HERSCHEL - SPIRE

Spectrometer Mirror Mechanism subsystem development plan

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3 April 2001	8	FIRST changed with HERSCHEL Dates revised
10 April 2001	9	More precisions on STQM Inconsistencies corrected on the LVDT topic
16 Oct 2001	10	Milestone dates corrected

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

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1. Scope of the document

This document describes the development plan of the HERSCHEL/SPIRE Spectrometer mirror mechanism subsystem.
The development plan is based on the applicable and reference documents listed 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 Spectrometer Mirror Mechanism Subsystem Specification	D.Pouliquen	LAS.PJT.SPI.SPT.200002 Ind 8	12 Oct 2001
AD2	SPIRE Development plan	K.King	SPIRE-RAL-PRJ-000035 1.1D	12 Apr 2001
AD3	Guide pour les projets scientifiques	CNES	DTS/AQ/QP 98-083	June 1998
AD4	SPIRE BSM Development plan	C.Cunningham	?	13 June 2000
AD5	SPIRE product assurance plan	G.Douglas	SPIRE-RAL-PRJ-000017 Iss 1.1	11 Apr 2001

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 2	12 Apr 2001
RD3	SMECm design description	D.Pouliquen	LAM.PJT.SPI.NOT.200008 Ind 4	16 Oct 2001
RD4	MCU Design description	D.Ferrand	LAM.ELE.SPI.000619 Iss 3	20 Sep 2001
RD5	SPIRE Mirrors and alignment tools development plan	D.Pouliquen	LAM.PJT.SPI.NOT.200006 Ind 3	30 Mar 2001

3. Description of the spectrometer mirror mechanism subsystem

The function of the Spectrometer mirror MEChanism subsystem (SMEC) is to move the SPIRE FTS corner cubes along a linear trajectory, at a given speed within given tolerances.
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.

The SMEC is made of 2 main parts :

- **The cryogenic mechanism** (SMECm), which includes the mechanical part of the mechanism, the actuator, the position sensor and its preamplifier, the ZPD position sensors, the launch latches, the temperature sensors, the cryoharness. The SMECm is integrated in the SPIRE FPU Structure.

- **The Mechanisms Control Unit** (MCU) , which includes the MAC board for the control of the mechanisms and the interface FPGAs the analog boards for the SMECm and the BSMm and the backplane board. The MCU is integrated in the SPIRE DRCU Unit.

See RD3 and RD4 for details

4. Constraints

4.1. Development constraints

4.1.1. Technical constraints

Note : the figures hereafter are for information only. The relevant figures are in [RD3] and [RD4]

The main performances specifications are:

- The mirror travel is +/-3.2 mm, -3.2/35.2 mm is a goal.
- The mirror speed is nominally 0.5 mm/s with a 0.01mm/s rms stability filtered with the detector filter on the travel over a 24 hours period. The mirror velocity shall be within 10 µ/s r.m.s. within a band width of 0.03 to 25 Hz over the ±3.2 mm range and within TBD outside this range.
- The speed value should be selectable from 0.2 to 1mm/s, up to 2mm/s is desirable.
- The mirrors tilt along travel axis < 10 arcminutes and decenter < 0.5 mm
- The measurement specification of the accuracy of the mirror position is 0.1µm over a 6.4mm travel, 0.3µm elsewhere.
- The measurement resolution of the mirror position is 0.5µm over the complete travel.

The main technical characteristics are :

- SPIRE lifetime on orbit = 4.25 years
- SPIRE spectrometer lifetime on orbit = 9 months
- SMECm operating temperature = 4K
- SMECm power = less than 2.4 mW, mean consumption along the whole mission
- SMECm mass = 1.65 kg including preamplifier and excluding 10% margin, mirrors and harness.
- SMECm level of radiations = 3.5 krad
- SMECm quasi static level : 25 g along X (launch direction), 14 g along Y and 14 g along Z
- SMECm sine vibrations level : 40 g along X, 25g along Y and 25 along Z
- SMECm random vibrations level = 10.2 g RMS along X (launch direction), 11.3g RMS along Y and 9.9 gRMS along Z
- SMECm shock level = TBD at 4K
- SMECm cleanliness = class 1000
- MCU level of radiations = 12 krad
- MCU vibrations levels = TBD
- Format of the MCU electronic cards = double Europe
- MCU Cleanliness = TBD

During its lifetime,

The SMECm is :

- transported to RAL under LAM responsibility.
- integrated at RAL in the SPIRE FPU Structure under joint RAL, MSSL and LAM responsibility.

