SPIRE

SUBJECT: SPIRE Mirrors and Alignment tools Development Plan

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HERSCHEL - SPIRE

SPIRE Mirrors and Alignment tools Development Plan

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Document change record

Date	Indice	Remarks
20 May 2000	Draft 0	Creation of the document
26 May 2000	Draft 1	Mirrors STM added Mirror list added M5 drawing added
13 June 2000	1	No change except document upgraded from draft status
20 Dec 2000	2	Dates revised
30 March 2001	3	Dates revised Optical design CDR replaced by CQM Interim review

Glossary

AD	Applicable Document
AVM	Avionic Model
BOL	Begin Of Life
BSM	Beam Steering Mirror
BSMm	BSM cryogenic mechanism
CEA-Sap	Commissariat à l'Energie Atomique, Service d'Astrophysique
CDR	Critical Design Review
CNES	Centre National des Etudes Spatiales
CoG	Center of Gravity
CQM	Cryogenic Qualification Model
DDR	Detailed Design Review
DESPA	Département des Etudes SPAtiales
DM	Development Model
DPU	Digital Processing Unit
DRCU	Digital Read-out and Control Unit
DSP	Digital Signal Processor
EGSE	Electrical Ground Support Equipment
EOL	End Of Life
ESA	European Space Agency
FPU	Focal Plane Unit
FS	Flight Spare model
FTS	Fourier Transform Spectrometer
GSFC	Goddard Space and Flight Center
H/K	House Keeping
H/W	Hardware
I/F	Interface
LAM	Laboratoire d'Astrophysique de Marseille
MAC	Multi Axis Controller
MCU	Mechanism Control Unit
MGSE	Mechanical Ground Support Equipment
MM	Mechanical Model
MSSL	Mullard Space Science Laboratory
NA	Not Applicable
OGSE	Optical Ground Support Equipment
PDR	Preliminary Design Review
PFM	Prototype Flight Model
RAL	Rutherford Appleton Laboratory
RD	Reference Document
SA	
S/C	Spacecraft
S/W	Software
SMEC	Spectrometer mirror MEChanism
SMECm	SMEC cryogenic mechanism
SPIRE	Spectral and Photometric Imaging REceiver
TBC	To Be Confirmed
TBD	To Be Defined
TBU	To Be Updated
TBW	To Be Written
TC	TeleCommands
TM	TeleMetry
WE	Warm Electronics
ZPD	Zero Path Difference

Table of contents

1. Scope of the document

This document describes the development plan of the HERSCHEL/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 [AD4].

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 5	21 Feb 2001
AD2	SPIRE Optical Alignment Plan	K.Dohlen and A.Origné	LOOM.KD.SPIRE.2000.001-2	16 May 2000
AD3	SPIRE Development plan	K.J.King	TBU	
AD4	Guide pour les projets scientifiques	CNES	DTS/AQ/QP 98-083	June 1998
AD5	SPIRE Alignment tools specifications	K.Dohlen and D.Pouliquen	LAM.PJT.SPI.SPT.200010 Ind 0	26 Oct 2000

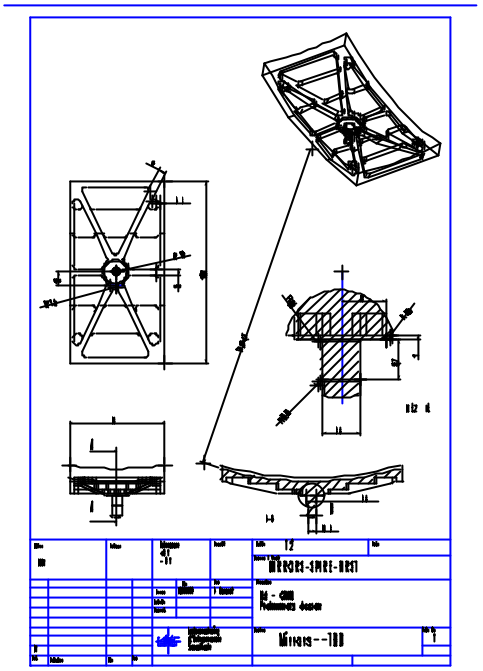
2.2. Reference documents

	Title	Author	Reference	Date
RD1	Intrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Iss 1.0	23 Nov 2000
RD2	SPIRE Major Milestone List	K.J.King	SPIRE-RAL-PRJ-000455 Iss 1.2 Draft 1	25 Feb 2001

3. Description of the mirrors

A detailed description is in AD1for themirrors and in AD5 for the alignment tools.
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 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]

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 = 2.5 kg, 20% margin included.
- Cleanliness = Class 100 (TBC)

During its lifetime, the mirrors are :
- designed under LAM responsibility.
- manufactured under LAM responsibility, (subcontract 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 HERSCHEL 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 providing the SPIRE project with the all the mirrors except the BSM's and with a participation in the optical alignment of the mirrors in SPIRE.

