Filters
Subsystem Development Plan

For approval

Draft

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Update history

Date	Version	Remarks
26 April 2000	Draft 1.0	First draft. No detailed design available.
14 July 2000	Issue 1.0	First issue
11 January 2001	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 instrument optical filters subsystem.

2. Documents

2.1. Applicable documents

	Title	Author	Reference	Date
AD1	SPIRE Filters subsystem specification	P. Hargrave	SPIRE-PRJ-000454	14 June 2000
AD2	SPIRE FPU PDR viewgraphs	P.Ade, C.Tucker, M.Griffin, P.Hargrave		7-9 July 1999

2.2. Reference documents

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

2.3. Glossary

AD	Applicable Document	JPL	Jet Propulsion Laboratory
CDR	Critical Design Review		
CoG	Centre of Gravity	LPE	Low Pass Edge
CQM	Cryogenic Qualification Model	MCA	Minimum Clear Aperture
DDR	Detailed Design Review	MGSE	Mechanical Ground Support Equipment
DM	Development Model	MSSL	Mullard Space Science Laboratory
DRCU	Digital Read-out and Control Unit	NA	Not Applicable
EGSE	Electrical Ground Support Equipment	O/d	Outside diameter

FIRST	Far InfraRed Space Telescope	OGSE	Optical Ground Support Equipment
FPU	Focal Plane Unit	PFM	ProtoFlight Model
FS	Flight Spare model	RAL	Rutherford Appleton Laboratory
FTS	Fourier Transform Spectrometer	RD	Reference Document
GSFC	Goddard Space and Flight Center	SPIRE	Spectral and Photometric Imaging Receiver
HPE	High Pass Edge	TBC	To Be Confirmed
I/d	Inside diameter	TBD	To Be Defined
		WE	Warm Electronics

3. Subsystem Description

A full description of the filter subsystem is contained in document [AD1]. Figures 1 and 2, and tables 1 and 2 give a summary of the SPIRE filtering scheme.
The filters will be:

- Designed by QMW.
- Manufactured by QMW
- Qualified/accepted and calibrated under QMW responsibility, mainly at QMW, with RAL assisting with cryovibration tests. The qualification/acceptance program includes thermal cycling and warm and cold vibrations. The calibration program verifies the performance requirements.
- Transported to RAL under QMW responsibility.
- Integrated at RAL in the SPIRE FPU Structure under TBD (QMW/RAL/MSSL) responsibility.
- The SPIRE WE and the SPIRE FPU are integrated under RAL responsibility and undergo the project calibration program under RAL responsibility.
- SPIRE is delivered to ESA under RAL responsibility.
- SPIRE is integrated in the FIRST satellite under ESA responsibility.
- SPIRE CQM is to undergo the ESA cryoqualification program under ESA responsibility.
- SPIRE PFM is to undergo the ESA Acceptance program.
- SPIRE FS is prepared in the event of SPIRE PFM failure.