The SPIRE-FPU is to undergo the project qualification/acceptance program under RAL responsibility.

The MCU is:

- designed under LAM responsibility.
- manufactured under LAM responsibility, part at LAM, part in the industry.
- qualified / accepted under LAM responsibility, part at LAM, part at CEA-SAp. The qualification / acceptance program includes thermal cycling, warm vibrations, EMI-EMC, tests with the SMECm, the BSMm and their associated boards.
- transported to CEA-Sap under LAM responsibility.
- integrated at CEA-Sap in the SPIRE DRCU under CEA-Sap responsibility.

The SPIRE-DRCU is to undergo the project qualification/acceptance program under CEA-Sap responsibility.

The SPIRE DRCU 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 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 SPIRE PFM failure.

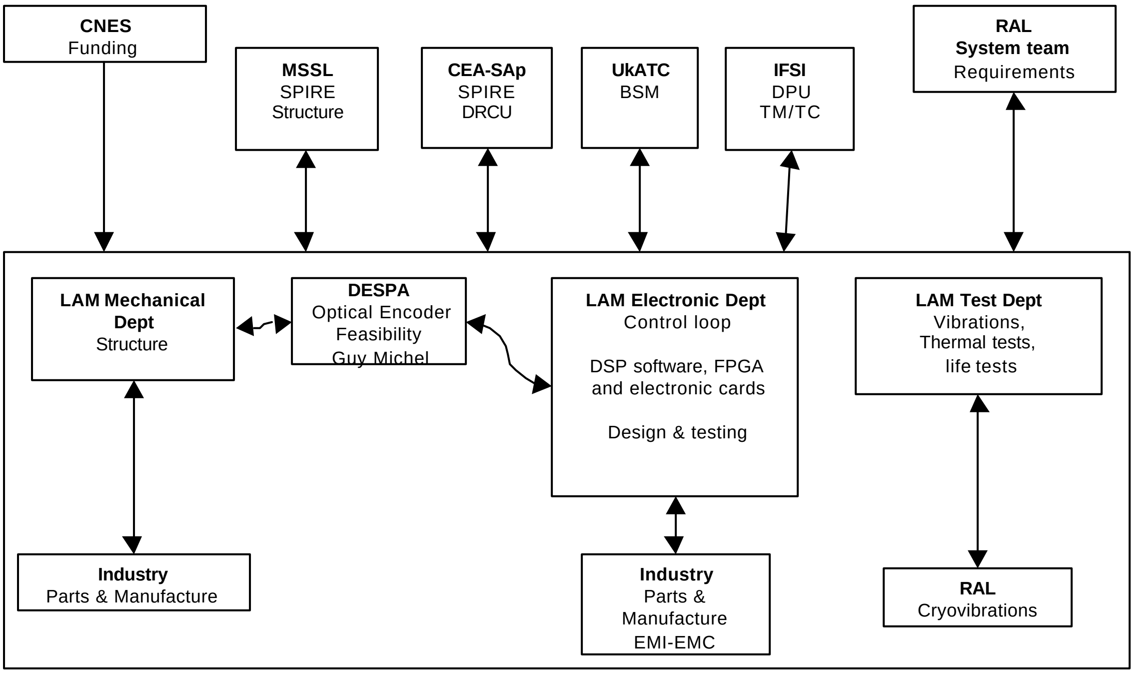
4.1.2. Organisation

LAM is responsible for providing the SPIRE project with the SMECm and the MCU which comprises the MAC board, the SMEC board, the BSM board and the backplane board.

The LAM responsibility covers :
- fulfillment of the performance requirements of the SMEC subsystem (SMECm+MAC+SMEC analog board).
- fulfillment of the technical requirements at the MCU level fulfillment of the technical requirements at the SMECm level.
- fulfillment of the interface requirements MCU – DPU, MCU – DRCU, MCU – BSMm and SMECm – Structure and optics.
- development, manufacture and qualification / acceptance of the SMECm and MCU.
- implementation of the UKATC electronic principles on the BSMm analog board in the MCU.
- implementation of the UKATC BSMm control algorithms.
- delivery of the SMECm and MCU models, their associated simulators, tools and documentation to RAL.

LAM is not responsible for
- the performance requirements for the SMEC subsystem. This is a SPIRE system team responsibility.
- the temperature sensor choice. This is a SPIRE system team responsibility.
- the temperature sensors measurement. This is a CEA-Sap responsibility.
- the principles of the BSMm analog board. This is a UKATC responsibility.
- the BSMm development, manufacturing and qualification / acceptance. This is a UKATC responsiblity.
- the BSM end to end performances. This is a UKATC responsibility.
- the BSMm control algorithms. This is a UKATC responsibility.

