Calibrators

Subsystem Development Plan

For approval

Draft

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Update history

Date	Version	Remarks
03 April 2000	Draft 1.0	First draft. No detailed design available.
14 July 2000	Issue 1.0	First issue
19 December 2000	Issue 2.0	Heavily revised plan based on new model philosophy

Table of Contents

1. Scope

This document describes the development plan for the FIRST/SPIRE calibrators subsystem.

2. Documents

2.1. Applicable documents TBW – pay no attention to those listed

	Title	Author	Reference	Date
AD1				
AD2	Interface control documents – Photometer calibrator/chopper Spectrometer calibrator/structure	P.Hargrave, C.Cunningham, B.Winter	SPIRE/ICD/1.5/1.6.1 SPIRE/ICD/1.1/1.6.2	
AD3	SPIRE instrument – Calibrators subsystem specification document	P.Hargrave		April 2000

2.2. Reference documents TBW

	Title	Author	Reference	Date
RD1	Instrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Issue 0.30	May 2000
RD2	Instrument development plan			

2.3. Glossary

AD	Applicable Document	FS	Flight Spare
ATC	Astronomy Technology Centre	FTS	Fourier Transform Spectrometer
CBB	Cryogenic Black Body	GSFC	Goddard Space Flight Centre
CEA	Commissariat a l'Energie Atomique	LAS	Laboratoire d'Astronomie Spatiale
CDR	Critical Design Review	MGSE	Mechanical Ground Support Equipment
CNES	Centre National des Etudes Spatiale	MSSL	Mullard Space Science Laboratory
CoG	Centre of Gravity	NA	Not Applicable
CQM	Cryogenic Qualification Model	OGSE	Optical Ground Support Equipment
DDR	Detailed Design Review	PCAL	Photometer CALibrator
DESPA	Department 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. Subsystem Description

The calibrators subsystem comprises the photometer calibrator (PCAL) and the spectrometer calibrator (SCAL).

3.1. Description

3.1.1. PCAL

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. It is NOT an absolute calibrator, 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.