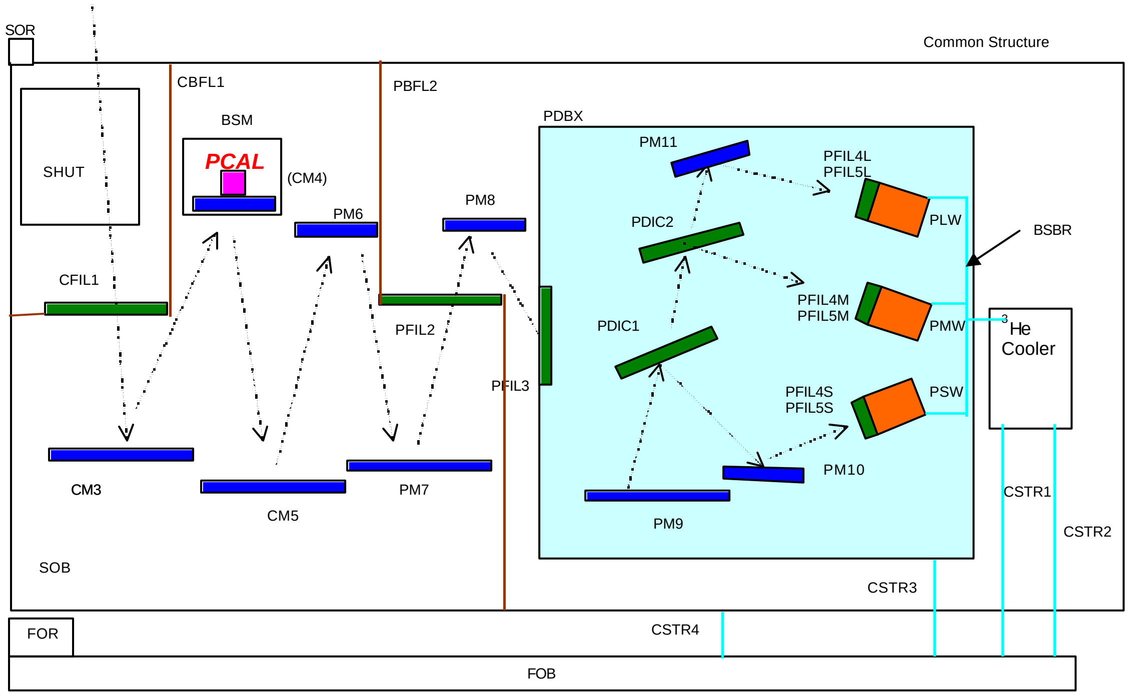


Figure 1 Photometer optics and filter locations

Table 1 List of photometer filters and dichroics

Specifications of photometer filters and dichroics						
Component ID	**Temp (K)**	**Location**	**Type**	**Edges (cm^{-1})**	**Minimum clear aperture (mm)**	**Comments**
CFIL1	4	Over entrance to 4-K box	Edge filter	10% 105 50% 100 90% 95	70 x 150 (Beam footprint on CIPM is 54 x 132)	Exact position TBD
PFIL2	4	Above CIPM (M3)	Edge filter	10% 84 50% 80 90% 76	70 x 150	Exact position TBD
PFIL3	2	Pupil between POFR2 and POFR3	Edge filter	10% 74 50% 70 90% 66	45 dia. (Pupil is 41 x 44 inc. 20% oversize)	
PDIC1	2	After POFR3	Low Pass Dichroic	10% 40 50% 37 90% 34	90 dia. TBC	Transmits long λ
PDIC2	2	After PDIC1	Low Pass Dichroic	10% 27 50% 25 90% 23	90 dia. TBC	Transmits long λ
PFIL4S	0.3	At SW array	Low pass edge High pass edge	53 38	40 dia. (Field is 19 x 38)	
PFIL4M	0.3	At MW array	Low pass edge High pass edge	36 25.7	40 dia.	

PFIL4L	0.3	At LW array	Low pass edge High pass edge	24 17 (if necessary)	40 dia.	
PFIL5S	0.3	At SW array	Edge filter	10% 70 50% 66 90% 62	40 dia.	
PFIL5M	0.3	At MW array	Edge filter	10% 46 50% 43 90% 40	40 dia.	
PFIL5L	0.3	At LW array	Edge filter	10% 27 50% 26 90% 25	40 dia.	