Under LAM responsibility, DESPA is responsible for the optical encoder feasibility, up to a PFM-like prototype.
LAM is in charge of the qualification processes, manufacture and test of the optical encoder models and their integration in the SMEC.
CEA-Sap is responsible for the DRCU mechanical box inside which the MCU is integrated.
MSSL is responsible for the SPIRE structure inside which the SMECm is integrated.
IFSI is responsible of the DPU with which the MCU on board software will communicate.



4.1.3. Calendar constraints

The main SPIRE milestones are [RD2]:

Milestone	Date
PDR	Jun 2000
UKATC delivers BSM Simulink model to LAM	
Interface and system review	27 Nov 2000
CNES End of phase A review	9 Jan -15 Feb 2001
DDR - BSM & SMEC	24 Apr 2001
UKATC delivers analog board detailed design to LAM	Jan 2001
LAM delivers the SMECm Simulator to CEA-SAp	Feb 2001
UKATC delivers BSM DM to LAM	Mar 2001
ESA delivers QM electronic components	Mar 2002
LAM delivers the SMECm STM to RAL	Aug 2002
LAM delivers the MCU-QM1 to CEA-SAp	Sep 2002
LAM delivers the MCU-QM2 to CEA-SAp	Nov 2002
UKATC delivers BSMm-CQM to LAM	Jul 2002
ESA delivers last PFM electronic components	Oct 2002
STM interim review (after 300K vibrations)	Oct 2002
LAM delivers SMECm and BSMm CQM to RAL	Jan 2003
WE CDR	Jul 2003
RAL delivers SPIRE CQM to ESA	Apr 2003
LAM delivers the MCU-PFM to CEA-SAp	Aug 2003
UKATC delivers BSM-PFM to LAM	Jul 2003
LAM delivers SMECm and BSMm PFM to RAL	Oct 2003
UKATC delivers BSMm-FS to LAM	Jan 2004
RAL delivers SPIRE PFM to ESA	Jun 2004
LAM delivers SMECm and BSMm FS to RAL	Jan 2005
RAL delivers SPIRE FS to ESA	Nov 2005
HERSCHEL launch	2007

4.2. Risk analysis

In this document, the risk analysis concerns only the risks for this development plan not to be completed on time or not to ne completed at all.

Risk	Type	Impact	Preventive action	Note
HERSCHEL Microvibrations level and spectrum	Technical	Problem meeting performance requirements	Know the level and spectrum ASAP	This level has a direct impact on the speed stability. Must be included during design Should include the transfer function of the SPIRE structure.
Optical encoder = source of straylight	Technical	Problem for the FTS to meet the performance requirements	None (from LAM point of view)	Baffles will have to be added around the optical encoder => increase of mass, how to prove the efficiency before the CQM?
Optical encoder qualification failure	Technical	Delay in design Problem meeting performance requirements	None	If it turns out that it is not possible to qualify the optical encoder for the flight, a new position sensor will have to be found and a delay in the delivery dates will occur. This delay is due to the fact that LAM cannot provide the manpower and the budget that would be necessary to conduct the development of a baseline solution along with a back-up solution. As the optical encoder is the only one that meets the performance specifications, inevitably, the new one will not meet all of them and a trade-off will have to be made at system level. A candidate is an LVDT based solution.
The flex pivots do not bear the launch conditions	Technical	Feasability		To be tested with the STM. In case of problem on the STM, an alternate STM will be provided.
Flex Pivot problems (parasitic resonances, life tests)	Technical	Delay, Power consumption increase	Provision for different types of pivots	Replace flex pivots by more rigid pivots. => increase in power consumption + redesign the actuator (peak current limitation)
Administrative delays	Planning	Delivery dates	None	These delays are completly independant of LAM goodwill. Concerns mainly the MCU

4.3. Redundancy

The redundancy philosophy adopted for SPIRE is to duplicate every part that would be a single point failure.
The MCU incorporates two complete sets of MAC cards with identical functions and the SMEC and BSM analog boards are fully redundant.
The SMECm incorporates two optical encoders components in one optical system and two actuator coils.
The SMECm temperature sensors are duplicated.
The SMECm is equipped with 2 redundant LVDT for ZPD measurement.
The redundancy philosophy is to build two functionnally independent MCU's, plugged to two electrically independent ciircuits on the cryogenic mechanisms and to two independent power supplies. No crossswitching of components is implemented at SMEC level. The switch from one assembly to the other is made at the DRCU level.
The redundancy for the SMECm launch latch is under discussion / progress.

