SPIRE Mirrors and Alignment tools Development Plan

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20 May 2000	Draft 0	Creation of the document
26 May 2000	Draft 1	Mirrors STM added Mirror list added M5 drawing added
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1. Scope of the document

This document describes the development plan of the FIRST/SPIRE Optics subsystem and of the different tools necessary for the development of the mirrors and for the alignment of the optics in the structure..
The development plan is based on the applicable documents cited in §2.
The format of this document is compliant with the CNES instructions applicable at LAM [AD3].

2. Documents

2.1. Applicable documents

	Title	Author	Reference	Date
AD1	SPIRE Mirrors Specification	K.Dohlen and D.Pouliquen	LAM.PJT.SPI.SPT.200007 Ind 1	22 May 2000
AD2	SPIRE Optical Alignment Plan	K.Dohlen and A.Origné	LOOM.KD.SPIRE.2000.001-1	3 Jan 2000
AD3	SPIRE Development plan	K.King	TBU	
AD4	Guide pour les projets scientifiques	CNES	DTS/AQ/QP 98-083	June 1998

2.2. Reference documents

	Title	Author	Reference	Date
RD1	Intrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Iss .21	30 Nov 1999
RD2	Instrument Development Plan	K.King	SPIRE WE Review viewgraphs	6 Dec 1999

2.3. Glossary

AD	Applicable Document
BSM	Beam Steering Mirror
CDR	Critical Design Review
CNES	Centre National des Etudes Spatiales
CoG	Center of Gravity
CQM	Cryogenic Qualification Model
DDR	Detailed Design Review
FIRST	Far InfraRed Submillimeter Telescope
FPU	Focal Plane Unit
FS	Flight Spare model
LAM	Laboratoire d'Astrophysique de Marseille
MSSL	Mullard Space Science Laboratory
NA	Not Applicable
PDR	Preliminary Design Review
PFM	Prototype Flight Model
RAL	Rutherford Appleton Laboratory
RD	Reference Document
SPIRE	Spectral and Photometric Imaging REceiver
STM	Structural Model
TBC	To Be Confirmed
TBD	To Be Defined
TBU	To Be Updated
TBW	To Be Written

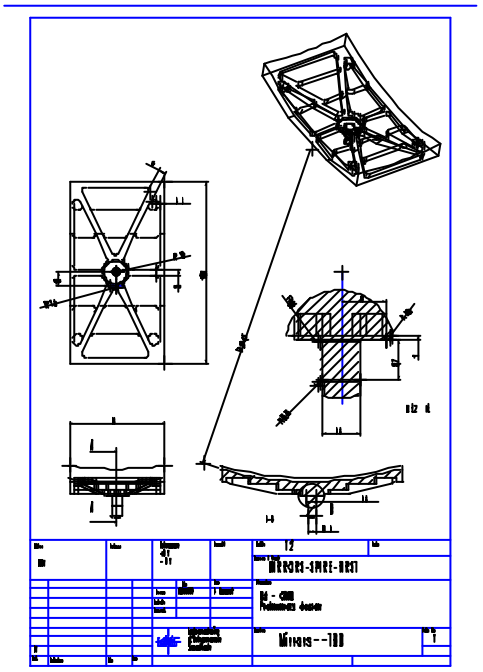
3. Description of the mirrors

The design of the mirrors is the same as the one used for ISO-LWS.
The mirrors are made in Aluminium 6061.
They all have a standard interface with the structure, i.e. an M8 screw and a pin.
Each mirror is machined in a single block of aluminium (diamond cutting). The screw part of the attachment exerts pressure only on the shoulder part of the mirror, avoiding deformation of the optical surface.
The mount of each mirror is located on the optical bench by means of a pin.
This pin ensures that in case of dismounting of the mirror it will be mounted again in its correct position.
During the integration of the mirrors in the SPIRE structure, the mirrors are mounted on brackets which are provided by MSSL.

The table below gives the list of the mirrors with their provisional dimensions and mass.