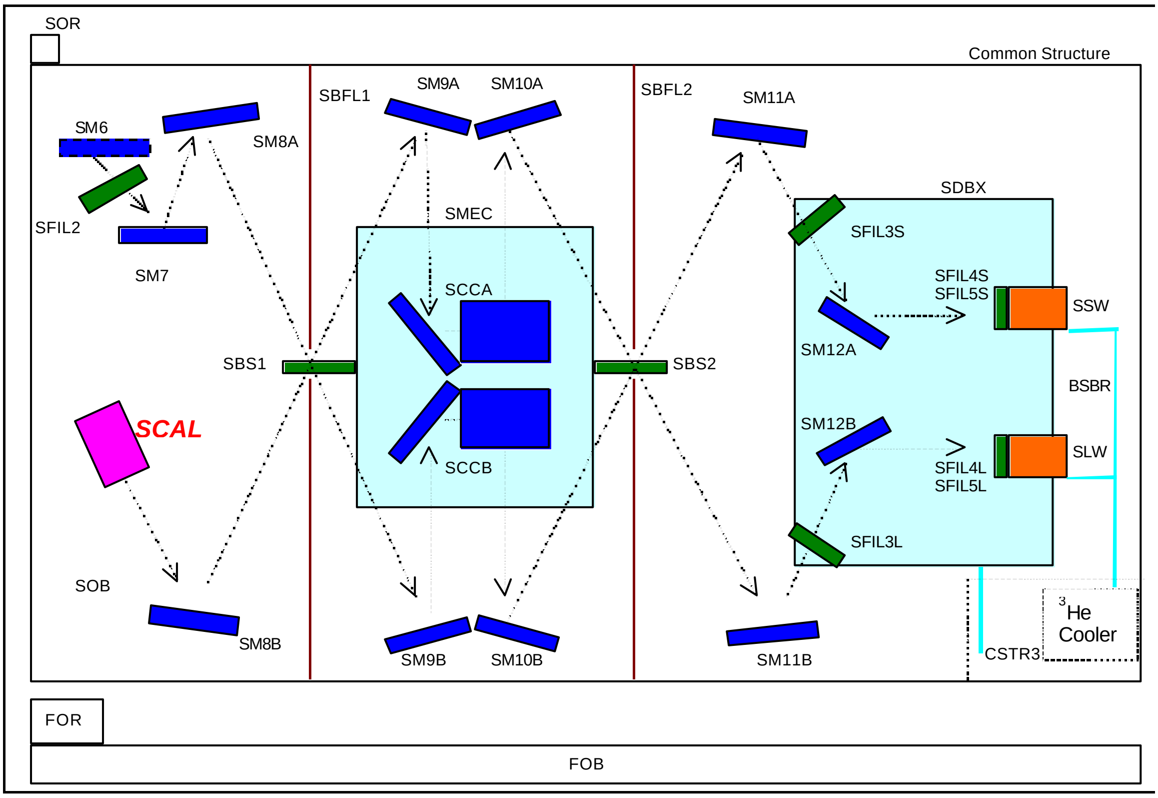


Figure 2 Spectrometer optics and filtering scheme

Table 2 List of spectrometer filters and beam dividers

Specifications of FTS filters and beam dividers						
Component ID	**Temp (K)**	**Location**	**Type**	**Edges (cm^{-1})**	**Clear aperture (mm)**	**Comments**
CFIL1	4	On entrance to 4-K box	Edge filter	10% 105 50% 100 90% 95	70 x 150 (Beam footprint on CIPM is 54 x 132)	Shared with photometer
SFIL2	4	Above M3	Edge filter	10% 84 50% 80 90% 76	70 x 150	Shared with photometer
SBS1	4	After SIRM	Beam divider	15 to 60	36 dia.	

				>90% 4RT		
SBS2	4	After SDCM-A or -B	Beam divider	15 to 60 >90% 4RT	36 dia	
SFIL3S SFIL3L	2	After SCAM-A or SCAM-B	Edge filter	10% 74 50% 70 90% 66	40 dia.	
SFIL4S1,2	0.3	At SW array	Low pass edge High pass edge	50 33	15	
SFIL4L1,2	0.3	At LW array	Low pass edge High pass edge	33 None?	15	
SFIL5S	0.3	At SW array	Edge	10% 70 50% 66 90% 62	15	
SFIL5L	0.3	At LW array	Edge	10% 46 50% 43 90% 40	15	

The first filter in the chain, situated on the 4-K box, should reflect back to the sky as much unwanted high frequency radiation as possible. Filters on lower temperature shields should then reject radiation from higher temperature boxes and shields. Strategic placement of filters will enable us to:

- Define the spectral passbands.
- Minimise the thermal loading on the ^{3}He fridge, 2-K, and 4-K stages by rejecting short wavelength thermal energy.
- Minimise stray light getting to the detectors.
- Maximise the in-band spectral transmission.

3.1. Requirements

See 4.1 (technical constraints)

3.2. Interfaces

SPIRE-ICD-1.1/1.2.1 Structure-Filters (13th June 2000) – filter mounts

3.3. 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 3 List of deliverables for each instrument model

Item	STM	CQM	PFM	FS
RAL Filters	01/07/02	01/10/02	01/10/03	10/11/04
		20/02/02	15/05/03	14/05/04
JPL 300mK Filters		TBD	TBD	TDB

The filter sets to be delivered to RAL and JPL.

Model	Flight representativity	Difference with flight	Deliverables
CQM	100% (TBC)	None (TBC)	1 set
PFM	100%	None	1 set
FS	100%	None	1 set

No special equipment is required for integration and alignment.
No simulators required.
No special tooling required.
Documentation to be delivered: Test reports
PA/QA documentation

4. Constraints

4.1. Technical constraints

The main performance specifications are shown in table 3. Please note that these figures are for information only. Full details are contained in document [AD1].