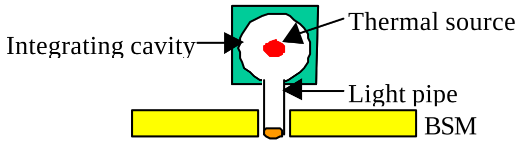

Figure 1 Schematic of photometer calibrator

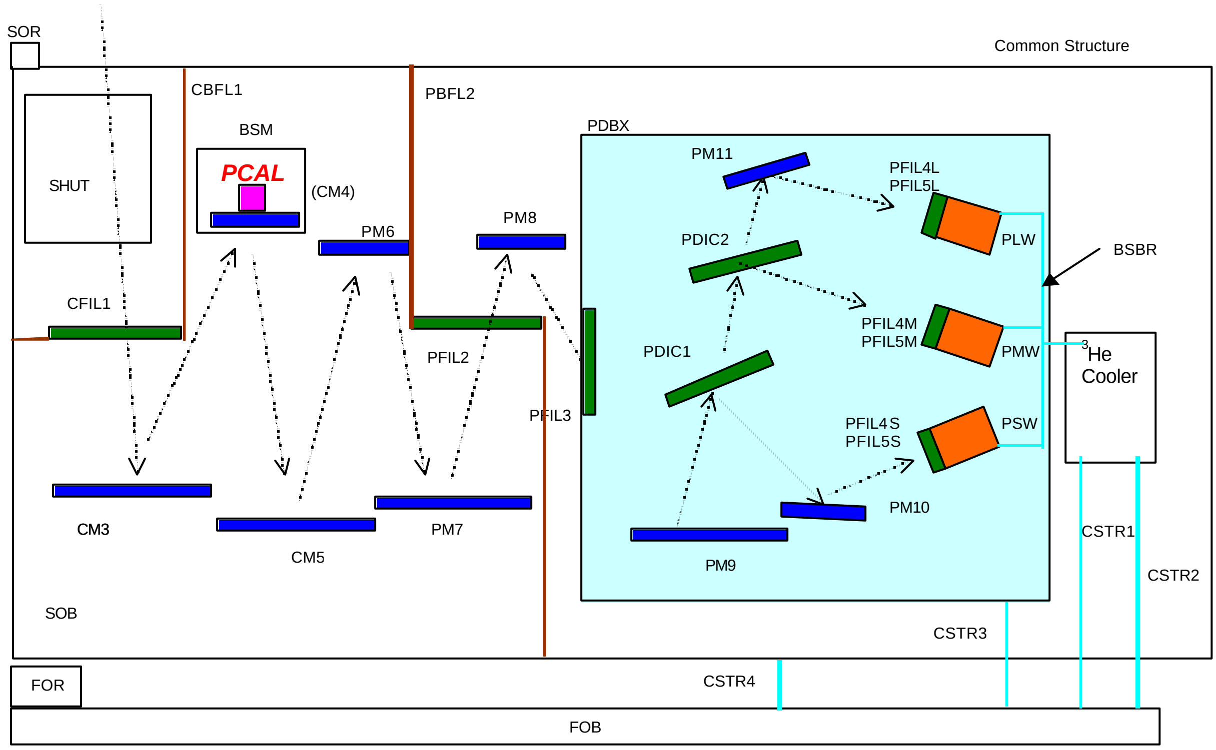

Figure 2 Location of photometer calibrator (PCAL)

3.1.2. SCAL

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 neutral density filter may 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 (4).

Throughout this document, the heated plate will be referred to as SCAL-flood, and the “hot” PCAL type source shall be referred to as SCAL-point.

