QUEEN MARY AND WESTFIELD COLLEGE UNIVERSITY OF LONDON **FIRST** **SPIRE**	Ref **: TBC** Author **: Peter Hargrave**	Page : **1 / 1** Date : 03 April 2000

SPIRE Calibrators Subsystem Development Plan

Draft 1.0

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Table of contents

1. Scope of the document

This document describes the development plan for the FIRST/SPIRE instrument optical calibrators.
The development plan is based on the applicable documents cited in paragraph #2.

2. Documents

2.1. Applicable documents

	Title	Author	Reference	Date
AD1	SPIRE calibrators subsystem specification	P.Hargrave	TBD	June 2000
AD2	SPIRE Instrument Development plan	K.King		
AD3	Intrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Iss .21	30 Nov 1999

2.2. Reference documents

	Title	Author	Reference	Date
RD1	SPIRE FPU PDR viewgraphs	B.Swinyard	TBD	7-9 July 1999

2.3. Glossary

AD	Applicable Document	FS	Flight Spare model
ATC	Astronomy Technology Centre	FTS	Fourier Transform Spectrometer
CBB	Cryogenic Black Body	GSFC	Goddard Space Flight Center
CEA	Commissariat à l' Energie Atomique	LAS	Laboratoire d'Astronomie Spatiale
CDR	Critical Design Review	MGSE	Mechanical Ground Support Equipment
CNES	Centre National des Etudes Spatiales	MSSL	Mullard Space Science Laboratory
CoG	Center of Gravity	NA	Not Applicable
CQM	Cryogenic Qualification Model	OGSE	Optical Ground Support Equipment
DDR	Detailed Design Review	PCAL	Photometer CALibrator
DESPA	Département des Etudes SPAtiales	PFM	ProtoFlight Model
DM	Development Model	RAL	Rutherford Appleton Laboratory
DRCU	Digital Read-out and Control Unit	RD	Reference Document
EGSE	Electrical Ground Support Equipment	SCAL	Spectrometer CALibrator
FIRST	Far InfraRed Space Telescope	WE	Warm Electronics
FPU	Focal Plane Unit		

3. Description of the calibrator subsystem

Note: This is for information only. At the time of writing this draft, the calibrator subsystem is still under development. The concept is described in more detail in [AD1].

3.1. Photometer calibrator

The purpose of the photometer calibrator is to provide a repeatable signal for monitoring of detector health and responsivity for ground testing and in-flight operation. The calibrator is not required to provide absolute calibration, but may be useful as part of the overall calibration scheme. The baseline design consists of a thermal source inside an integrating cavity, the body of which will be at 4-K. The cavity will have a light pipe output with a 1-mm diameter aperture, as shown in figure (1). The calibrator will be located behind the beam steering mirror (M4) at an image of the telescope secondary mirror, as shown in figure (2). The fraction of M4 area obscured will be 0.2%. The limit on the calibrator aperture is set by the ratio of the telescope secondary to primary mirror diameters.

