

L.A.M.	HERSCHEL SPIRE	Spectrometer Mirror Mechanism subsystem specifications Reference : LAM.PJT.SPI.NOT.200002 Ind 8	Page : 1 / 19 12 Oct 2001
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HERSCHEL - SPIRE

Spectrometer Mirror Mechanism subsystem specifications

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Document change record

Date	Indice	Remarks
11 Feb 2000	1	Creation of the document
14 Apr 2000	2	Update of performances specifications following an internal meeting at LAM with JP Baluteau.
25 Apr 2000	3	Design description added.
9 May 2000	4	Adjustements after LAM reading Mission profile added Product tree added
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20 Dec 2000	6	Filtering bandwidth added to the P10 specification Number of cycles for the on ground lifetests added Specifications for SMECm and MCU separated
12 Apr 2001	7	FIRST replaced by HERSCHEL Reference of documents updated Adjustments on the on-ground lifetime Shocks suppressed.
12 Oct 2001	8	Most of TBD's suppressed

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Glossary

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

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1. Scope of the document

This specification defines the requirements applied to the performances, the design and the qualification of the SPIRE spectrometer mirror mechanism. It is applicable to the PFM and the FS.

2. Documents

2.1. Applicable documents

	Title	Author	Reference	Date
AD1	Instrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Issue 1.0	23 Nov 2000
AD2	ICD Structure - Mechanical I/F	B.Winter	SPIRE/MSS/PRJ/000617 Issue 1.0	Apr 2001
AD3	MCU / DPU Command list ICD	D.Ferrand & M.Jevaud	LAM/ELE/SPI/011011 Issue 1.0	20 Sep 2001
AD4	Optics / SMEC Interface		SPIRE 1.2/1.5.2	
AD5	SMEC / DRCU Interface		SPIRE 1.5.2/2.2	
AD6	Systems budgets	C.Cunningham	SPIRE/ATC/DOC/000450 1.0	11 Jun 2000
AD7	Optical error budgets	K.Dohlen	LOOM.KD.SPIRE.2000.002-DRAFT	22 May 2000
AD8	FIRST/Planck IID-A	ESA	PT-IID-A-04624 Iss1 Rev0	1 Sep 2000
AD9	SPIRE Product assurance plan	RAL	SPIRE-RAL-PRJ-000017 Issue 1.0	11 Apr 2001
AD10	MCU Flight model Inter connections list	P.Levacher & B.Travers	LAM/ELE/FTS/NTT/010314 Issue 1.0	20 Sep 2001
AD11	Qualification Random vibrations Specification 01 October 2001	B.Winter	Noref Issue 8	1 Oct 2001

2.2. Reference documents

	Title	Author	Reference	Date
RD1	MCU Design description	D.Ferrand, M.Jevaud, P.Levacher	LAM.ELE.SPI.NOT.000619 Iss 2 Rev 0	12 Apr 2001
RD2	SMECm design description	D.Pouliquen	LAM.PJT.SPI.NOT.200008 Ind 4	16 Oct 2001
RD3	Product Breakdown Structure	P.Dargent	SPI.PFM.00.PB.01.A	3 Oct 2001

3. The SMEC Subsystem

3.1. General overview

The Spectrometer mirror MECHANism subsystem (SMEC) is a major part of the SPIRE Spectrometer. It is in charge of the movement of the FTS corner cubes mirrors inside the SPIRE spectrometer.

The critical performances of SMEC [AD1] are the mirror velocity and its stability, the mirror movement around its travel axis and the required accuracy of the mirror position measurements.

3.2. Description of the spectrometer mirror mechanism subsystem

The SMEC is made of 2 main parts :

- **The cryogenic mechanism** (SMECm)
- **The Mechanisms Control Unit** (MCU)

See RD1 and RD2 for details

3.3. Mission profile

Here are the successive phases of the subsystem life from the end of manufacturing to the end of life.

These are for information only. Discrepancies with actual AIV and operation plan are allowed.

Durations are TBC.