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 mechanical design is based on the GSFC design. The first resonance frequencies and the mass are verified by tests.
An actuator type is chosen.
The optical encoder is a critical part and a qualification program has to be established. To establish a start point for the qualification program, a series of cryogenic tests is conducted to check the survivability of the encoder and to measure its output signal at cryogenic temperature.
The tests leads to the position sensor preamplifier specifications and the establishment of the list of components to be used for the flight in the optical encoder. These components include optical, electronic and mechanic ones.
The control loop design is verified by simulation and with a DSPACE system associated with mechanical mockups. The speed range and the speed stability are verified. The position accuracy is checked with a reference LASER source. The prototype #1 is equiped with an actuator and the ground version of the SMECm PFM optical encoder and its stiffness is similar to the one expected on SMECm PFM.
The typical tests are defined. The typical tests are to be used through the life of the subsystem to check that it stays within the specifications. The typical tests are to be applied to the mechanism, the preamplifier and the warm electronic.
The interfaces with SPIRE WE are defined during this step.

The preliminary design is presented at the Preliminary Design Review. The PDR freezes the technical specifications and the interfaces.

5.1.2. Procurement of long delay electronic components

Once the preliminary design has been validated by the PDR, the activities for procurement of long delay components is initiated. These are the electronic components to be mounted on the MCU, the SMECm PFM and FS and whose procurement will be made through ESA.
The optical encoder electronic components are procured. Those one cannot find in flight grade are individually tested. The tests are to demonstrate that these components are suitable for the flight. They consist in warm tests for accelerated aging and cold tests. Radiation tests or analysis are conducted.

5.1.3. SMEC and MCU development

The development of the MCU and of the SMECm will follow parallel paths.
Due to planning constraints, the MCU's being delivered to CEA-SAp well in advance w.r.t. to the delivery of the SMECm's to RAL, there will never be a complete deliverable integrated SMEC subsytem at LAM.
The only exception will be the SMECm CQM + MCU QM1. This is needed to discover all possible problems when mating the MCU with the mechanism. The planning does not allow to extend that verification to the SMECm CQM + BSMm CQM.
To circumvent that difficulty, all the deliverable SMECm's will be tested allways with a unique non deliverable MCU model and all the deliverable MCU models will be tested with the SMECm and BSMm simulator..
Thanks to the MCU design solution (DSP based), there will be no analog adjustements to be performed on the various MCU's to match them with the relevant SMECm model. The match will be done through a set of parameters which will be used through the DPU and identified as the CQM parameters, the PFM parameters and the FS parameters.

5.1.3.1. To the SMECm PFM

__**Detailed mechanical design**__
The mechanical design is based on the GSFC prototype design.
The detailed mechanical design encompasses the launch latch design and the flex pivot selection (manufacturer, type)

- Structure : the structure is defined and manufactured at LAM
- Launch latch : A commercial launch latch is bought to be tested at 300K and LN2 at LAM. A study is subcontracted in the industry to check the performances and reduce the peak current. The magnets are then purchased and the windings manufactured in the industry. It will be mounted in the SMECm-STM. As the SMECm-STM will have some kind of EGSE, it will be possible to activate the launch latch for real integrated tests.
- Flex pivots : A study is conducted to prove that flex pivots are compatible with the structure design and the launch vibrations conditions. Modified pivots could have to be used. They will be purchased after selection of a manufacturer.
- Sensor position : a development model has been developed by DESPA. Commercial components have been purchased to build a prototype of the PFM (dimensions, redundancy, power, mass). This prototype is being prepared for cryo tests. As soon as the tests have been successfully passed, three models are built at LAM to be integrated in the SMECm-DM, the SMECm-CQM and the SMECm-STQM.
- ZPD sensors : two redundant LVDT's are used for this function.
- Actuator : The SMECm prototypes have been fitted with a commercial actuator. Its power consumption is within specifications but the peak current is too high and its dimensions are slightly too large. The flight actuator is a modified version. A study is subcontracted in the industry. As for the launch latches, magnets are purchased in the industry and the windings realised in the industry too.
- Thermal sensors : the sensors type is defined by the system team.