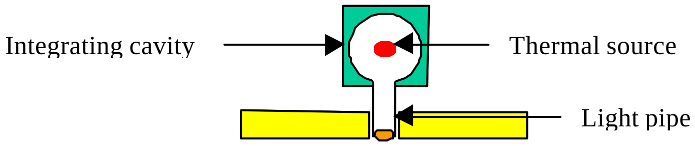

Figure 1 Conceptual design of photometer calibrator

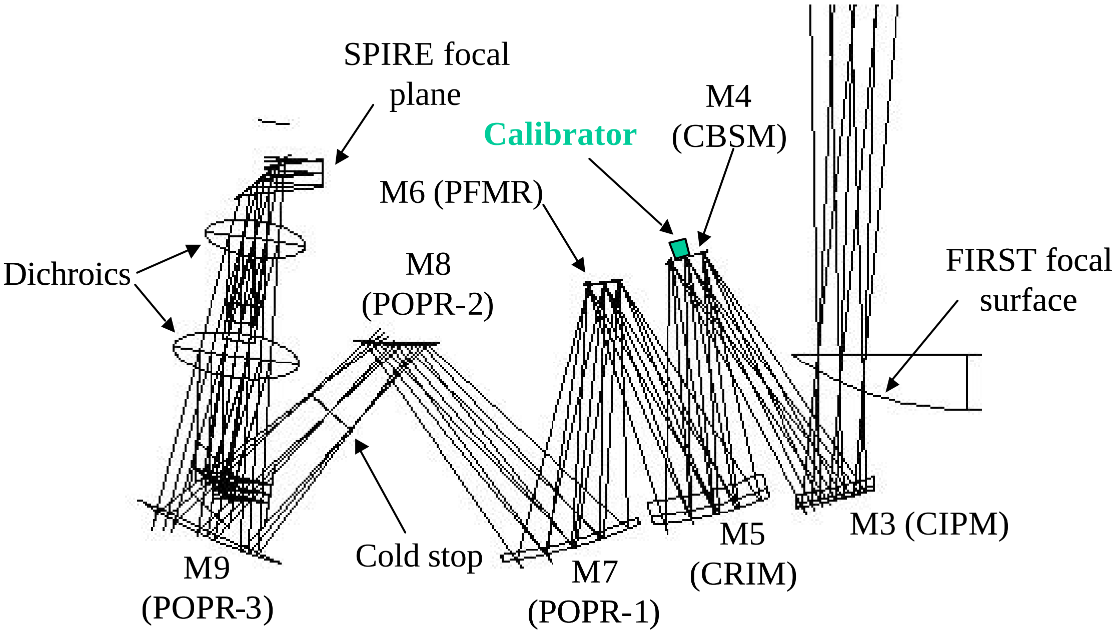

Figure 2 Location of photometer calibrator

3.2. Spectrometer calibrator

The purpose of the spectrometer calibrator is to null the telescope emission by mimicking its spectrum and brightness in the second input port of the FTS. The telescope is assumed to be at 80-K with overall wavelength-independent emissivity $\varepsilon = 0.04$. The overall emissivity of the system is assumed to be uncertain by a factor of 2 (actual value will not be known before launch). The baseline design, shown in figure (3), is the use of a heated black plate (or possibly a metallised film), together with a “hot” source in an integrating cavity with light pipe, to uniformly illuminate the pupil. A possible alternative design is a thermal source with Winston Cone optic to present uniform illumination across the pupil as shown in figure (4). A neutral density filter will be used to dilute the emission. The calibrator will be located at the second input port to the FTS, at an image of the telescope pupil (diameter = 30 mm) as shown in figure (5).