Subass'y	Mirror	Shape	Dimensions (mm)	Number of parts	Mass (kg)	**Total Mass (kg)**
Fore optics	M3	Rect	132x54	1	0.183	
	M4	Ell.	15x16	1	0.021	
	M5	Rect	161x85	1	0.360	**0.564**
Photometer	M6p	Rect	46x27	1	0.027	
	M7p	Rect	118x101	1	0.300	
	M8p	Circle		1	0.056	
	M9p	Cricle		1	0.223	
	F1	Rect	78x40	1	0.065	
	F3	Rect	56x53	1	0.060	**0.731**
Spectrometer	M6s	Rect	51x27	1	0.029	
	M7s	Rect	40x57	1	0.044	
	M8s	Circle		2	0.112	
	M9s	Circle		2	0.074	
	CC face1	Rect	40x40	2	0.044	
	CC face2	Rect	30x62	2	0.070	
	CC face3	Rect	30x62	2	0.070	
	M10s	Circle		2	0.112	
	M11s	Circle		2	0.194	
	M12s	Ell	21x16	2	0.050	**0.799**
Total				**27**		**2.094**

The figure below gives a drawing of the M5 mirror, which is the heaviest one.



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 [RD1]

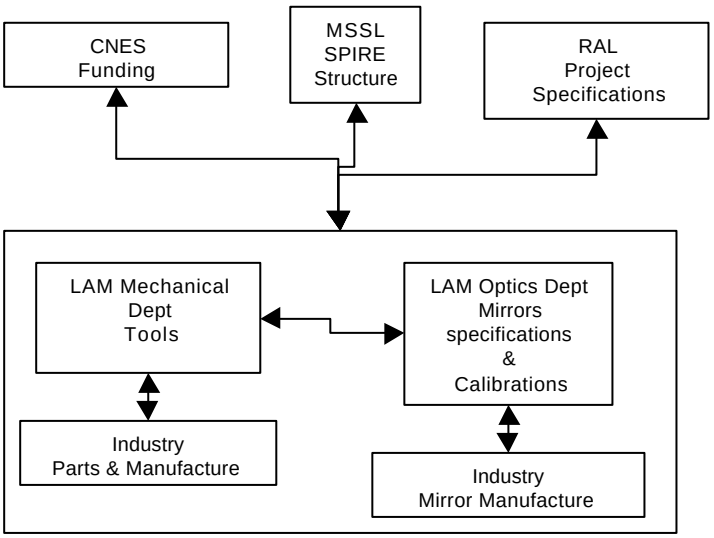
The main specifications are:
- Infrared reflectivity > 0.99
- Surface roughness = 2µm. (for alignment purpose in the visible light range)
- Material = Aluminium 6061
- SPIRE lifetime on orbit = 4.25 years
- Operating temperature = 4K
- Mirrors mass = TBD
- Cleanliness = Class 100 (TBC)

During its lifetime, the mirrors are :
- designed under LAM responsibility.
- manufactured under LAM responsibility, (subontract in the industry).
- controlled at LAM responsibility
- transported to RAL under LAM responsibility.
- integrated at RAL in the SPIRE FPU Structure under joint RAL, MSSL and LAM responsibility.

Once integrated, the mirrors will follow the life of the SPIRE-FPU:
- The SPIRE-FPU is to undergo the project qualification/acceptance 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 test program under ESA responsibility.
- SPIRE PFM is to undergo the ESA Acceptance program.
- On the launch pad, before launching, the SPIRE FPU is cooled down to its operating temperature and launched cold.
- SPIRE FS is prepared in the event of a SPIRE PFM failure.

4.1.2. Organisation

LAM is responsible for the mirrors, except the BSM mirror, and for the alignment tools.
LAM designs the tools and manufacture them part at LAM, part in the industry.
MSSL is responsible for the structure inside which the Optics is integrated.
RAL is responsible for the SPIRE experiment.



4.1.3. Calendar constraints

The main SPIRE project rendez-vous are [RD2]:

Milestone	Date
PDR	Jun 2000
DDR	Oct 2000
LAM delivers the MM mirrors to MSSL	Jan 2002
LAM delivers the CQM mirrors and the alignment tools to RAL	Apr 2002
CDR	Apr 2003
LAM delivers the PFM and FS mirrors and the alignment tools to RAL (If no modification, delivery could take place immediately after CDR)	Apr 2004
FIRST launch	2007

4.2. Risk analysis

Due to the fact that no coating is applied to the mirrors, no risk has been identified.

4.3. Redundancy

This part is not applicable to the optics subsystem.

5. Work description

5.1. Development and model philosophy

The model philosophy is compliant with the SPIRE project requirements and meets the LAM development needs.