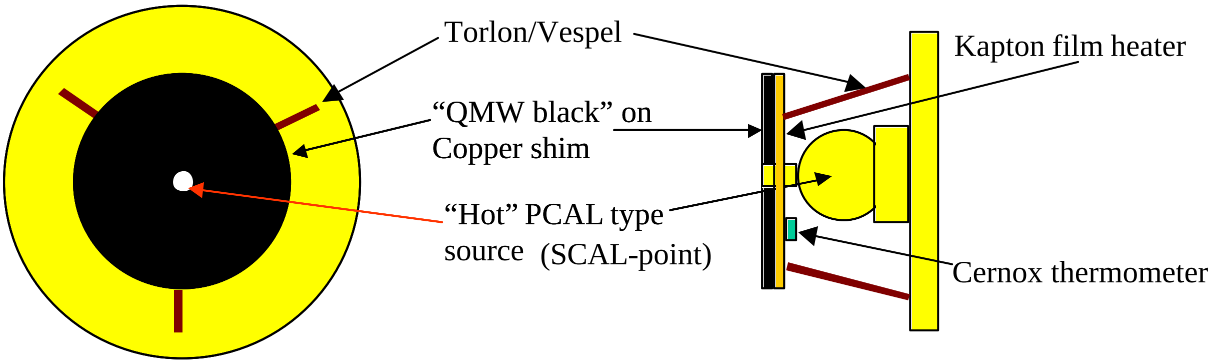

Figure 3 Conceptual design of spectrometer calibrator

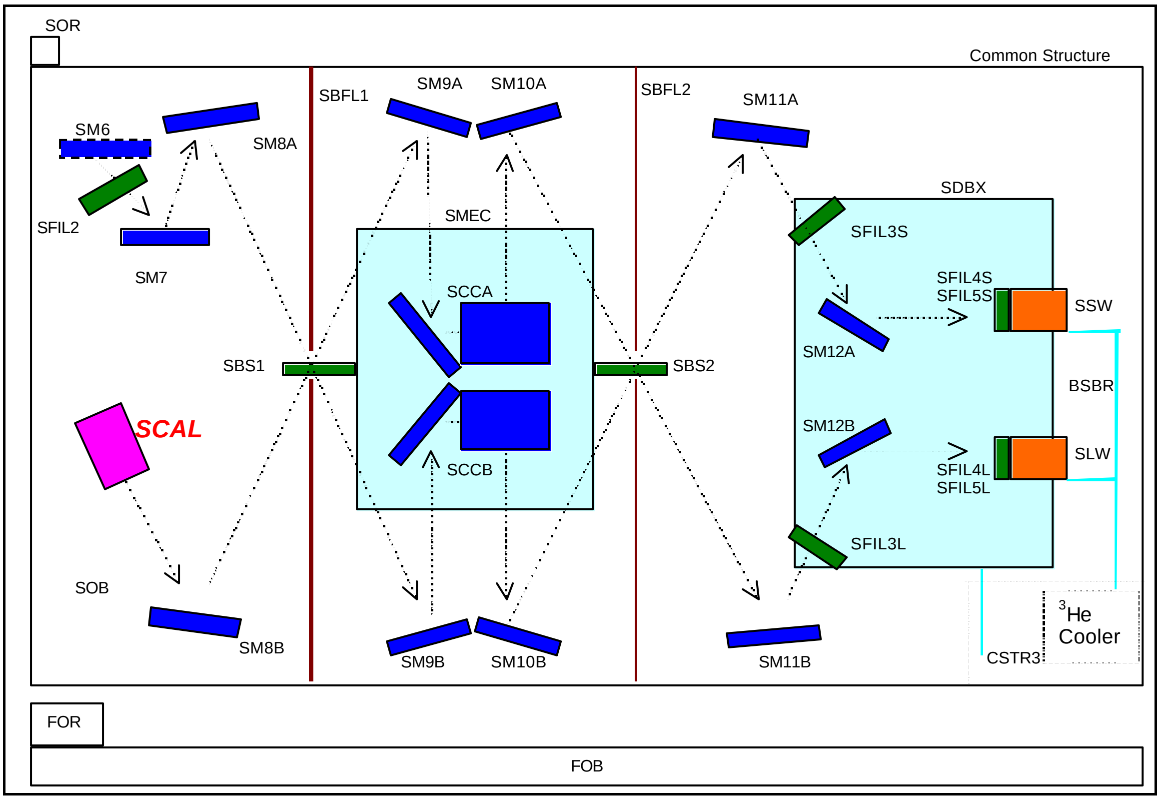

Figure 4 Location of spectrometer calibrator

3.2. Requirements

Covered in 4.1 (tech. constraints)

3.3. Interfaces

List of interfaces & reference to appropriate ICDs (to be written?)

3.4. Deliverables

In the table below, the dates in black are those imposed by the project, and the green/red dates are estimated delivery dates. Green indicates an early/on-schedule delivery, while red indicates a possible late delivery.

Table 1 List of deliverables for each instrument model

Item	STM	CQM	PFM	FS
PCAL(1)	Mass estimate only – date TBD	01/03/02	28/04/03	17/10/03
		19/02/02	29/04/03	01/10/03
SCAL(2)	10/4/02	1/10/02	1/10/03	10/11/04
	29/10/01	`28/05/02	19/08/03	07/01/04

(1) These will be delivered to ATC
(2) These will be delivered to RAL

4. Constraints

4.1. Technical constraints

The performance requirements for PCAL and SCAL are listed below, and are extracted from RD1.

4.1.1. PCAL performance requirements

Requirement ID	*Description*	*Value*
IRD-CALP-R01	Nominal operating output	Equivalent to εT=40 K for 200<λ<700 mm
IRD-CALP-R02.	Operating range	4-80 K for 200<λ<700 mm commandable in 256 (TBC) steps
IRD-CALP-R03	Equivalent obscuration of aperture through BSM mirror	<0.2%. Actual size is referred to the telescope secondary mirror image at the position of the beam steering mirror.
IRD-CALP-R04	Speed of response	Requirement 150 ms. Goal 30 ms
IRD-CALP-R05	Repeatability	RMS better than 1% over 20 operations. Drift less than10% over lifetime of the mission.
IRD-CALP-R06	Operation	Nominally once per hour for no more than 10 seconds.
IRD-CALP-R07	Frequency	Continuously or pseudo continuously variable between 0 and 5 Hz.

4.1.2. SCAL performance requirements

Requirement	*Description*	*Value*

ID		
IRD-CALS-R01	Radiated spectrum	Null the central maximum to accuracy of 5% (goal 2%) [TBC] Replicate the dilute spectrum of the telescope to an accuracy of better than 20% (goal 5%) [TBC] over 200-400 mm.
IRD-CALS-R02	Beam pattern	Replicate the appropriate beam pattern at the second input port pupil image
IRD-CALS-R03	Adjustability	Zero - maximum in 256 steps
IRD-CALS-R04	Uniformity	The uniformity of the intensity from the calibration source across the second input port pupil image shall be better than TBD%
IRD-CALS-R05	Repeatability and drift	The output intensity of the calibration source shall drift by no more than 1% over one hour of continuous operation. The absolute change in the output intensity of the source shall be no more than 15% over the mission lifetime
IRD-CALS-R06	Operation	The calibration source shall be capable of continuous operation for periods of up to 2 hours with no loss of operational performance.
IRD-CALS-R07	Number of operations	The calibration source shall be capable of up to 12000 operational cycles

4.2. System constraints

The system requirements for PCAL and SCAL are listed below, and are extracted from RD1.