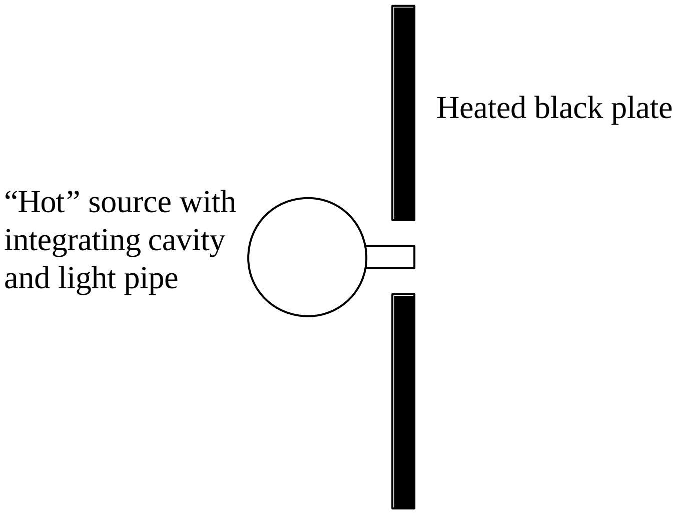

Figure 3 Baseline concept for spectrometer calibrator

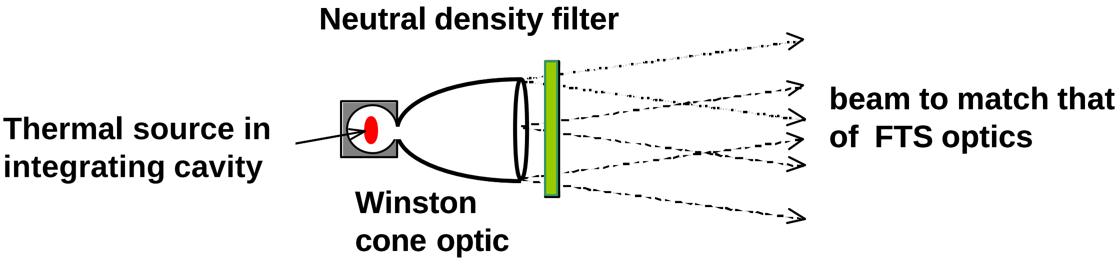

Figure 4 Alternative design of spectrometer calibrator

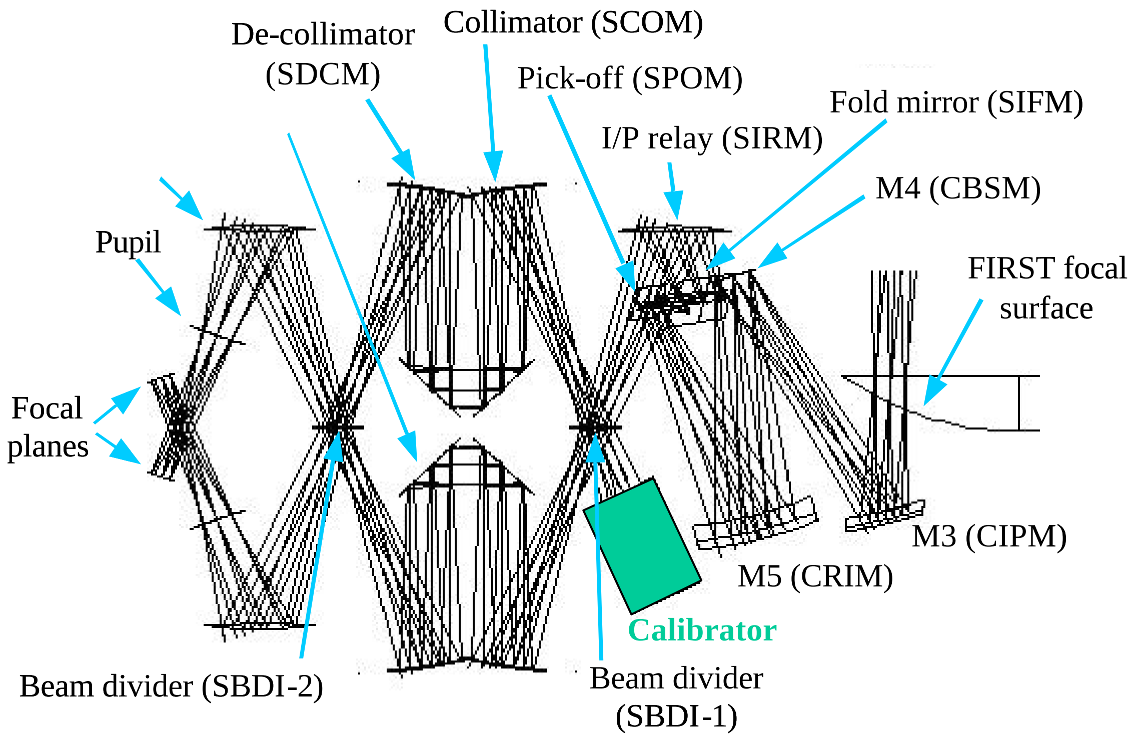

Figure 5 Location of spectrometer calibrator

3.3. Thermal sources

Two types of thermal source are under consideration.

3.3.1. Modified ISO style sources

Devices based on the design of the Infra Red Labs TRS sources, as used on ISO, can be manufactured in-house with improved reliability and reduced power dissipation.

3.3.2. SIRTF/IRAC type devices

Micromachined Si devices have been developed by NASA/GSFC for use on SIRTF/IRAC. Further development and testing is needed for use on SPIRE. This has already started at QMW.