5.1.1. Preliminary Design (*Phase B*)

The optical design is made. The alignment plan is written. The optics specifications are written.
A mirror mockup is built and tested in vibrations to ensure that no deformation of the mirror happens.
The interfaces with SPIRE Structure are defined during this step.
The preliminary design is presented at the Preliminary Design Review which freezes the technical specifications and the interfaces.

5.1.2. Detailed design and CQM/PFM mirrors manufacture (*Phase C/D*)

A set of test mirrors is manufactured by different industrials to check their ability to manufacture aluminium mirror with the adequat diffusion caracteristics. The mirrors are tested on the Mirror Diffusion Bench.
Following these measurements,

- an ITT is emitted by LAM for the procurement of all the mirrors for both the CQM and the PFM mirrors and for the CCA Tool and the Apex Tool. No mirror set is planned for the FS as the FS mirrors are supposed to be the CQM mirrors. Once received, the tools and the CQM mirrors optical characteristics are controlled (3D measurements and interferometry). Their masses are measured along with the CoG of the heaviest ones. The CQM mirrors are then baked-out, thermally cycled and controlled again. The PFM mirrors endure then the same treatment.
- At the same time, the Position Sensing Device (PSD) is ordered in its cryogenic version (estimated delay = 6 months). The PSD Control Bench is designed and optical components ordered along the design, manufacture and bake out of the PSD Tool mounting. Once eevrything is received, the PSD tool is assembled, controlled on the PSD Control Bench, thermally cycled (3 cycles), and controlled again.
- At the same time, the diffusion measure are fed into the optical simulator (ZEMAX software) and the complete alignment procedure is simulated. This simulation specifies the MAT supplementary lens and checks that the tools reticules will be seen with the correct precision and sensitivity.

The MAT supplementary lens is then ordered while the supplementary lens mechanical mounting is designed and manufactured. Once the lens is received, the assembly is integrated and controlled on the MAT Control Bench.
At the same time, the different tools are now to be specified. To do so, a set of each tools is ordered along with a lenses set to simulate the instrument. The detector tool (D-Tool) is mechanically designed, manufactured and baked out.
When received, the instrument simulator and the MAT are assembled on the Tools Bench and each appropiate tool is then selected.

After the Optics-CQM and the tools delivery, the SPIRE CQM is integrated, aligned and 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 modifications of the optics and the alignement tools.
Then, the SPIRE CQM is delivered to ESA for cryogenic tests of the FIRST payload.

5.1.3. Flight design modifications and PFM/FS manufacture

Following the SPIRE CQM tests, some modifications may have to be implemented in the design.
In this case, the design changes are implemented in the flight design, the modified mirrors are subcontracted to the industry (2 identical sets, one for the PFM and one for the FS) while the alignment tools modifications are handled by LAM.
If no modification is needed, no activity happens as the PFM mirrors have already been manufactured, controlled, etc… and as the FS mirrors are the CQM mirrors (as it is the case for the SPIRE structure)

5.2. Verification plan

- All the mirrors are measured at 300 K w.r.t. their individual optical specifications. This measurement is done in visible light.
- The interfaces of all the mirrors are controlled (3D)
- The CoG of the <big> mirrors is measured. These mirrors are tested in vibration at 300 K with a mock up of the typical mechanical interface with the structure and measured afterwards (visible light)
- The mass of each mirror is measured.
- All the mirrors are baked out (48 hours / 80°C, TBC)
- All the mirrors are now handled under class 100 cleanliness (TBC).
- All the mirrors are cycled between 300 K and 20 K (Number of cycles = TBD) and measured afterwards (visible light)
- No lifetime tests are to be conducted as there is no coating.

These operations are conducted at LAM.
These operations are done for both the CQM set and the PFM set.

5.3. Ground associated equipment

The tables hereafter sum up the ground equipement needed for the development of the mirrors and for the alignment of SPIRE.

5.3.1. Simulators

Simulator	Used for…	Functions
Alignement Simulator	…the detailed specifications of the alignment tools ... the verification of the alignement procedure	Replaces the hardware Allows to virtually place the alignement tools according tp the procedure Simulates what will be seen through the MAT

5.3.2. Alignment Tools

The alignment tools are deliverable.
As the alignment tools are to be integrated in the SPIRE structure, their interfaces are controlled and they are baked-out, and handled afterwards under Class 100 (TBC) cleanliness conditions.
The PSD-Tool is also thermally cycled and checked at cryogenic temperature as it is to be used also at cryogenic temperature.