3.3.1. SMECm mission profile

Operation	Where	Duration	Note
Bakeout	LAM	1 week	
Control and integration	LAM	TBD	
Warm Vibrations	LAM	1 week	Including correlated controls
Transport	From LAM to RAL (TBC)	2 days	
Cold vibrations	RAL (TBC)	3 weeks	Including correlated controls There will be no 4K vibrations test facility at LAM.
4K control test	RAL (TBC)	1 week	Including correlated controls There will be no 4K test facility at LAM.
Transport	Back to LAM	2 days	
Thermal cycles	LAM	4 weeks	Including correlated controls
Characterisation	LAM	4 weeks	
Transport	From LAM to RAL	2 days	
Integration in the FPU	RAL	1 week	Including correlated controls
FPU Bakeout	RAL	1 week	
FPU 300K vibrations	RAL	1 week	
FPU Transport	From RAL to ?	TBD	
FPU Cold vibrations	?	3+ weeks	Including correlated controls
FPU Transport	Back to RAL	TBD	
FPU Thermal cycles	RAL	TBD	Including correlated controls
FPU Transport	From RAL to ESA	TBD	
SPIRE integration in HERSCHEL	ESA	TBD	Including correlated controls
Satellite tests	ESA	TBD	Including correlated controls

Lock of launch latch	ESA	TBD	Including correlated controls
Storage	ESA	2 years (TBC)	
Launch	CNES Kourou	TBD	
Power on	Orbit		Including correlated controls
Unlock of launch latch	Orbit	1/2 day	Including correlated controls
Beginning of operation	Orbit	TBD	Health assesement of the subsystem
Operations	Orbit	4.25 years	The SMECM will not be operated along the complete 4.25 years of HERSCHEL on orbit but approximately 8.5 non contiguous months. The subsystem will be stored (power off) during TBD months and powered on but non operating during TBD months.
End of operations	Orbit	TBD	

3.3.2. MCU Mission profile

Operation	Where	Duration	Note
Bakeout	LAM	1 week	
Control and integration	LAM	TBD	
Warm Vibrations	LAM	1 week	Including correlated controls
Transport	Form LAM to CEA	2 days	
Integration in the DRCU	CEA	1 week	Including correlated controls
DRCU transport	From CEA to INTESPACE	TBD	
DRCU Warm vibrations	INTESPACE (TBC)	1 week	Including correlated controls
DRCU Thermal cycles	INTESPACE (TBC)	TBD	Including correlated controls
DRCU EMI EMC	INTESPACE (TBC)	TBD	Including correlated controls
DRCU transport	Back to CEA	TBD	
DRCU transport	From CEA to RAL	TBD	
SPIRE Calibrations	RAL	TBD	
SPIRE Transport	From RAL to ESA	TBD	
SPIRE integration in HERSCHEL	ESA	TBD	Including correlated controls
Satellite tests	ESA	TBD	Including correlated controls
Lock of SMECM and BSMm launch latches	ESA	TBD	Including correlated controls
Storage	ESA	2 years (TBC)	
Launch	CNES Kourou	TBD	
Power on	Orbit		Including correlated controls
Unlock of SMECM and BSMm launch latches	Orbit	1/2 day	Including correlated controls
Beginning of operation	Orbit	TBD	Health assesement of the subsystem

Operations	Orbit	4.25 years	The MCU will not operate during the complete 4.25 years of HERSCHEL on orbit but approximately 1.4 year (non contiguous).
End of operations	Orbit	TBD	

3.4. Product trees

SMECM : Proto Flight Model (extracted from RD3)

- 10 : Base structure
- 20 : Linear guidance means
 - 21 : Rocking frames
 - 22 : Intermediate frames
 - 23 : Flex-pivots
 - 24 : Synchronization
- 30 : Carriage
- 40 : Mirrors
- 50 : Actuator
 - 51 : Stator
 - 52 : Coils
- 60 : Optical position Sensor
 - 61 : Sensor head
 - 62 : Sensor rule
- 70 : L.V.D.T. position sensors
 - 71 : Coils
 - 72 : Core
- 80 : Launch Latch
 - 81 : Coil
 - 82 : Core
 - 84 : Pin
 - 85 : Switch
- 90 : Harness

4. SMEC Performances Requirements

#	Requirement	IRD [AD1]	Note
SMEC_P1	Scientific Travel = -3.2 / +3.2 mm	SMEC-R01	w.r.t. ZPD position goal : -3.2 to +32 mm
SMEC_P2	Minimum movement sampling interval = 5 μ	SMEC-R02	
SMEC_P3	Sampling interval = 5 to 25 μ	SMEC-R03	2 to 26 μ with 2 μ steps 13 values selectable in the range.
SMEC_P4	Scan length = Start and stop anywhere in the travel range	SMEC-R04	
SMEC_P5	Deadtime = Less than 10% of the useful time	SMEC-R05	Allocation of the 10% will be made by technical team
SMEC_P6	Velocity range = 0.2 to 1 mm/s	SMEC-R06 & 07	any value selectable in the range 0 to 5 mm/s with a 1 μ /s resolution
SMEC_P7	Velocity stability = 10 μ /s RMS in the velocity range, filtering bandwidth = 0.03 to 25Hz	SMEC-R08	
SMEC_P8	Velocity stability duration = 24 consecutive hours	SMEC-R08	
SMEC_P9	Mirrors position measurement range = -3.2 / +3.2 mm		Goal : -3.2 to 32 mm (see SMEC-P1)
SMEC_P10	Mirrors position measurement accuracy = 0.1 μ in the +/- 3.2 mm travel range, +/- 0.3 μ elsewhere, filtering bandwidth = 0.03 to 25Hz	SMEC-R09	The position is measured relatively to fiducial mark position