4. Constraints

4.1. Development constraints

4.1.1. Technical constraints

Note : the figures hereafter are for information only. The applicable figures are in [AD1] which refers to [AD3]

The main performances specifications are:

The main technical constraints are :

- SPIRE lifetime in orbit = 4.25 years
- Operating temperature = 4K
- Power = less than 2 mW
- Mass = <20g (TBC)
- CoG position = TBD
- Available volume envelope = 30 x 15 x 10 mm (TBC)
- Number of wires from FPU to warm electronics = 4 (TBC)

- Level of radiation = TBD
- Vibration level = TBD at 4K
- Shock level = TBD at 4K
- Format of the electronic cards =
- Cleanliness = TBD

4.2. Responsibilities

4.2.1. Evaluation devices

- GSFC are responsible for the design and manufacture of micromachined Si sources for evaluation at QMW.
- QMW are responsible for evaluation and qualification of candidate GSFC sources, and for providing GSFC with test feedback.
- QMW are responsible for the design, manufacture and testing of modified ISO-type sources.
- QMW are responsible for the design of the photometer calibrator housing which will contain the thermal source.
- QMW are responsible for the design, manufacture and testing of the spectrometer calibrator.

4.2.2. CQM, PFM and FS devices

- If the final photometer calibrator design is based on GSFC thermal sources, GSFC will be responsible for providing QMW with sources for integration to the calibrator structure. The same also applies for the spectrometer calibrator, whether it is based on a Winston-cone optic or the baseline black plate/hot source concept.
- If the final photometer calibrator design is based on modified ISO-type thermal sources, QMW will be responsible for building sources for integration to the calibrator structure. The same also applies for the spectrometer calibrator, whether it is based on a Winston-cone optic or the baseline black plate/hot source concept.
- QMW will build the photometer calibrator structure.
- QMW will build the spectrometer calibrator structure.
- QMW will be responsible for qualification, acceptance and calibration of the photometer and spectrometer calibrators.
- The calibrators will be transported to RAL under the responsibility of QMW.
- The calibrators will be integrated to the SPIRE FPU structure under the responsibility of QMW/RAL/MSSL.
- The SPIRE WE and the SPIRE FPU are integrated under RAL responsibility and undergo the project calibration program under RAL responsibility.

4.3. Organisation

- GSFC provides thermal sources to QMW for evaluation.
- QMW provides test feedback to GSFC.
- If these devices prove unsuitable for SPIRE, QMW will design, manufacture and test new devices based on the design of the ISO thermal sources (Infra Red Labs – no longer produced).
- QMW will design, manufacture and test the photometer and spectrometer calibrator structure.
- QMW will work closely with the ATC as the photometer calibrator will be an integral part of the BSM assembly

4.4. Calendar constraints

The main SPIRE project milestones are [RD2]:

PDR	26-27 June 2000
DDR	
CQM calibrators delivery to RAL	15 Aug 2002
CDR	
SPIRE CQM delivery to ESA	
PFM calibrators delivery to RAL	15 Apr 2004
SPIRE PFM delivery to ESA	
FS calibrators delivery to RAL	15 Apr 2005
SPIRE FS delivery to ESA	
FIRST launch	2007

5. Risk analysis – To be completed

In this document, the risk analysis concerns only the development risk to the calibrator sub-system.

Risk	Impact	Preventive action	Note
GSFC thermal source qualification failure	QMW will need to develop devices in-house	Regular test feedback from QMW	
QMW thermal source qualification failure	No photometer calibrator. Spectrometer calibrator performance compromised (depending on final design).		Failure of the photometer calibrator would not lead to loss of photometer science capabilities, but would prevent on-ground checking of detectors with modulated photometric signals when the cryostat is closed. It would also compromise the ease and convenience of instrument monitoring and calibration in flight, resulting in less efficient operation. The development programme may not result in device with low enough power dissipation for required radiated power. This could restrict the frequency of operation in flight or require an undesirable reduction in the operating signal levels. Failure of the FTS calibrator would lead inability to null the telescope offset with significant impact on dynamic range (detailed consequences are being analysed). However, the FTS calibrator also has a heated black plate or metallised film, and so an element of redundancy is inherent in the design, although performance may be compromised.
FTS calibrator plate (if needed) has too high electrical power dissipation for required radiated power	Increased FPU dissipation or restricted FTS operation (decreased dynamic range)		

6. Redundancy – To be completed

6.1.1. Redundancy philosophy

The redundancy philosophy adopted for SPIRE is to duplicate every part that would be a single point failure. The level of redundancy required is currently under discussion. The GSFC microlamps have four emissive elements, and a total of six wires will be required for full, four-fold redundancy. However, this provides no redundancy in the wiring. A QMW built device will have one emissive element and will require a minimum of two wires for operation with no redundancy.