Additional overall system constraints are:-

- SPIRE orbital lifetime = 4.25 years
- PCAL volume envelope
- PCAL mass (including margin) = TBD (info. from ATC needed)
- PCAL vibration level = TBD (from Berend)
- PCAL shock level = TBD (from Berend)
- SCAL volume envelope (see accompanying table -TBD)
- SCAL mass (including margin) = TBD (info. from ATC needed)
- SCAL vibration level = TBD (from Berend)
- SCAL shock level = TBD (from Berend)
- Cleanliness = class 10,000??
- Transit loads = ??
- Storage = 3 years
- Bake-out temperature on AIV integration = 80°C for 48 hours

4.2.1. PCAL system requirements

Requirement ID	*Description*	*Value*
IRD-CALP-R08	Interface	The calibrator will be integrated into the beam steering mechanism.
IRD-CALP-R09	Volume envelope	30 x 15 x 10 mm
IRD-CALP-R10	Thermal isolation	The temperature of the surrounding structure (including the beam steering mirror) shall rise by no more than 1 K after 10 seconds when the calibrator is operated unmodulated at nominal power output.
IRD-CALP-R11	Operating temperature	4-K
IRD-CALP-R12	Cold power dissipation	Less than 2 mW when operated unmodulated at nominal power output.
IRD-CALP-R13	Warm power dissipation	Less than TBD W when operated unmodulated at nominal power output
IRD-CALP-R14	Operating voltage	Less than 28 V at input power level of 5 mW
IRD-CALP-R15	Redundancy	Cold redundancy for the thermal source

4.2.2. SCAL system requirements

Requirement ID	*Description*	*Value*
IRD-CALS-R08	Operating voltage	No more than 28 V DC
IRD-CALS-R09	Power dissipation in the focal plane	No more than 5 mW with a goal of 2 mW
IRD-CALS-R11	Envelope	50x50x70 mm (TBC)
IRD-CALS-R12	Thermal isolation	The surrounding structure of the calibrator shall rise in temperature by no more than TBD K after one hour of continuous operation
IRD-CALS-R13	Operating temperature	4 K
IRD-CALS-R14	Redundancy	Fully redundant systems shall be provided for the active elements.

4.3. Calendar constraints

The major SPIRE project dates are (RD2):-

PDR	26/27 Jun 2000
DDR – Interface Review	28/29 Nov 2000
DDR – Calibrators	Jan 2001 (TBC)
STM SCAL delivery to RAL	10 Apr 2002
STM PCAL delivery to ATC	21 Sept 2001
CQM PCAL delivery to ATC	01 Mar 2002
CQM SCAL delivery to RAL	01 Oct 2002
CDR	3 Feb 2003
SPIRE CQM delivery to ESA	Apr 2003
PFM PCAL delivery to ATC	28 Apr 2003
PFM SCAL delivery to RAL	01 Oct 2003
FS PCAL delivery to ATC	17 Oct 2003
FS SCAL delivery to RAL	10 Nov 2004
SPIRE FS delivery to ESA	Dec 2005
FIRST launch	2007

5. Work Description

5.1. Model philosophy

The model philosophy is compliant with the SPIRE project.

5.1.1. PCAL

The following models will be produced:-

- PCAL DM – several devices will be built and evaluated to produce a developmental model (DM) which will be tested and form the basis of our CQM design
- PCAL STM – This will be just a mass dummy. This may be provided by the ATC (TBD)
- PCAL CQM – This device will be provided to the ATC with limited functionality (no redundancy) to be incorporated into the BSM assembly for CQM testing
- PCAL PFM – This is the flight device
- PCAL FS – This is the flight spare device

5.1.2. SCAL

The following models will be produced:-

- SCAL DM - several devices will be built and evaluated to produce a developmental model (DM) which will be tested and form the basis of our CQM design
- SCAL STM – This device will have limited functionality, but will be thermally and structurally representative of the flight device. This will be delivered to RAL for STM tests.
- SCAL CQM - This device will be provided to RAL with limited functionality (no redundancy) to be incorporated into SPIRE for CQM testing
- SCAL PFM – This is the flight device
- SCAL FS – This is the flight spare

5.2. Organisation

Inputs, outputs & responsibilities.

