2 Jiggle

Using DSpace test module "bsm_verification.mdl", scan the Jiggle axis by commanding a square wave motion at 0.1 Hz between +0.3 (+/- 0.1) deg and –0.3 (+/- 0.1) deg.

Continue testing using the same method as for Chop Repeatability. Record a number for the rms repeatability.

For the four hours, the maximum deviation of the positive peaks will be <= 0.0035 deg rms from the mean value of the previously recorded positive peaks.
For the four hours, the maximum deviation of the negative peaks will be <= 0.0035 deg rms from the mean value of the previously recorded negative peaks.
[See AD 3 Spec. Requirement BSM-SSSD-R16]

4.12 Frequency

4.12.1 Chop

Using DSpace Test Software Module 'Bsm_verification.mdl' and measuring using the linearised and calibrated sensor output, apply a 2 Hz square wave signal to the Chop axis at nominal amplitude of +/- 2.5°. Record this movement from sensors for 1.5 seconds using dSPACE's signal capturing capability to show that the mirror can chop at the desired rate. Record the frequency at which the mirror chops.
[See AD 3 Spec. Requirement BSM-SSSD-R6]
Repeat the test at 5 Hz for data purposes for test 4.13 (Settling time).

4.12.2 Jiggle

Using DSpace Test Software Module 'Bsm_verification.mdl' and measuring using the external optical equipment, apply a 0.5 Hz square wave signal to the Jiggle axis at nominal amplitude of +/- 0.5°. Record this movement for 4 seconds using dSPACE's signal capturing capability to show that the mirror can jiggle at the desired rate. Record the frequency at which the mirror jiggles.
[See AD 3 Spec. Requirement BSM-SSSD-R8]

Repeat the test at 1 Hz for data purposes for test 4.13 (Settling time).

4.13 Settling Time

4.13.1 Chop

Using data from test 4.12, verify that the Chop angle settling time (defined as the time for the mirror to reach, and stay within, 0.019° of the commanded angle after movement in the chop axis) is <20ms, for the 2 Hz data. Record the settling time.
[See AD 3 Spec. Requirement BSM-SSSD-R13]

4.13.2 Jiggle

Using data from test 4.12, verify that the Jiggle angle settling time (defined as the time for the mirror to reach, and stay within, 0.019 deg of the commanded angle after movement in the jiggle axis) is <= 0.09 sec, for the 0.5 Hz data. Record the settling time.
[See AD 3 Spec. Requirement BSM-SSSD-R14]

4.14 Cold Power Dissipation

Ensure that the BSM is running at 4-6K here in case super-conducting effects are significant.
Using the test software, apply nominal half angles of Chop and Jiggle amplitudes (+/-1.27 deg chop, +/-0.287 deg jiggle [See Functions POF1 and POF2 (tables 5.2 and 5.3) of RD 2].) and the nominal maximum signal periods to the BSM. Verify that the mirror is moving using external optical test equipment.
Measure the average power dissipation of all motors and sensors over a 1 min period after 10 minutes operating by measuring the voltage and current at the sensors and motors using a 4-wire technique.
The voltage and current of signals going to the BSM can be measured at the harness breakout box.

Pin numbers refer to the breakout box:

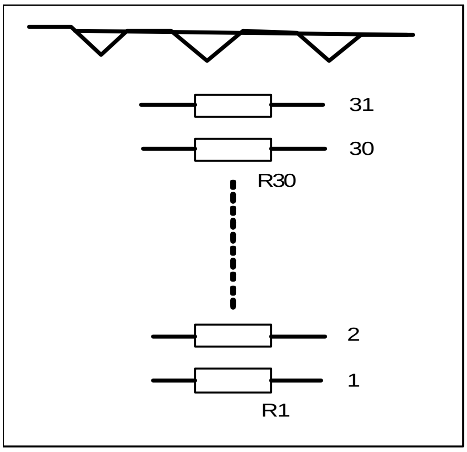


Figure 3. Rough Sketch of Breakout box.

Voltages and currents are measured using the following method:

Using an oscilloscope, with the BSM operating at the above operating angles and the nominal operating frequency for the axis under test,

Firstly record the position sensor power dissipation:
Simultaneously record the Chop sensor applied voltage between pins 1 and 2, and the Chop sensor current across R2.
Simultaneously record the Jiggle sensor applied voltage between pins 23 and 24, and the Chop sensor current across R25.

Now measure motor power dissipation:
Simultaneously record the Chop motor applied voltage between pins 8 and 9, and the Chop motor current across R6.
Simultaneously record the Jiggle motor applied voltage between pins 30 and 31, and the Jiggle motor current across R28.

Using Excel or a similar analysis package, obtain the product of each voltage and current pair. Sum the sensor and motor powers obtained, and finally calculate the average.

The power dissipation shall be less than 4mW. Record the actual power dissipation.
[See AD 3 Spec. Requirement BSM-SSSD-R23]

4.15 Operating Modes

4.15.1 Combinations of Modes

1. The BSM shall be able to operate whilst moving in both axes simultaneously. This requirement is proven in the following tests –

   4.5 Angular Travel – Combined Jiggle and Chop.
   4.9 Holding Position.

   Since the motors and sensors of each different axis are self contained, it is evident that they will both be able to work at the same time. Test 4.12 Settling Time proves the ability of the mirror to settle in both axes after a movement in only one.

2. BSM operation has been tested in other tests which prove the ability to chop without jiggle movement and jiggle without chop movement (again see cross coupling test 4.12 Settling Time).

[See AD 3 Spec. Requirement BSM-SSSD-R62]

4.16 Degraded Modes

4.16.1 BSM Open Loop

This test is performed for both the prime and redundant circuits of both the PFM and the FS.

Remove sensor feedback to the chop axis. Now, using DSpace, characterise chop motor current demands such that current demand algorithms can be devised which can be used to operate the chop axis of the mirror across its range with no feedback fromthe chop axis position sensor. Check that the algorithms still work for a range of jiggle angles. Record results using dSPACE's signal capturing ability. It is understood that the use of this mode will almost certainly lead to reduced performance.
[See AD 3 Spec. Requirement BSM-SSSD-R60]

4.16.2 Single Axis BSM Operation

This test is performed on both the prime and redundant circuits of both the PFM and the FS.

With motors and sensors on the jiggle axis out of operation, give settling times of the mirror when chopping between angles of +/-2.0 deg and +/-0.5 deg.

With motors and sensors on the chop axis out of operation, give settling times of the mirror when jiggling between angles of +/-0.45 deg and +/- 0.2 deg.
Using dSPACE's signal capturing ability, record results for both axes.
[See AD 3 Spec. Requirement BSM-SSSD-R61]