5. SMECm Requirements

5.1. Technical requirements

#	Requirement	Ref	Note
SMECm_Tm1	Axis definition = X is the direction of the travel and of the launch direction Y is perpendicular to the interface SMECm fixation plane Z is the third direction	AD2	The XZ plane is the interface plane between the structure and SMECm
SMECm_Tm2	SMECm Alignment tolerances = <math><1^\circ</math> (TBC) all directions w.r.t. optical path	AD7	
SMECm_Tm3	Dimensions = 140 mm x 140 mm x 165 mm	AD2	Plus a 24 mm deep pocket under the XZ plane
SMECm_Tm4	Center of gravity = $X_m = -7,47\text{mm}$, $Y_m = +1\text{mm}$, $Z_m = +0,54\text{ mm}$		
SMECm_Tm5	Mass = 1650 g excluding margins, mirrors, harness	AD6	The mass budget is 1300 g for SMECm excluding margins, mirrors.
SMECm_Tm6	Inertia = TBD		
SMECm_Tm7	Emitted vibrations = TBD		
SMECm_Tm8	Power consumption = $\leq 2.4\text{ mW}$	AD6	Required mean power consumption over the mission.
SMECm_Tm9	EMC = TBD		
SMECm_Tm10	Fiducial mark position = inside the +/- 0.32 mm subtravel		
SMECm_Tm11	Fiducial mark position accuracy = +/- 50 μ w.r.t. ZPD theoretical position, goal +/- 25 μ		
SMECm_Tm12	Operational position = SMECm must be in the specs only in 0g conditions or simulated 0g. with the travel axis within +/- 8 degrees from the horizontal plane.		Actuator power limits the inclination from horizontal.
SMECm_Tm13	Stray light = Must be as IR light tight as possible		
SMECm_Tm14	Number of thermometers = 2 Nominal and one redundant	AD1	Location to be agreed with system team.
SMECm_Tm15	Movement = No friction allowed, no shocks allowed		For optimum movement control
SMECm_Tm16	Resonance frequency = None in the 0.03 – 25 Hz that cannot be notched by the control		
SMECm_Tm17	Corner Cubes decenter <math>< 0.5\text{ mm}</math> Corner cubes tilts <math>< 10\text{ arcmin}</math>		

5.2. Operational requirements

5.2.1. Reliability

Cold redundant hardware shall be provided wherever practicable within the SMECm design. Every electrical components is duplicated. Two completely independant electric systems are implemented, one redundant, one nominal, without electrical crossing.

The mechanical system cannot be duplicated.

5.2.2. Lifetime

#	Requirement	Ref	Note
SMECm_OL1	Ground Storage lifetime = 2 years cumulated time		A guess
SMECm_OL2	Ground Integrated lifetime = 4 years cumulated time		About
SMECm_OL3	Ground operational lifetime = 3 months cumulated time		1 month for subsystem acceptance 1 month for SPIRE acceptance 1 month for HERSCHEL acceptance Under 1g conditions The distribution will be : - 1 month : SMECm travel = -0.32 to +0.32 mm => 1.8^{E6} cycles - 1 month : SMECm travel = -3.2 to +3.2 mm => 1.8^{E5} cycles - 1 month : SMECm travel = -3.2 to +32 (goal) mm => 3.7^{E4} cycles Number of cycles calculated assuming a speed of 0.5 mm/s plus 10% deadtime (*)
SMECm_OL4	On orbit operational lifetime = 8.5 months cumulated time		Operating during 1/6 of the mission duration (4.25 years). 1/6 comes from: - 3 experiments on herschel (PACS, HIFI and SPIRE) - 2 sub instruments on SPIRE : the photometer and the spectrometer. Distribution: - 85 days : SMECm travel = -0.32 to +0.32 mm => 5.2^{E6} cycles - 85 days : SMECm travel = -3.2 to +3.2 mm => 5.2^{E5} cycles - 85 days : SMECm travel = -3.2 to +32(goal) mm => 1^{E5} cycles Number of cycles calculated assuming a speed of 0.5 mm/s plus 10% deadtime (**)
SMECm_OL5	On orbit non operational lifetime = 3.5 years cumulated time		

(*) The qualification factor for on ground operational lifetime is 4

(**)As the number of on orbit cycles is always greater than $1E5$, the qualification factor to be applied during lifetime tests is 1.25 (see AD8)

5.2.3. Operating modes

The SMECm has only one operating mode which is moving along the trajectory and back.