Table 4 Performance requirements for the filter subsystem

IRD-PHOT-R01	Nominal pass band 250 mm, 350 mm and 500 mm (TBC) $\lambda/\Delta\lambda = 3$
IRD-SPEC-R01	Wavelength range Band A = 200-300mm, 33-50cm^{-1} (TBC) Band B = 300-670mm, 15-33cm^{-1} (TBC)
IRD-OPTP-05	Overall optical efficiency: Greater than 0.27
IRD-OPTP-R07	Out of band radiation: Requirement TBD until telescope optical properties defined

The main technical constraints are:

- SPIRE lifetime in orbit = 4.25 years
- Operating temperature = 0.3 K - 4 K
- Total mass of all filters = TBD kg including 20% margin
- Filter CoG position = TBD – list of all filters
- Filter Volume = TBD mm3 - list
- Level of radiation = TBD
- Vibration level = TBD at 4K
- Shock level = TBD at 4K

- Cleanliness = 100,000 or better (TBD)

4.2. System constraints

4.2.1. Filter system requirements

Requirement ID	***Description***	***Value***
IRD-STRC-R03	Items requiring support from 4K common structure	Photometer filters All spectrometer optics Beam splitters
IRD-STRC-R04	Optics & associated subsystem alignment	The common structure shall be capable of maintaining the alignment of the photometer and spectrometer optics and associated components (eg. Filters) to within the specifications given in RD7 both at room temperature and during cryogenic operation
IRD-STRP-R01	Items requiring support	The photometer 2K structure shall support: photometer 2K optics, dichroics and filters.
IRD-STRP-R02	Optics & Filters alignment	The 2K photometer structure shall be capable of maintaining the alignment of the photometer 2K optics; filters and dichroics to within the requirements set out in RD7 at room temperature and during cryogenic operation
IRD-STRS-R01	Items requiring support	The spectrometer 2K structure shall support: Cold Stop filters, Fold mirrors
IRD-OPTP-R05	Throughput	The throughput of the photometer mirrors, filters, dichroics and baffles shall be greater than 0.27 (TBC) over the instrument waveband. This includes losses due to manufacturing defects, surface finish and alignment tolerances.
IRD-OPTP-R07	Out of band radiation	The end to end filtering of the photometer shall control the out of band radiation to be no more than 10-3 for 40cm-1 to 200cm-1 10-6 for 200cm-1 to 1000cm-1 10-9 for 1000cm-1 to 100000cm-1

		of the in-band telescope background radiation.
IRD-OPTS-R05	Theoretical throughput	The theoretical throughput of the spectrometer mirrors, filters, beam splitters and baffles individually shall be greater than 0.9 (TBC) over the 2.6 arcmin FOV at 250µm including all losses due to alignment, mirror quality, etc.
IRD-OPTS-R08	Out of band radiation	The end-to-end filtering of the spectrometer shall control the out of band radiation to be no more than 10-3 for 40cm-1 to 200cm-1 10-6 for 200cm-1 to 1000cm-1 10-9 for 1000cm-1 to 100000cm-1 of the inband telescope background radiation.

4.3. Calendar constraints

The main SPIRE project milestones are [RD2]:

PDR	November 2000
DDR	
CQM filters delivery to RAL	1 Oct 2002
CQM filters delivery to JPL	TBD
CDR	3 Feb 2003
SPIRE CQM delivery to ESA	
PFM filters delivery to RAL	1 Oct 2003
PFM filters delivery to JPL	TBD
SPIRE PFM delivery to ESA	
FS filters delivery to RAL	10 Nov 2004
FS filters delivery to JPL	TBD
SPIRE FS delivery to ESA	
FIRST launch	2007

5. Work Description

5.1. Model philosophy

The model philosophy is compliant with the SPIRE project.
The following models will be produced:-

- Filter 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
- Filter STM – this will be thermally and structurally representative of the flight filters.
- Filter CQM – these will be provided for incorporation into SPIRE for CQM testing
- Filter PFM – This is the flight device
- Filter FS – This is the flight spare

5.2. Organisation

QMW is responsible for the filter subsystem. This involves the design, manufacture and testing of all filters, dichroics and beam dividers for each instrument model.
RAL will assist with cryo-vibration tests.
MSSL is responsible for the structure to which the filters are integrated.
JPL are responsible for the structure to which the 300mK filters are integrated as part of the detector array modules.