Launch vibrations (STM deliverable then back to LAM and STQM, non deliverable)

Once the mechanical design is finished, a SMECm STM is built. It will be used to verify that the design can survive the launch. This STM will have no active components. These components will be replaced with equivalent mass dummies. But, as the SPIRE STM (subsystems STM's mounted in the CQM structure) will be used to check the SPIRE FPU thermal modelisation, heaters will be mounted to be able to simulate the power dissipations.

The vibrations will be made at 300K at the LAM vibration facility, up to calculated qualification levels provided by MSSL.

At this point, design modifications are envisioned.

After that, cryogenic flex pivots will be mounted and a 300K vibration test at low level (signature test) will be performed to check that the change of pivots has not affected the mechanical behaviour of the mechanism.

A heater for thermal dissipation simulation will be mounted.

Then the STM will be delivered to RAL to be integrated into the CQM SPIRE structure.

In case of delays in this development, to avoid delaying the SPIRE STM tests, the SMECm STM pivots could be replaced with Teflon rods of apporximately the same behaviour. This configuration is tested at 300K, warm vibrations prior to delivery to RAL.

Once integrated, the SPIRE structure will be warm vibrated, then cold vibrated and thermally tested. During these vibrations, the structure / SMECm interface levels will be measured.

As soon as the results of these tests are available, the SMECm STM is dismounted from the SPIRE structure and shipped back to LAM.

At LAM, the mass dummies will be replaced with non redundant active components (one actuator, one set of position sensors) to become a « STQM » i.e. a full qualification model. This model will be warm vibrated at the LAM vibration facility at the levels measured during the 300K vibrations of the SPIRE structure and then cryovibrated at RAL at the levels measured during the cryovibrations of the SPIRE structure. The STQM is not a deliverable model.

During this development, vibrations include sine, random and shocks.

Then the design will be declared good for launch.

Lifetests (DM, non deliverable)

As soon as the first 300K vibrations have been performed on the SMECm STM and design modification identified and done, a SMECm DM will be built. This model will be used to demonstrate that the components are able to withstand the lifetime on orbit. For that the DM will be a mechanical copy of the STM and equipped with cryogenic flex pivots, an actuator, the position sensors and temperature sensors. It will be driven by MCU MI3 (see MCU paragraph). It will sustain the lifetests, i.e. about 2.6 months at various travel values with the max 5 mm/s speed, at 20K.

It will not be subjected to vibrations.

Microvibrations impact will be evaluated on this model, the ones emitted by the mechanism and those to which the model is susceptible.(level and spectrum)
Then the design will be declared good for the on orbit life.

The SMECm CQM (deliverable)
The SMECm CQM is a cryogenic model which has no vibration capability (due to planning constraints.).
It is equipped with functional components but with no redundancy. As for the DM, it will be built after the first SMECm STM 300K warm vibrations to be as near as possible to the final mechanical design. It will incorporate a launch latch for functional tests and transportation purpose.
It will be full functional, i.e. fully compliant with the performance, electrical and thermal requirements and with the mechanical interfaces. Microvibration behaviour will be checked.
It will be tested at LAM with MCU MI4 (see MCU paragraph). The tests will include 20K tests at LAM to tune the control parameters.
Provision has been made in the planning to allow for 20K tests at LAM with the BSMm CQM to check the compatibility of both mechanisms in the cryogenic environment with the MCU.

The SMECm PFM (deliverable)
The SMECm PFM will be built as soon as the mechanical design has been declared mechanically good for the launch and for the on orbit life.
It will sustain the classical path of a PFM, acceptance vibration tests (both warm at LAM and cold at RAL) , thermal cycles at LAM, performance tests at LAM including microvibrations, etc…
Povision has been made for joint tests with the BSMm but that operation could be skipped if the CQM tests have shown no problem.

The SMECm FS (deliverable)
The SMECm-FS could be the SMECm-CQM refurbished to flight level. This is still TBC as it depends on ESA that the back delivery of the CQM arrives on time and on the amount of modifications. For the moment, it is planned to manufacture a full new SMECm-FS. In any case, most of the components would have to be replaced as they would have sustained the qualification program. In consequence, it is planned to build a completly new SMECm model.
The SMECm FS is a copy of the SMECm PFM and will follow the same history.

5.1.3.2. To the MCU PFM

Detailed electrical design
The detailed design encompasses all the functions of the subsystem. A working version of the on-board software is written.
For that purpose, one development model MCU is built at LAM, which is functionnal, not geometrically correct, fitted with commercial components and witout redundancy. It is used to verify the principles.