- QMW to test candidate Beeman devices for suitability
- QMW to design, manufacture and test alternative options in parallel in case Beeman devices fail to conform to requirements
- QMW to design, manufacture and test the PCAL and SCAL structure
- QMW to integrate calibrators to calibrator housing
- QMW to coordinate with ATC as PCAL is an integral part of the BSM assembly
- QMW to ensure qualification, acceptance and calibration of PCAL and SCAL
- QMW responsible for transport of SCAL to RAL and PCAL to the ATC
- Calibrators to be integrated to FPU with joint responsibility between QMW, RAL, MSSL and ATC

5.3. Preliminary design phase

The PDR freezes the technical specifications/requirements, while the interfaces are frozen at the interface review.

5.3.1. Thermal source testing & development

Thermal sources for PCAL and SCAL-point are currently being developed & tested at QMW. These are:-

- GSFC devices – Tests have shown that these devices do not meet the requirements of SPIRE in terms of power dissipation vs. photometric power. It is unlikely that these devices will be investigated further.
- Haller-Beeman Associates – Two devices have been tested at QMW so far, and both meet the SPIRE requirements for optical power vs electrical power dissipation. However, they do not yet meet the speed requirement, but QMW is working with Jeff Beeman to improve this in the next batch of devices by making some simple modifications. These devices have already been qualified for flight on MIPS.

- QMW devices – QMW are planning to develop thermal sources in-house. These are currently in the modeling phase.

5.3.2. Modeling - SCAL

A MathCad model has been produced for simple thermal/mechanical analysis of design concepts. The thermal analysis is compared to results from ThermXL (Alstom technology).This is used as the first step in the design process.
Detailed thermal analysis of candidate designs will then be carried out by RAL using ESATAN. Detailed mechanical FE analysis will be carried out at QMW using the IDEAS Master Series CAD package.

5.3.3. Prototyping – PCAL & SCAL

Prototype devices will be built to verify design assumptions and highlight problem areas.

5.3.4. Testing – PCAL & SCAL

All prototype devices will undergo the following tests as a minimum:-

- Thermal tests
  - Device temperature vs power to SOB/structure (i.e. thermal conductance of supports & wires from heated element to 4K)
  - Thermal time constants
- Electrical tests
  - Impedance vs device temperature
  - Device temperature vs applied power
- Mechanical tests
  - Resonant frequency (warm)
- Photometric tests
  - Emitted in-band power vs applied power

Prototype devices will evolve into developmental models of PCAL and SCAL which will then undergo more rigorous tests, which include all of the above as well as repeated thermal cycling and accelerated lifetime tests.
One prototype device each of SCAL-flood and PCAL will also be tested to electrical and mechanical failure.

5.4. *Procurement of long lead-time components*

Once a preliminary design has evolved, long lead-time items will be procured. These items are likely to comprise mainly of space qualified thermometers, heaters and connectors.

Note – need to get list of CPP items to Ken

5.5. Detailed design phase

The DM SCAL will be sent to RAL as the STM SCAL for structural & thermal tests in the SPIRE STM. The results of these tests will be taken into account for any re-design needed for the CQM SCAL.
Results of tests on the DM PCAL will be used for the detailed PCAL CQM design.
The schedule allows the DM PCAL to be sent to ATC as the STM PCAL, rather than just a mass dummy.

5.6. CQM manufacture & test

The detailed design is presented at the Detailed Design Review. 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 final versions of the PCAL-DM and SCAL-DM are deliverable for the STM to ATC and RAL respectively.
PCAL-CQM and SCAL-CQM are deliverable.
The DM models are used to qualify the design, to conduct lifetests, and as active components (rather than mass dummies) in the STM.
The CQM models are to be qualified but do not undergo lifetests.
The DM and the CQM include all the functions of the flight design, except redundancy (TBD).