Tool	Functions	Description	Note
MAT	Used to check the position of the reticule on the alignement tools		Used at room temperature only
Apex Tool	Used to check the position of each pirror Apex in the SPIRE structure.	An aluminium flat mirror with a central reticule whose plane is at the real mirror Apex distance from the interface plane with the SPIRE structure.	Used at room temperature only
3D Tool	Used to check the position of each mirror interface with the SPIRE structure.	An auminium monobloc piece associating a disk and a sphere.	Used at room temperature only
D Tool	Acts as a source in the place of the detectors.	A plate containing central and peripheral sources. Each source is individually lightable.	Used at room temperature only.
CCA Tool	Replaces SMECm during the spectrometer alignment.	Corner cubes mirrors placed at the ZPD position (TBC)	Used at room temperature only.
CS-Tool	Materializes the cold stop location	A glass plate with central reticule	Used at room temperature only
O-Tool	Materializes the SPIRE object plane	A glass plate with central and peropheral reticules	Used at room temperature only
M2-Tool	Materializes the telescope pupil (M2)	A glass plate with central and peripheral reticules	Used at room temperature only
PSD-Tool	Used to check the position of the incoming beam on the entrance plane of the detectors.		Used at room and croygenic temperature.

5.3.3. Additional equipment

The additional equipment are the benches used in the development.
This equipment is not deliverable.

Bench	Used to…	Note
Diffusion Bench	… characterize the diffusion of Aluminium mirrors	This test prepares the ITT.
PSD Control Bench	… verify check the PSD	Some parts are used when testing the PSD Tool at cryogenic temperature.
MAT Control Bench	… control the supplementary lens and its mounting on the MAT	The optical mounting consists in a set of lenses which projects the image of a reticule behind the position of the MAT.
Tools Bench	… to specify in details the caracteristics of the DTool, the CSTool, the Otool and the M2Tool … to prepare the detailed alignment procedures	

5.3.4. STructural Model (STM)

For the purpose of the SPIRE Structure development, a set of STM mirrors is delivered to MSSL.
These are not really mirrors but mass dummies whose CoG and inertia are within 5% of the real mirrors mass. The shape is to be simimlar to the real mirrors. No requirement is made on the surface as no optical test is to be conducted on this model.
These mirrors will be integrated in the SPIRE CQM Structure, along with STM of various critical subsystems, for the structure to sustain 300K vibrations to check the interface vibrations levels of the critical subsystems.

6. Development calendar

Hardware	Operations	Note	Dates
Diffusion measurement	Procurement and measurement	Beginning = PDR	Jul - Dec 2000
Alignment tools	Design, manufacture, controls		Dec 2000 - Oct 2001
CQM and PFM mirrors	ITT		Dec 2000 - Dec 2001
STM mirrors	Design, manufacture, bakeout		Oct - Dec 2001
STM mirrors	Delivery to MSSL		Jan 2002
CQM mirrors	Controls and tests		Dec 2001 - Mar 2002
CQM mirrors	Delivery to RAL		Apr 2002
PFM mirrors	Control and tests		Mar 2002 - Jun 2002
PFM mirrors	Delivery to RAL	If no modification needed (checked during CDR)	Apr 2003
PFM and FS modified mirrors	Modification, design, manufacture, controls and tests	Beginning = CDR	Apr 2003 - Dec 2003
PFM and FS modified mirrors	Delivery to RAL		From Jan 2004

See file Mirrors_Devplan_20000601.mpp for details.

7. Description of deliverables

7.1. Mirrors Deliverable models

Model	Flight representativity	Difference with flight	Deliverables	Delivered to
MM	Mass and CoG	Geometry	1 set	MSSL
CQM	100%	None	1 set	RAL
PFM	100%	None	1 set	RAL
FS	100%	None	1 set of the modified mirrors w.r.t. CQM	RAL

7.2. Alignment tools

The alignment tools are delivered to RAL
One set will be delivered with the mirrors CQM. If no modification is needed, no further set will be delivered.

7.3. Associated documentation

The documentation is TBD.