The MCU QM1 (deliverable)
A QM1 set of cards is built at LAM. It is functionnally correct without redundancy. It has not to fit in the PFM allocated volume/surface, is fitted with commercial components. At LAM, it will be used to operate the SMECm CQM. There will not be time enough to have it operate both SMECm and BSMm mechanisms at LAM. So, it will be delivered to CEA-SAp before and tested along with the DRCU box at CEA-Sap, then delivered to RAL to operate the SPIRE CQM. The QM1 will stay at RAL once the SPIRE CQM has been delivered to ESA. The MCU QM1 will have maximum flexibility (donwloading of software, electronic options implemented) to be able to check all possible configurations.

The MI's (Modèle d'Identification in french) (MI4 deliverable TBC, the others not)
Three MI's (Modèle d'Identification in french) will be subcontracted in the industry, which are copies of the QM1 and which will be used as follows (there is no number 1, this being QM1)
- MI2 : kept by the LAM electronic service so that they always have a model to test the software
- MI3 : will be used for the LAM tests on the deliverable mechanisms models
- MI4 : could be delivered to UKATC to allow them to operate the BSMm's with a representative MCU (The need has to be confirmed by UKATC)

The QM1 flexibility will be retained.

<u>The MCU QM2 (deliverable)</u>
This model will be subcontracted to the industry.
This model will be the real qualification model for the MCU electronic and will sustain the relevant tests (thermal, vibrations, EMC). The components are flight like components, redundancy is implemented. MCU QM2 will be integrated in the DRCU QM2 box at CEA-Sap for CEA-Sap to qualify the complete DRCU box.
Prior to delivery to CEA-Sap, the MCU QM2 will be tested at LAM with mechanisms simulators.

<u>The MCU PFM (deliverable)</u>
This model is a copy of the MCU QM2 with flight components.
It will be subcontracted to the industry.
It will follow the same path (with acceptance levels), be integrated in the DRCU PFM box and so on.

<u>The MCU FS (deliverable)</u>
This model is a copy of the MCU PFM.
It will be subcontracted to the industry.
It will follow the same path and will be delivered to CEA-Sap if needed, as spare parts for the PFM.

5.1.3.3. To the MCU software PFM

The software development will follow the ESA OBS specification (ESA PSS5) applicable to the MCU software.
The software development will be made on the DSP evaluation board.
Preliminary design = function and tasks list.
Detailed design = algorithm specification.
Coding
Unitary tests = elementary function tests with test report.
Integrated software tests :
comparison between the DSPACE based control performance and the DSP based control software.
Telecommands software qualification based on commands scenarii.
Integration of the software on the MCU DSP, with the boot program and the memory mapping.
Redo the tests, beginning with the unitary tests.
The first version of the MCU software will be loaded int he MCU QM1 DSP.

5.2. Verification

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

In the tables below,

T =	a real test or measure is performed
A =	an analysis is performed
NA =	Non applicable

Basic performances (functional test) are controlled during environmental testings. This control is based upon the typical test (yet to be defined) and always performed following the same procedure.

- 300K vibrations are conducted at LAM.
- Vacuum cycles, soak cycles, thermal cycles (temperature between 20K and 80°C) are conducted at LAM.
- 20K Lifetime tests are conducted at LAM.
- 20K Performance tests are conducted at LAM.
- EMI/EMC tests are conducted in the industry (at INTESPACE, TBC).
- Microphonics tests are conducted at SPIRE level.
- 4K vibrations are conducted at RAL
- Functional 4K tests are conducted at RAL.

5.2.1. SMECm

	SMECm-DM	SMECm-STM	SMECm-STQM ([8])	SMECm-CQM	SMECm-PFM	SMECm-FS
Interface control	T	T	T	T	T	T
Mass, CoG, Stiffness mesasurement	T	T	T	T	T	T
Carriage tilts measurement	T	T	T	T	T	T
Travel measurement	T	T([4])	T	T	T	T
Launch latch test	T	T	T	T	T	T
Microvibrations	T([7])	NA	NA	T([7])	T([7])	T([7])
Vibrations 300K	NA	T	T	NA	T	T
Vibrations 4K	NA	T	T	NA	T	T
Power Consumption measurement	T	T([5])	T	T	T	T
Thermal/Vacuum cycle	T	NA	NA	T	T	T
Functional 4K test	NA	NA	T([6])	T([9])	T([9])	NA
Bakeout	T	T	NA	T	T	T
Lifetime	T	NA	NA	NA	NA	NA
Radiation tolerance	NA	NA	NA	A([2])	A([2])	A([2])
Microphonics	NA	NA	NA	A([3])	A([3])	A([3])
EMI / EMC	NA	NA	NA	A([1])	A([1])	A([1])