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.

5.7. PFM & FS manufacture & test

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 delivery.

6. Risk analysis

Risk	Likelihood	Impact	Preventative Action	Notes
Beeman device failure	Low	No photometer calibrator. Spectrometer calibrator performance severely compromised.	None for PCAL. 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.	Failure of the photometer calibrator would not lead to loss of photometer science capabilities but would prevent ground checking of detectors with modulated photometric signals when the cryostat is closed. It would 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 to inability to null the telescope offset with significant impact on dynamic range – a severe impact.

FTS calibrator plate has too high electrical power dissipation for the required radiated power	Low	Increased FPU dissipation or restricted FTS operation (decreased dynamic range)	Qualification testing	Heat dissipation on the FPU could become unacceptable
Delay in thermal source testing/protyping	Medium	Delay in PCAL DM prototyping and testing	None – insufficient human resources	Delay in PCAL CQM delivery to ATC
Delay in SCAL DM prototyping	Medium	Delay in SCAL DM testing	None – insufficient human resources	Delay in SCAL STM and CQM delivery to RAL

7. Verification plan

The verification plan must be compliant with the project verification plan [Refs – AD??, RD??].
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.
In the tables below,

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

7.1. PCAL

	PCAL-DM	PCAL-CQM	PCAL-PFM	PCAL-FS
Mass measurement	X	X	X	X
CoG measurement	X	X	X	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**	TBD	TBD	TBD	TBD
Microphonics	N/A	N/A	N/A	N/A
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.

7.2. SCAL

	SCAL-DM	SCAL-CQM	SCAL-PFM	SCAL-FS
Mass measurement	X	X	X	X
CoG measurement	X	X	X	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	TBD	TBD	TBD	TBD
Microphonics	N/A	N/A	N/A	N/A
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.

8. Development calendar & schedule

The major project milestones pertinent to the calibrators sub-system are:-

STM SCAL to RAL	**10/04/02**
CQM PCAL to ATC	**01/03/02**
CQM SCAL to RAL	**01/10/02**
PFM PCAL to ATC	**28/04/03**
PFM SCAL to RAL	**01/10/03**
FS PCAL to ATC	**17/10/03**
FS SCAL to RAL	**10/11/04**

Internal milestones and delivery dates are:-

Candidate thermal source tests complete	**4/4/01**
BSM/PCAL interface frozen	**5/4/01**
SCAL STM delivery to RAL	**29/10/01**
CQM PCAL to ATC	**19/02/02**
CQM SCAL to RAL	**06/05/02**
PFM PCAL to ATC	**29/04/03**
PFM SCAL to RAL	**19/08/03**
FS PCAL to ATC	**01/10/03**
FS SCAL to RAL	**07/01/04**

9. Calibrators sub-system schedule

The schedule shown is realistic, with a lot of margin built into estimated task durations. However, it should be noted that this is extracted from the overall QMW SPIRE schedule (SPIRE_QMW_ALL_v1.2.mpp), which at present has a lot of tasks running in parallel. QMW need to go through this schedule and allocate resources to tasks, which may cause the calibrator schedule to change slightly to accommodate other tasks, but the delivery dates shouldn't be affected to any great degree. This document will be updated once the resource allocation exercise has taken place.