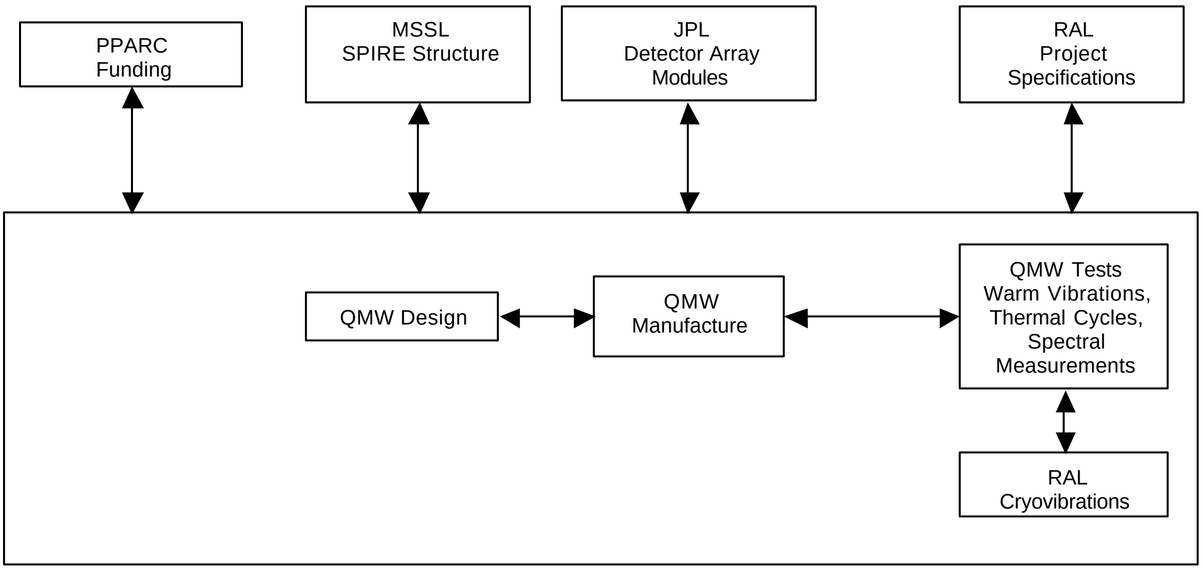
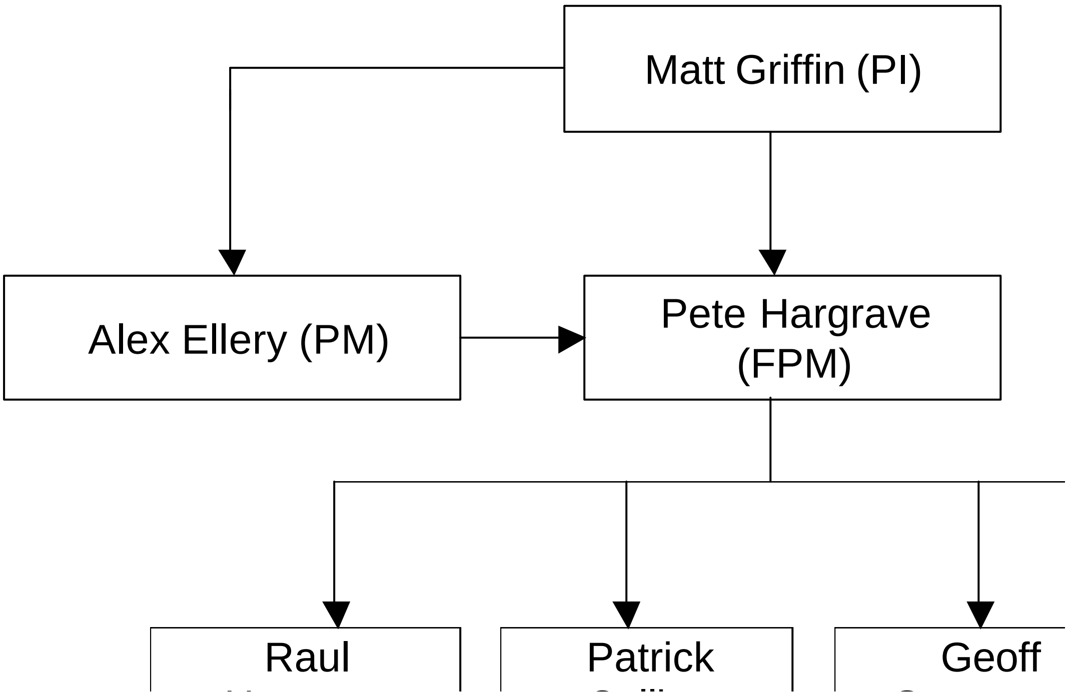