([1]) : At subsystem level, only EMI/EMC analysis can be performed.
([2]) : The radiation tolerance is verified by analysis only, taking into account the materials involved.
([3]) : At subsystem level, only an analysis is to be performed. Real microphonic tests are to be done at the SPIRE FPU level.
([4]) : Done to check that the possible travel is the expected one. No real actuator implemented.
([5]) : Measurement of the power dissipated in a heater simulating the real actuator.
([6]) : Done during 4K vibrations campaign.
([7]) : Not yet defined
([8]) : Not a new model : STQM = STM + position sensor + actuator
([9]) : Done on the PFM during 4K vibrations campaign.

5.2.2. MCU

	MCU-MI's	MCU-QM1	MCU-QM2	MCU-PFM	MCU-FS
Interface control	T	T	T	T	T
Power Consumption measurement	T	T	T	T	T
Vibrations 300K	NA	NA	T	T	T
Soak/Cycle	NA	NA	T	T	T
Radiation tolerance	A([1])	A([1])	A([1])	A([1])	A([1])
Thermal Range	A	NA	T	T	T
Thermal stability	A	NA	T	T	T
EMI / EMC	A	A	A	A	A

(1) : The radiation tolerance is verified by analysis only, taking into account the materials and the components involved.
(2) : the EMI/EMC tests are to be conducted at the DRCU level.

5.2.3. SMEC

SMEC = SMECm + MCU Evaluation board for the DM or QM1 for the CQM, or MI3 for the PFM and FS.
At the SMECm subsystem level, the performances are thoroughly verified.
They are checked at 300K and 20K at LAM and at 4K at RAL (TBC).

In every operational modes,	SMEC-DM	SMEC-STQM	SMEC-CQM	SMEC-PFM	SMEC-FS
Travel range	T	T	T	T	T
Speed range	T	T	T	T	T
Speed stability	T	T	T	T	T
Position measurement accuracy	T	T	T	T	T
Mirror movement (tilts)	T	T	T	T	T
Travel/Speed calibration	NA	NA	T	T	T
Power consumption	T	T	T	T	T

5.2.4. BSM

For the BSM board, the verification is included in the MCU verification.
The verification of the BSMm is done first at UKATC (see the BSM development plan) and with SMEC once integrated with the MCU. At this level, the verification will consist in adjusting the control loop parameters.

5.3. Ground associated equipment

The ground equipments are used to develop and test one item without the presence of the others.
Only the equipements needed for SMEC development are listed.
The simulators replace one or more items.
The tools are used to operate, check or integrate an item.
Most simulators are PC based as it is the most flexible and economical solution.
All the simulators and tools are needed since all subsystems are to be tested at approximately the same time.

5.3.1. Simulators

Simulator	Used for…	Functions	Deliverable
DRCU / DPU EGSE	…the control and monitoring of the MCU during tests and commissionning	Replaces DRCU and the DPU Receives position data, synchro signals and temperature signals. Simulates Interfaces: Serial, Parallel, Analog and Synch. Bus Supplies power. Sends commands.	No
SMECm and BSMm Simulator	…MCU development and testing and …post DRCU / MCU integration testing.	Replaces SMECm Receives actuator current values. Simulates the main parameters of the real SMECm : resonance frequencies, stiffness, noises, electrical behaviour. Delivers simulated thermometer values and simulated preamplified optical encoder signals	Three will be produced , one for LAM and two deliverables, one for CEA-Sap and one for UKATC.

5.3.2. Tools

Tool	Used for …	Functions
CCA Tool	… the alignment of SPIRE mirrors	Replaces SMECm during the alignment. Note that this tool appears in the SPIRE mirrors and alignment tools development plan. It is not mentioned any further here.
SMECm EGSE	… SMECm development and testing	Replaces MCU. Receives commands : travel range, speed value. Is able to control and monitor SMECm Sends actuator current analog values, powers the temperature sensors and the optical encoder Receives and processes temperature, actuator current, synchro signals and preamplified or non-preamplified position measurements. Sums up the operational time.
SMECm AT	…mirror cinematic checking and …mirror alignment w.r.t. SMECm baseplate	Measures travel range, mirror position, mirror tilt around travel axis w.r.t. the fixations points of the SMECm in the SPIRE structure..
SMECm OGSE	…SMECm alignment in SPIRE spectrometer structure	Allows SMECm position control and adjustement inside SPIRE spectrometer structure. Will be avoided if it is proved that mechanical tolerances are OK with optical tolerances.
SMECm MGSE	…SMECm Integration in the SPIRE spectrometer structure or in any test equipment	Allows SMECm handling during its integration in a structure.
MCU STM	… DRCU level vibrations and thermal tests	Replaces the MCU cards in case of problem, avoiding halting the DRCU qualification or acceptance program. Only cards plus masses in lieu of the components. CoG representative. Power dissipation representative (heaters)