Calibrators Subsystem Development Plan

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
182	*Calibrators*	1 day?	Thu 26/10/0	Thu 26/10/0		
183	**Milestones**	**704 days?**	**Fri 01/03/02**	**Wed 10/11/04**		
184	STM SCAL to RAL	1 day?	Wed 10/04/0	Wed 10/04/0		
185	CQM PCAL to ATC	1 day	Fri 01/03/0	Fri 01/03/02		
186	CQM SCAL to RAL	1 day	Tue 01/10/0	Tue 01/10/0		
187	PFM PCAL to ATC	1 day	Mon 28/04/0	Mon 28/04/0		
188	PFM SCAL to RAL	1 day	Wed 01/10/0	Wed 01/10/0		
189	FS PCAL to ATC	1 day	Fri 17/10/0	Fri 17/10/03		
190	FS SCAL to RAL	1 day	Wed 10/11/0	Wed 10/11/0		
191	**Design & Manufacture**	**1027 days?**	**Tue 01/02/00**	**Wed 07/01/04**		
192	GSFC source testing	20 wks	Tue 01/02/0	Mon 19/06/0		
193	**Thermal source testing**	**232 days?**	**Tue 16/05/00**	**Wed 04/04/01**	**192FS-5 wks**	
194	**Beeman devices**	**232 days?**	**Tue 16/05/00**	**Wed 04/04/01**		
195	HB source 1 tests	30 wks	Tue 16/05/0	Mon 11/12/0		
196	HB source 2 tests	6 wks	Tue 12/12/0	Mon 22/01/0	195	
197	Test report source 1	1 day?	Tue 12/12/0	Tue 12/12/0	195	
198	Test report source 2	1 day?	Tue 23/01/0	Tue 23/01/0	196	
199	Design for new source	2 wks	Wed 13/12/0	Tue 26/12/0	197	
200	Manufacture source 3 & 4	6 wks	Wed 27/12/0	Tue 06/02/0	199	
201	HB source 3 tests	4 wks	Wed 07/02/0	Tue 06/03/0	200	
202	Test report source 3	1 day?	Wed 07/03/0	Wed 07/03/0	201	
203	HB source 4 tests	4 wks	Wed 07/03/0	Tue 03/04/0	201	
204	Test report source 4	1 day?	Wed 04/04/0	Wed 04/04/0	203	
205	**QMW device development**	**1 day?**	**Tue 16/05/00**	**Tue 16/05/00**		
206	**Thermal modelling**	**1 day?**	**Tue 16/05/00**	**Tue 16/05/00**		
207	Film type	1 day?	Tue 16/05/0	Tue 16/05/0		
208	Carbon fibre type	1 day?	Tue 16/05/0	Tue 16/05/0		
209	Design review	1 day?	Tue 16/05/0	Tue 16/05/0		
210	Build Carbon fibre prototype	1 day?	Tue 16/05/0	Tue 16/05/0		
211	Build film prototype	1 day?	Tue 16/05/0	Tue 16/05/0		
212	**PCAL DM prototyping**	**61 days?**	**Thu 05/04/01**	**Thu 28/06/01**	**193**	
213	HB DM source testing	4 wks	Thu 05/04/0	Wed 02/05/0		
214	Interface definition from ATC	1 day?	Thu 05/04/0	Thu 05/04/0		
215	PCAL enclosure design	2 wks	Fri 06/04/0	Thu 19/04/0	214	
216	PCAL DM prototype build	4 wks	Fri 20/04/0	Thu 17/05/0	215	
217	PCAL DM prototype testing	3 wks	Fri 18/05/0	Thu 07/06/0	216	
218	PCAL DM prototype modification	3 wks	Fri 08/06/0	Thu 28/06/0	217	
219	**SCAL DM prototyping**	**161 days?**	**Fri 27/10/00**	**Fri 08/06/01**		
220	SCAL thermal modelling	8 wks	Fri 27/10/0	Thu 21/12/0		
221	Order Cernox 1070s	1 day?	Fri 08/12/0	Fri 08/12/00		
222	Order Minco Heaters	1 day?	Fri 22/12/0	Fri 22/12/00	220	
223	Order MDM-37s	1 day?	Fri 08/12/0	Fri 08/12/00		
224	Order Vespel/Torlon	1 day?	Fri 15/12/0	Fri 15/12/00		
225	SCAL therm-mech prototype build	4 wks	Fri 15/12/0	Thu 11/01/0	220FS-1 wk	
226	SCAL therm-mech prototype test	3 wks	Fri 12/01/0	Thu 01/02/0	225	