Figure 1 Organisation of the filter subsystem

5.2.1 QMW Organisation



5.3. Preliminary design phase

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

5.3.1. Filter development

The final design of the instrument structure and optics has a significant impact on the design of some filter components. Some ring-mounted components may need to be manufactured to non-standard sizes. Small dimension filter version of these large, non-standard dimensioned filters may be prototyped. If the actual non-standard filters require prototyping, before QMW re-tools and prototyping of these components can begin, the instrument structure and optics design needs to be finalised. This section lists each filter component to be produced by QMW, and gives details of any factors affecting its design and manufacture.

CFIL1 – Hot pressed LPE filter

The original location for CFIL-1 was over the entrance to the 11-K box but the 11-K box is no longer being implemented on SPIRE. It is therefore proposed to mount CFIL-1 over the aperture to the 4K box, intercepting the input beam at 4-K. The size of beam to be intercepted is dependent upon the position within the 4-K box. The

smallest MCA will result from placing the filters at a beam waist, in this case the telescope focal plane. The implications of placing filter components here need to be investigated, and will be discussed at a splinter meeting around the time of the PDR, along with other options for modifying the structure.
QMW is waiting for the SPIRE structural model (CAD file) with the integrated optical beams from RAL, which will enable us to determine the filter sizes needed. This obviously depends upon the final position of these filters in the optical train.
These filters present a small schedule risk, as it is almost certain that the MCA needed will be greater than 110mm diameter, which is the largest set of lithographic masters that QMW have. To produce these large filters (possibly up to 150mm diameter), QMW will have to procure new masters. It is not anticipated that manufacture of these components will present a problem, as we have press tools which can handle up to 170mm diameter, although these components will need to be thoroughly prototyped and checked for de-lamination after thermal cycling. We may also require a new sample chamber for the FTS (at present 120mm x 140mm cross-section) if the filter sizes exceed 140mm in diameter.

PFIL2 and PFIL3 - Hot pressed LPE filters

This item will be directly mounted to the structure with a clamping ring, and will not present a development problem/risk.

PDIC1 – Low pass dichroic

PDIC1 will be a hot pressed, dielectric gap or air gap component (TBC). However, this has to be flat (spec. TBD), and therefore ring mounted. Space restrictions in the instrument dictate that a ring of 80mm i/d, and 95mm o/d is needed, with a maximum thickness of 11mm (TBC). This is not one of the QMW standard ring sizes, and so QMW will need to re-tool to produce rings of this size. Before this can happen, QMW need final confirmation of the ring size. There is therefore a slight schedule risk relating to the re-tooling process.

PDIC2 - Low pass dichroic

PDIC2 will also be a hot pressed, dielectric gap or air gap component (TBC). As the present SPIRE structure is drawn, a ring of 72mm i/d, and 85mm o/d is needed. Again, this is a non-standard ring size. However, it may be possible to accommodate a ring of 75mm i/d, 90mm o/d, as this is a standard size. This will greatly help reduce delay and cost. We are working with MSSL to resolve this issue.

PFIL4-S,M,L – LPE/HPE hot pressed filters

These were baselined as combinations of two hot pressed filters to define the pass bands. However, the selection of the feedhorn option now means that the feedhorn waveguide may serve as a sufficient HPE filter. This will be discussed with JPL in early May.
These items will be directly mounted to the array modules, and will not present a development problem/risk.

PFIL5-S,M,L – LPE hot pressed filters

These items will be directly mounted to the array modules, and will not present a development problem/risk.

SFIL2 - Hot pressed LPE filter

This item will be directly mounted to the structure with a clamping ring, and will not present a development problem/risk.

SBS1,2 – Spectrometer beam dividers

As drawn, these components have to be 38mm i/d and 46mm o/d. These are non-standard sizes, and re-tooling will be necessary. QMW needs final confirmation of sizes before re-tooling and prototyping.
Prototype hot-press beam dividers are running on the SPIRE prototype FTS in the QMW lab, and perform very well. However, they have not yet undergone qualification tests. Additionally, these components need to be checked for microphonic effects.
These components present a small development risk.

SFIL3-S,L – Hot pressed LPE filters

These filters present no development problem/risk. However, as drawn in the SPIRE CAD model, there is provision for a mounting lip of only 1.5mm to the structure. This is not sufficient and has to be resolved. QMW is working with MSSL on this issue.