7. Work description

7.1. *Development and model philosophy*

7.1.1. Preliminary Design

- GSFC provides QMW with devices for evaluation.
- QMW test devices and provide GSFC with feedback for future modifications.
- QMW design prototype photometer calibrator housing in collaboration with the ATC.
- QMW design prototype spectrometer calibrators based on heated plates/metallised films and thermal source/Winston cone optics.
- QMW estimate electrical/wiring requirements during early test phase. The interfaces with SPIRE WE are defined during this step.

The preliminary design is presented at the Preliminary Design Review in June 2000. The PDR freezes the technical specifications and the interfaces.

7.1.2. Procurement of long delay cryogenic components

Once the preliminary design has been validated by the PDR, the procurement for long delay components is initiated. These components include Eltec feedthroughs, cryogenic connectors, GSFC thermal sources, sapphire substrates etc.
Certain components may be subjected to warm tests for accelerated aging and cold tests. Radiation tests or analysis may also be conducted.

7.1.3. Detailed design and CQM manufacture

The detailed design encompasses all the functions of the subsystem. The design is verified by more detailed modelling where necessary.
The detailed design is presented at the Detailed Design Review (mid October 2000 ??). The DDR must have happened before CQM manufacture can begin.

To verify the design, a complete qualification and lifetests are to be conducted.
At least two models for each of the photometer and spectrometer calibrator are necessary. The two models are the development model (DM) and the cryogenic qualification model (CQM).
The PCAL-DM and SCAL-DM are not deliverable and the PCAL-CQM and SCAL-CQM are deliverable.
The DM model is used to qualify the design and conduct lifetests.
The CQM is to be qualified but does not undergo the lifetests. The DM and the CQM include all the functions of the flight design, except redundancies.

The components are of flight grade as the DM's are to be tested at cryogenic temperature..

The design verification tests include:-

- Verification of the basic mechanical parameters (Mass, stiffness, resonance frequencies).
- Performance verification.
- Qualification tests .
- Lifetests .

After the PCAL and SCAL CQM delivery, the SPIRE CQM is tested at project level.
The results of the qualification tests are to be presented at the SPIRE CDR which is the start point of the PFM and FS manufacture.
Then, the SPIRE CQM is delivered to ESA for cryogenic tests of the FIRST FPU.

7.1.4. Flight design modifications and PFM/FS manufacture

Following the lifetests and SPIRE CQM tests, some modifications may have to be implemented in the design.

The design changes are to be implemented in the flight design and be validated using the DM.

The PCAL and SCAL PFM's are then manufactured and undergo the acceptance tests and performance verification.

The FS models are duplicates of the PCAL and SCAL PFM and are manufactured at the same time as the PFM. The PCAL and SCAL FS models undergo the acceptance tests and performance verification after the PFM.

7.2. Verification plan

The verification plan must be compliant with the project verification plan [AD2, RD1] and must fulfill the PCAL and SCAL development needs.

In the tables below,

X = a real test is conducted
A = an analysis is conducted
NA = Non applicable

300K vibrations are conducted at QMW.
Cryovibrations are conducted at RAL (TBC).
Vacuum cycles, soak cycles, thermal cycles are conducted at QMW.
Lifetime tests are conducted at QMW.
EMI/EMC tests are conducted at TBD.
Microphonics tests are conducted at TBD.
Performance tests are conducted at QMW.

7.2.1. PCAL

	PCAL-DM	PCAL-CQM	PCAL-PFM	PCAL-FS
Mass measurement	X	X	X	X
CoG measurement	X			
Spectral measurements	X	X	X	X
Absolute photometric calibration	X	X	X	X
Cross calibration with CBB sources	X	X	X	X
Power consumption	X	X	X	X
Vibrations 300K	X	X	X	X
Vibrations 4K	X	X	X	X
Thermal/Vacuum cycle	X	X	X	X
Accelerated lifetime (12,000 operations)	X			
Radiation tolerance	TBC	TBC	TBC	TBC
Microphonics	TBC	TBC	TBC	TBC
EMI / EMC	X	A(*)	X(*)	A(*)

(*) : EMI/EMC tests are to be conducted on the PFM only if design changes have occurred.
(**) : The radiation tolerance is verified by analysis only, taking into account the materials involved.
(***) : Microphonic tests are to be conducted on the PFM only if design changes have occurred.