227	SCAL DM prototype build	6 wks	Mon 19/02/0	Fri 30/03/01	221,222FS+8 wks,223,226	
228	SCAL DM prototype testing	6 wks	Mon 02/04/0	Fri 11/05/01	227	
229	SCAL DM prototype modification	4 wks	Mon 14/05/0	Fri 08/06/01	228	
230	**PCAL DM testing**	**20 days**	**Fri 29/06/01**	**Thu 26/07/01**	**218**	
231	PCAL DM qualification	2 wks	Fri 29/06/0	Thu 12/07/0		
232	PCAL DM lifetests	2 wks	Fri 13/07/0	Thu 26/07/0	231	
233	**SCAL DM testing & STM modification**	**101 days?**	**Mon 11/06/01**	**Mon 29/10/01**		
234	SCAL DM qualification	4 wks	Mon 11/06/0	Fri 06/07/01	229	
235	SCAL DM lifetests	4 wks	Mon 09/07/0	Fri 03/08/01	234	
236	SCAL STM modification/rebuild	6 wks	Mon 06/08/0	Fri 14/09/01	235	
237	SCAL STM tests	6 wks	Mon 17/09/0	Fri 26/10/01	236	
238	**SCAL STM delivery to RAL**	1 day?	Mon 29/10/0	Mon 29/10/0	237	
239	**CQM build & qualification**	**151 days**	**Tue 30/10/01**	**Tue 28/05/02**		
240	CQM design	4 wks	Tue 30/10/0	Mon 26/11/0	232,238	
241	CQM PCAL build	8 wks	Tue 27/11/0	Mon 21/01/0	240	
242	CQM SCAL build	12 wks	Tue 27/11/0	Mon 18/02/0	240	
243	CQM PCAL testing	4 wks	Tue 22/01/0	Mon 18/02/0	241	
244	**COM PCAL to ATC**	1 day	Tue 19/02/0	Tue 19/02/0	243	
245	CQM PCAL integration & test	12 wks	Wed 20/02/0	Tue 14/05/0	244	
246	CQM SCAL testing	14 wks	Tue 19/02/0	Mon 27/05/0	242,243	
247	**CQM SCAL to RAL**	1 day	Tue 28/05/0	Tue 28/05/0	246	
248	**PFM build & qualification**	**141 days**	**Tue 04/02/03**	**Tue 19/08/03**		
249	PFM PCAL build	6 wks	Tue 04/02/0	Mon 17/03/0	245,3	
250	PFM SCAL build	8 wks	Tue 04/02/0	Mon 31/03/0	247,3	
251	PFM PCAL qualification	6 wks	Tue 18/03/0	Mon 28/04/0	249	
252	**PFM PCAL to ATC**	1 day	Tue 29/04/0	Tue 29/04/0	251	
253	PFM PCAL integration & test	16 wks	Wed 30/04/0	Tue 19/08/0	252	
254	PFM SCAL qualification	20 wks	Tue 01/04/0	Mon 18/08/0	250	
255	**PFM SCAL to RAL**	1 day	Tue 19/08/0	Tue 19/08/0	254	
256	**FS build & qualification**	**242 days**	**Tue 04/02/03**	**Wed 07/01/04**		
257	FS PCAL build	10 wks	Tue 04/02/0	Mon 14/04/0	245,3	
258	FS SCAL build	10 wks	Tue 04/02/0	Mon 14/04/0	247,3	
259	FS PCAL qualification	6 wks	Wed 20/08/0	Tue 30/09/0	257,255	
260	**FS PCAL to ATC**	1 day	Wed 01/10/0	Wed 01/10/0	259	
261	FS PCAL integration & test	12 wks	Thu 02/10/0	Wed 24/12/0	260	
262	FS SCAL qualification	20 wks	Wed 20/08/0	Tue 06/01/0	258,255	
263	**FS SCAL to RAL**	1 day	Wed 07/01/0	Wed 07/01/0	262	
264	**Documentation**	**1 day?**	**Thu 26/10/00**	**Thu 26/10/00**		
265	Internal design document	1 day?	Thu 26/10/0	Thu 26/10/0		
266	SSSD - SPIRE	1 day?	Thu 26/10/0	Thu 26/10/0		
267	SSDP - SPIRE	1 day?	Thu 26/10/0	Thu 26/10/0		
268	ICD - QMW	1 day?	Thu 26/10/0	Thu 26/10/0		
269	ICD info. to MSSL	1 day?	Thu 26/10/0	Thu 26/10/0		
270	ICD info. to LAM	1 day?	Thu 26/10/0	Thu 26/10/0		
271	QA documentation - CQM	1 day?	Thu 26/10/0	Thu 26/10/0		
272	QA documentation - PFM	1 day?	Thu 26/10/0	Thu 26/10/0		
273	QA documentation - FS	1 day?	Thu 26/10/0	Thu 26/10/0