SFIL4-S,L-1,2 - LPE/HPE hot pressed filters

These were baselined as combinations of two hot pressed filter assemblies to define the pass bands. However, the selection of the feedhorn option now means that the feedhorn waveguide may serve as a sufficient HPE filter. This will be discussed with JPL in early May.

These items will be directly mounted to the array modules, and will not present a development problem/risk.

SFIL5-S,L – Hot pressed LPE filters

These items will be directly mounted to the array modules, and will not present a development problem/risk.

5.3.2. Filter testing

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

More rigorous tests will be implemented, which include all of the above as well as repeated thermal cycling and accelerated lifetime tests.

5.4. Procurement of long lead-time components

Once a preliminary design has evolved, long lead-time items will be procured – these include new masters for non-standard sized filters (TBD).

Note – need to get list of CPP items to Ken

5.5. Detailed design phase

The detailed design will encompass all the functions and interfaces of the filter subsystem.

The detailed design will be presented at the Detailed Design Review. The DDR must have taken place before CQM manufacture can begin.

The design verification tests include:-

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

5.6. CQM manufacture & test

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 filters are necessary. The two models are the development model (DM) and the cryogenic qualification model (CQM). The Filter DM is deliverable in part and the Filter CQM is deliverable.

The DM models are used to qualify the design and conduct lifetests.

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 CQM Filter 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.

CFIL-1 will be provided for the STM for warm/cold vibration tests and thermal cycling tests. This component will also comprise the CQM and FS CFIL-1 filter.

The PFM Filters are then manufactured and undergo the acceptance tests and performance verification.

It may be possible to use the CQM filters as the FS filters – this depends on ESA that the return delivery of the CQM arrives on time (baseline). There is the possibility for manufacturing a new set of FS filters if the CQM filters are not returned to QMW without significant impact on the schedule. The FS filters undergo the acceptance tests and performance verification after the PFM delivery.

6. Risk analysis

There is minimal risk associated with the production of the edge and ND filters. These are standard filter types that are routinely produced by QMW for ground, airborne and space experiments. In terms of performance, the filter stacks will be undergoing qualification for BLAST thereby increasing confidence in their functionality. There is a risk associated with production throughput of filters with respect to other programmes which requires careful coordination to ensure no schedule impacts to SPIRE.

There is no provision for filter component redundancy on SPIRE. Loss of edge or ND filters would change the background power on the detector arrays, as well as changing the power loading on the various temperature stages.
The items that would constitute a single point failure are: -

1. Dichroics – loss of a dichroic would compromise at least two photometer arrays, depending on the failure mode
2. Beam splitters – loss of a beam splitter would cause the loss of the FTS

Risk	Likelihood	Impact	Preventative Action	Notes
Beam splitter qualification failure	Low	Re-design of spectrometer	None	Prototype beam splitters have been built, and perform well on the SPIRE FTS optical test bed at QMW. However these have not yet been subjected to any qualification test.
Dichroic qualification failure	Low	Re-design photometer optics	None	Prototype dichroics are to built. They have yet to be subjected to any qualification tests (BLAST will provide

				this).
CFIL-1 qualification failure	Low	Need to re-locate filters to intercept a smaller beam cross section. May affect instrument thermal balance and stray light environment	None	This filter has a higher than usual development risk associated with them as they are larger than any manufactured by QMW in the past. New lithographic masters need to be ordered. Furthermore, being the first filter common to both photometer and spectrometer, it represents a single point failure mode.

7. Verification plan

The verification plan must be compliant with the project verification plan [AD2, RD1] and must fulfil the filter development needs.

300K vibrations are conducted at QMW/RAL (TBD).
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. Prototype filters

		Components
Mass measurement	X	All
CoG measurement		
Vibrations 300K	X	All
Vibrations 4K	X	All
Thermal/Vacuum cycle	X	All
Radiation tolerance	A(**)	All
Microphonics	X	SBS1, SBS2
Spectral measurements	X	All

(*) : 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. CQM filters

		Components
Mass measurement	X	All
CoG measurement		
Vibrations 300K	X	All
Vibrations 4K	X	All
Thermal/Vacuum cycle	X	All
Radiation tolerance	A(**)	All
Microphonics	X	SBS1, SBS2
Spectral measurements	X	All