7.2.2. SCAL

	SCAL-DM	SCAL-CQM	SCAL-PFM	SCAL-FS
Mass measurement	X	X	X	X
CoG measurement	X			
Spectral measurements	X	X	X	X
Absolute photometric calibration	X	X	X	X
Cross calibration with CBB sources	X	X	X	X
Power consumption	X	X	X	X
Vibrations 300K	X	X	X	X
Vibrations 4K	X	X	X	X
Thermal/Vacuum cycle	X	X	X	X
Accelerated lifetime (12,000 operations)	X			
Radiation tolerance	TBC	TBC	TBC	TBC
Microphonics	TBC	TBC	TBC	TBC
EMI / EMC	X	A(*)	X(*)	A(*)

(*) : As EMI/EMC is verified on the CQM, no further verification are conducted on the subsequent models.
(**) : The radiation tolerance is verified by analysis only, taking into account the materials involved.

7.3. Ground associated equipment – to be completed

The ground equipment is used to develop and test one item without the presence of others.
The simulators replace one or more items.
The tools are used to operate, check or integrate an item.
Most simulators are PC based as it is the most flexible and economical solution.

7.3.1. Simulators

Simulator	Used for…	Functions

7.3.2. Tools

Tool	Used for …	Functions

8. Development calendar

DM	Detailed design	May 2000 – Nov 2000
DM	Manufacture	Nov 2000 – Jan 2001
DM	Preliminary tests	Jan 2001 – Apr 2001
DM	Modification	Mar 2001 – May 2001
DM	Qualification, Calibration	Apr 2001 – Jul 2001
DM	Lifetests	May 2001 – Sept 2001
CQM	Manufacture	Sept 2001 – Nov 2001
CQM	Qualification & calibration	Nov 2001 – Mar 2002
CQM PCAL delivery	to ATC	Feb 2002
CQM PCAL	integration & test at ATC	Feb 2002 – May 2002
CQM delivery	to RAL	May 2002
PFM & FS	Manufacture	May 2002 – Aug 2002
PFM	Acceptance & calibration	Aug 2002 – Apr 2003
PFM PCAL delivery	to ATC	Nov 2002
PFM PCAL	integration & test at ATC	Nov 2002 – Mar 2003
PFM delivery	to RAL	Apr 2003
FS	Acceptance & calibration	Apr 2003 – Jan 2004
FS PCAL delivery	to ATC	Jul 2003
FS PCAL	integration & test at ATC	Jul 2003 – Oct 2003
FS delivery	to RAL	Jan 2004

Note that the qualification and acceptance time periods stated above are the total time periods for qualifying and accepting the photometer and spectrometer calibrators.
Detailed planning may be found in the file Cal_dev.mpp (MS Project 98).
The scheduled delivery date for the CQM calibrators to RAL misses the “old” deadline by 1 month, but is 3 months earlier than the “new” deadline.

9. Description of deliverables - TBC

9.1. *Deliverable models*

The photometer calibrator is delivered to the ATC for integration with the beam steering mirror.
The spectrometer calibrator is delivered to RAL.

9.1.1. PCAL models

Model	Flight representativity	Difference with flight	Deliverables
DM	Dimensions, interface, functions	No redundancy	0
CQM	Dimensions, interface, functions	No redundancy	1
PFM	100%	None	1
FS	100%	None	1

9.1.2. SCAL models

Model	Flight representativity	Difference with flight	Deliverables
DM	Dimensions, interface, functions	No redundancy	0
CQM	Dimensions, interface, functions	No redundancy	1
PFM	100%	None	1
FS	100%	None	1

9.2. *Associated equipment – to be completed*

The associated equipment is for integration and alignment.

Model	Use/Function	Associated with	Deliverable

9.3. *Associated documentation – to be completed*

The documentation is TBD.