5.2.4. Telemetry

NA

5.2.5. Telecommands

NA

5.3. Interface requirements

The interfaces are defined in the relevant applicable documents.

Interface	With	Document
Mechanical	SPIRE Structure	[AD2]
Thermal	SPIRE Structure	[AD2]
Optics	SPIRE Optics	[AD4] SPIRE 1.2 / 1.5.2
Electronic	MCU	[AD10]

5.4. Design and manufacture requirements

5.4.1. Design requirements

LAM design procedures are adopted where applicable

5.4.2. Manufacture requirements

These are requirements on accessibility, dismountability, testability and manufacturing processes.

As a general rule, the manufacture and cleaning processes will be compatible with class 100 specifications and with the SPIRE PA plan (AD9)

Materials and processes will be declared in the relevant Declared Materials List.

5.5. Logistic requirements

The subsystem will be transported to and from RAL and CEA.

The containers will have to guarantee that:

- no shocks are greater than those defined for the launch.
- no pollution sneaks to the subsystem

5.6. Environment requirements

These requirements describe the environment in which the subsystem will live.

5.6.1. Natural environment

This is the description of the natural environment around the subsystem.

#	Requirement	Ref	Note
SMECm_EN1	Vacuum = Less than 10 ⁻⁴ Pa		During tests, launch and in operation
SMECm_EN2	<ul style="list-style-type: none"> • Operating temperature during system qualif and on orbit = 4K • during subsystem qualification = 300K and 20K, (4K for specific tests) • during SPIRE bake out = +80°C (353K) 		Components at 100K inside the preamplifier
SMECm_EN3	Storage and handling temperature = -20 to +30 °C Humidity = Less than 45% Cleanliness = Class 100		Under atmospheric pressure, on ground In clean room In clean room
SMECm_EN4	Radiations = Less than 3.5 kRAD	AD8	On orbit

5.6.2. Operating environment

This is the description of the environment imposed by the location of the subsystem in SPIRE and in HERSCHEL.

#	Requirement	Ref	Note
SMECm_ON1	Vibrations <ul style="list-style-type: none"> quasi static level : 25 g along X (launch direction), 14 g along Y and 14 g along Z sine vibrations level : 40 g along X, 25g along Y and 25 along Z random vibrations level = 10.2 g RMS along X (launch direction), 11.3g RMS along Y and 9.9 gRMS along Z 	AD11 AD2	At 4K. Same levels at 300K for preliminary tests.
SMECm_ON2	Shocks = NA		
SMECm_ON3	Microvibrations = TBD		On orbit
SMECm_ON4	Acoustic = NA	AD8	launched under vacuum
SMECm_ON5	Electrostatic = TBD		
SMECm_ON6	EMC = TBD		

5.7. Verification requirements

The verification requirements is in AD1.

6. MCU Requirements

6.1. Technical requirements

#	Requirement	Ref	Note
MCU_Tm1	Axis definition = TBD		
MCU_Tm2	Dimensions = TBD		Cards format is eurodouble or a little more (220 x 223 mm ²)
MCU_Tm3	Center of gravity = TBD		Only for the boards
MCU_Tm4	Mass = TBD		Only mass of the boards. Mechanical box in the DRCU mass budget.
MCU_Tm5	Inertia = TBD		Only for the boards
MCU_Tm6	Power consumption = 15.5W mean, 22.5W peak	RD1	
MCU_Tm7	EMC = TBD		

6.2. Operational requirements

6.2.1. Reliability (see AD1)

IRD-REL-03 : Cold redundant hardware shall be provided wherever practicable within the MCU design.

IRD-REL-04 : As far as possible, all control loops shall be implemented through the use of on board software

IRD-REL-05 : It shall be possible to break all control loops implemented in hardware..

6.2.2. Lifetime

Based on AD8

#	Requirement	Ref	Note
MCU_OL1	Ground Storage lifetime = 2 years cumulated time		A guess
MCU_OL2	Ground Integrated lifetime = 4 years cumulated time		About
MCU_OL3	Ground operational lifetime = 1.5 years cumulated time		6 months for subsystem acceptance 6 months for SPIRE acceptance 6 months for HERSCHEL acceptance Under 1g conditions
MCU_OL4	On orbit operational lifetime = 8.5 months cumulated time		Operating during 1/6 of the mission duration (4.25 years)
MCU_OL5	On orbit non operational lifetime = 3.5 years cumulated time		

6.2.3. Operating modes

See RD1 for further explanations.