(*) : 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. PFM filters

		Components
Mass measurement	X	All

CoG measurement		
Vibrations 300K	X	All
Vibrations 4K	X	All
Thermal/Vacuum cycle	X	All
Radiation tolerance	A(**)	All
Microphonics	X	SBS1, SBS2
Spectral measurements	X	All

(**) : The radiation tolerance is verified by analysis only, taking into account the materials involved and experience of previous space missions

7.4. FS filters

		Components
Mass measurement	X	All
CoG measurement		
Vibrations 300K	X	All
Vibrations 4K	X	All
Thermal/Vacuum cycle	X	All
Radiation tolerance	A(**)	All
Microphonics	X	SBS1, SBS2
Spectral measurements	X	All

(**) : The radiation tolerance is verified by analysis only, taking into account the materials involved and experience of previous space missions

8. Development calendar & schedule

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

Detailed design available	??
CQM Prototyping	7 Feb 2001–12 Jun 2001
CQM Manufacture	13 Jun 2001–27 Nov 2001

CQM Modif, qualification & calibration	5 Sep 2001-19 Feb 2002
CQM delivery to RAL	20 Feb 2002
PFM Manufacture	8 Aug 2002–22 Jan 2003
PFM Acceptance & calibration	28 Nov 2002–14 May 2003
PFM delivery to RAL	15 May 2003
FS manufacture	8 Aug 2003–22 Jan 2004
FS Acceptance & calibration	28 Nov 2003–13 May 2004
FS delivery to RAL	14th May 2004

Detailed planning is outlined in filter SPIRE_QMW_ALL_v1.3.mpp

9. Filters 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_v1.3.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 filter 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.

ID	Task Name	Duration	Start	Finish
6	**Filters (SPIRE)**	**1138 days?**	**Mon 03/07/00**	**Wed 10/11/04**
7	**Milestones**	**1055 days?**	**Thu 26/10/00**	**Wed 10/11/04**
8	STM input filter to RAL	1 day?	Mon 01/07/02	Mon 01/07/02
9	CQM filters to RAL	1 day	Tue 01/10/02	Tue 01/10/02
10	CQM 300mK filters to JPL	1 day?	Thu 26/10/0C	Thu 26/10/0C
11	PFM filters to RAL	1 day	Wed 01/10/03	Wed 01/10/03
12	PFM 300mK filters to JPL	1 day?	Thu 26/10/0C	Thu 26/10/0C
13	FS filters to RAL	1 day	Wed 10/11/04	Wed 10/11/04
14	FS 300mK filters to JPL	1 day?	Thu 26/10/0C	Thu 26/10/0C
15	SRD finalised	1 day	Thu 26/10/0C	Thu 26/10/0C
16	IRD finalised	1 day	Thu 26/10/0C	Thu 26/10/0C
17	Optics design finalised	1 day	Thu 26/10/0C	Thu 26/10/0C
18	Mechanical design finalised	1 day	Fri 22/12/00	Fri 22/12/00
19	Filtering scheme finalised	1 day	Mon 22/01/01	Mon 22/01/01
20	Filter specifications	1 day	Tue 06/02/01	Tue 06/02/01
21	**Design & Manufacture**	**853 days?**	**Wed 07/02/01**	**Fri 14/05/04**
22	**CQM prototyping**	**90 days**	**Wed 07/02/01**	**Tue 12/06/01**
43	**CQM manufacture**	**120 days**	**Wed 13/06/01**	**Tue 27/11/01**
64	**CQM Qualification & calibration**	**120 days**	**Wed 05/09/01**	**Tue 19/02/02**
85	CQM modification	12 wks	Wed 17/10/01	Tue 08/01/02
86	**CQM Delivery to RAL**	1 day?	Wed 20/02/02	Wed 20/02/02
87	**PFM Manufacture**	**120 days**	**Thu 08/08/02**	**Wed 22/01/03**
108	**PFM Acceptance & calibration**	**120 days**	**Thu 28/11/02**	**Wed 14/05/03**
129	**PFM delivery to RAL**	1 day	Thu 15/05/03	Thu 15/05/03
130	**FS manufacture**	**120 days**	**Fri 08/08/03**	**Thu 22/01/04**
151	**FS Acceptance & calibration**	**120 days**	**Fri 28/11/03**	**Thu 13/05/04**
172	**FS delivery to RAL**	1 day	Fri 14/05/04	Fri 14/05/04
173	**Documentation**	**923 days?**	**Mon 03/07/00**	**Wed 14/01/04**