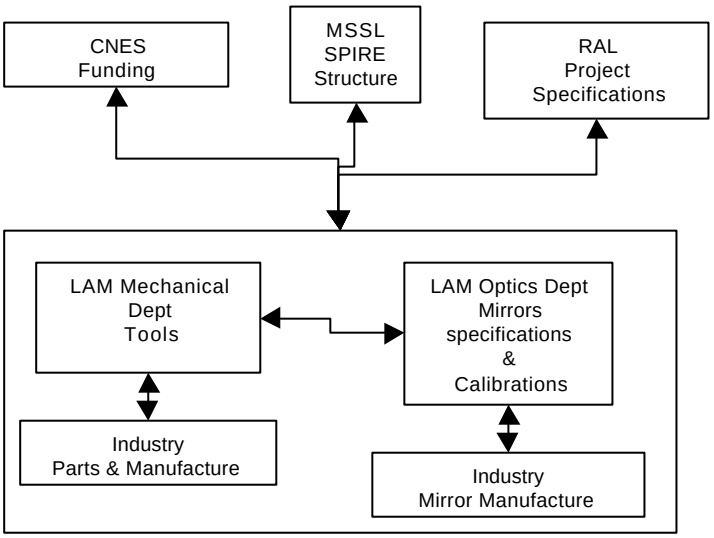
The LAM responsibility covers :

- fulfillment of the performance requirements of the mirrors subsystem, except BSM's mirror.
- fulfillment of the technical requirements at the mirrors level except BSM's mirror.
- fulfillment of the interface requirements mirrors – structure except BSM's.
- development, manufacture and qualification / acceptance of the mirrors except BSM's.
- delivery of the mirrors models and their associated alignment tools except BSM's and documentation to RAL.

LAM is not responsible for

- the performance requirements for the mirrors subsystem. This is a SPIRE system team responsibility.
- the BSM's mirrors.

MSSL is responsible for the SPIRE structure inside which the SMECm is integrated.



4.1.3. Calendar constraints

The main SPIRE milestones are (RD2):

Milestone	Date
PDR	Jun 2000
Interface and system review	27 Nov 2000
CNES End of phase A review	9 Jan 2001
Structure, Optics, Cooler detailed design review	Mar 2001
LAM delivers the CQM mirrors to RAL	1 Jul 2002
CQM Interim review	15 Apr 2003
CQM CDR	20 Jun 2003
RAL delivers SPIRE CQM to ESA	11 Aug 2003
LAM delivers the PFM mirrors to RAL	1 Aug 2003
ESA returns the SPIRE CQM to RAL	29 Mar 2004
RAL delivers SPIRE PFM to ESA	Jul 2004
LAM delivers the FS mirrors to RAL (only if modifications following CQM alignment)	10 Nov 2004
RAL delivers SPIRE FS to ESA	Jul 2005
HERSCHEL launch	2007

4.2. Risk analysis

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

Due to the fact that an ITT for the mirrors manufacture might have to be issued, the risk is that the administrative delays plus the manufacturing and control duration induce a delay in the delivery date.
As the optics DDR is in Mar 2001 and the CQM mirrors delivery date is in July 2002, the risk is minimal.

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

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

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 HERSCHEL 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 the CQM set and the PFM set and for the modified mirrors if any (PFM and FS).

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.
See AD5 for the specifications of the alignment tools.

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	A plate containing central and peripheral sources. Each source	Used at room temperature only.

	detectors.	is individually lightable.	
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
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	

6. Development calendar

Hardware	Operations	Note	Dates
Alignment tools	Design, manufacture, controls	LAM	Mar 2001 - Jan 2002
CQM and PFM mirrors	ITT & manufacture & controls	Administration & industry	Mar 2001 – Dec 2002
CQM and PFM mirrors	Bake out and thermal tests	LAM	Jan - Mar 2002
CQM mirrors	Controls and doc	LAM	Apr - May 2002
PFM mirrors	Controls	LAM	May - Jun 2002
CQM mirrors & alignment tools	Delivery to RAL	LAM	Jul 2002
SPIRE CQM Alignment	At RAL	LAM + RAL	Jul-Sep 2002 (realistically Sep 2002 due to summer holidays)
Mirrors modification for PFM and FS	Manufacture & controls	LAM + industry	Sep 2002 - Apr 2003
PFM mirrors	Delivery to RAL	LAM	Aug 2003 (realistically Sep 2003 due to summer holidays)
SPIRE PFM Alignment	At RAL	LAM + RAL	Sep - Oct 2003
FS mirrors (if modifs)	Delivery to RAL	LAM	Nov 2004
SPIRE FS Alignment	At RAL	LAM + RAL	Nov - Dec 2004

See file LAM_SPIRE_Mirrors_Devplan_20010330.mpp for details.

7. Description of deliverables

7.1. Mirrors Deliverable models

Model	Flight representativity	Difference with flight	Deliverables	Delivered to
CQM	100%	None	1 set	RAL
PFM	100%	None	1 set	RAL

Nota : Some mirrors could have to be modified according to the results of the CQM alignement campaign. In that event, these mirrors will be manufactured as PFM's and FS's.

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.