Mode #	Mode Name	Action	Possible Next Mode	On Command
0	Off	The set of boards is not powered. No function available	On	Power On
1	On	The set of boards (main or redundant) board is powered .	Off	Power Off
1.0	Booting	<ul style="list-style-type: none"> The software is initialised after reset. The software is downloaded from Prom memory to SRam memory 	Downloaded	MAC Reset On
1.1	Downloaded	<ul style="list-style-type: none"> The communication is available. The status of the system is available. Waiting for commands Goes initially to Open loop mode 	Booting	MACReset On 'ResetMAC'
1.1.0	Open Loop	<ul style="list-style-type: none"> Waiting for Advanced Configuration Commands (Control gains,etc ...) Goes initially to open loop standby 	Close Loop	'CloseLoop'
1.1.1	Close Loop	<ul style="list-style-type: none"> nominal control loop mode using a digital PID controller at 300 μs sampling rate Goes initially to Stand By mode 	Open Loop	'OpenLoop'
1.1.1.0	CLoop Stand By	Waiting for motion configuration: (Scan Length, etc..)	Motion init	'Init Motion'
1.1.1.1	CLoop Motion Init	Searching for limits and diagnostics	Ready	End of Motion initialization
1.1.1.2	CLoop Ready	Waiting for motion commands and configuration	Scan	'StartMotion'
1.1.1.3	CLoop Scan	Motion underway: scan for the SMEC, chopping and jiggling for BSM	Ready	End of Motion 'StopMotion' 'ResetMotion'

6.2.4. Telemetry

The telemetry interface link has a rate of 1 Mbits/s, based on 16 bits words. Data may be provided in 32 bits format in two words.

6.2.5. Telecommands

The MCU shall receive a 32 bits word for each command. The 32 bit word shall include (i) 2 or 3 bits for subsystem id (ii) 7/8 bits for command type (e.g. set scan_length), (iii) the rest for the parameter itself. There are 2 registers (for command receipt and command reply) in interface with MCU DSP.

There is a specific broadcast @ a dedicated address.

There are typically three types of commands :

- Set Command : the parameter is put in the DSP memory for immediate or delayed execution
- Get Command : the dedicated parameter in memory can be read by the DPU
- Immediate Command: Reset Command or Start Datation Counter

The detailed commands list is in AD3.

6.3. Interface requirements

The interfaces are defined in the relevant applicable documents.

Interface	With	Document
Mechanical	DRCU	[AD5] SPIRE 1.5.2 / 2.2
Thermal	DRCU	[AD5] SPIRE 1.5.2 / 2.2
Electronics	DRCU	[AD10]
	DPU	[AD10]
	SMECm	[AD10]
	BSMm	[AD10]
TM/TC	DPU	[AD3]

6.4. Design and manufacture requirements

6.4.1. Design requirements

All electronics will be mounted on double eurocards.

6.4.2. Design rules

TBD

6.4.3. Manufacture requirements

These are requirements on accessibility, dismountability, testability and manufacturing processes.

As a general rule, the manufacture and cleaning processes will be compatible with the SPIRE PA plan (AD9)

6.5. Logistic requirements

The subsystem will be transported to and from CEA-SAp under LAM responsibility.

The containers will have to guarantee that:

- no shocks are greater than those defined for the launch.
- no pollution sneaks to the subsystem

6.6. Environment requirements

These requirements describe the environment in which the subsystem will live.

6.6.1. Natural environment

This is the description of the natural environment around the subsystem.

#	Requirement	Ref	Note
MCU_EN1	Vacuum = Less than 10 ⁻⁴ Pa		During tests, launch and in operation
MCU_EN2	Operating temperature = -55 to +55 °C	AD8	
MCU_EN3	Storage and handling temperature = -20 to +30°C Humidity = Less than 45% Cleanliness = Class 10 000		Overall, on ground In clean room In clean room
MCU_EN4	Radiations = Less than 12 kRAD	AD8	On orbit

6.6.2. Operating environment

This is the description of the environment imposed by the location of the subsystem in SPIRE and in HERSCHEL.

#	Requirement	Ref	Note
MCU_ON1	Vibrations = TBD		At 300K, atmospheric pressure
MCU_ON2	Shocks = TBD		At 300K, atmospheric pressure
MCU_ON3	Acoustic = TBD		At 300K, atmospheric pressure
MCU_ON4	Electrostatic = TBD		
MCU_ON5	EMC = TBD		

6.7. Verification requirements

The verification requirements is in AD1.