5.3.3. Additional equipment

A mechanical box identical to the MCU part of the DRCU box is to be built. This will allow the integration procedure verification at LAM and the mechanical tests on the MCU to be conducted at LAM.

6. Development calendar

SMECm calendar

		Dates	Comments
GSFC Prototype 2	Tests at RAL	Mar 2001	Performances OK => design and control software OK for the science.
Flex pivots	Design study	Mar - Jun 2001	Feasability of the SMECm + pivots concept Adaptation of standard pivots
	ITT	Jun - Dec 2001	
STM program	Manufacture	Oct 2001 - mar 2002	Vibration campaign with modifs in between 300K. If ITT avoided, campaign with BE System
	Vibrations tests	Apr - May 2002	Still 300K
	Delivery	From May 2002	3 months margin. Could be used for a vibration tests in a STQM like configuration and/or for a cryovibrations campaign?
	Back delivery RAL to LAM	Feb 2003	
	STQM configuration & tests	Feb - Apr 2003	On time for CDR with a 1 month margin Could possibly be done before STM delivery
Actuator & launch latches	Development & manufacture	Apr 2001 - Feb 2002	6 actuators and 12 launch latches for the CQM, DM, PFM, FS and 2 redundancies.
CQM program	Flex pivots procurement	Feb - May 2002	
	Manufacture & tests	Jan - Aug 2002	Excluding vibrations
	Association with BSMm CQM & tests	Sep - Oct 2002	Verifies the software with real models.
	Delivery	Fom Oct 2002	2.5 months margin
DM program	Flex pivots procurement	May - Jul 2002	Excluding vibrations
	Manufacture, controls & life tests	Jan 2001 - Feb 2003	On time for the CDR 4 months margin
PFM program	Design modif	Oct - Dec 2002	Following STM interim review
	Manufacture, controls and acceptance tests	Jan 2002 - Jul 2003	Begins after STM interim review. Including CryoVibrations FS manufactured with PFM
	Association with BSMm PFM and tests	Aug - Sep 2003	Could be avoided? (already done on CQM)
	Delivery	From Sep 2003	<1 month margin. To increase the margin, start the PFM when delivering the STM and do not conduct common tests with the BSMm
FS program	controls and acceptance test	Oct 2003 - Jan 2004	Often waits for the PFM Including CryoVibrations
	Association with BSMm PFM and tests	Jan - Mar 2004	Could be avoided? (already done on CQM)
	Delivery	From Mar 2004	8 months margin

MCU Calendar

		Dates	Notes
Dvlpt	Electrical model and DSP evaluation board	Jun 2000 - Aug 2001	
	CEA-SAp delivers to LAM the definitive card dimensions	May 2001	Needed for the ITT
QM1	Manufacture, tests, software	Jan 2001 - Mar 2002	
	Tested with SMECm-CQM	Apr - Jul 2002	
	QM1 delivery to CEA	Jul 2002	1 month late w.r.t. milestone. We must test the QM1 with the SMECm CQM (and it would be better to test it also with the BSMm)
MI's	Manufacture	Mar - Jul 2002	
	MI4 delivery to UKATC	Jul 2002	The UKATC need is TBC
	MI3 available for SMECm+BSMm CQM tests	Jul 2002	
	ITT for the QM2, PFM and FS	Sep 2001 - Apr 2002	
Qualif electronic components	Delivery from ESA	15 Oct 2001	
QM2	Manufacture and tests	Apr - Dec 2002	LAM + industry
	Delivery to CEA-Sap	From End Dec 2002	2 months late We must be sure that everything is Ok with the QM1 before manufacturing the QM2
Flight electronic components	Delivery from ESA	15 Oct 2002	
PFM	Manufacture and tests	Nov 2002 - Aug 2003	Waits for QM2 declared OK No way to wait for the CDR
	Delivery to CEA	From Jul 2003	1 month late
FS	Manufacture and tests	Mar 2003 - Jan 2004	Waits for the PFM to be completed
	Delivery to CEA	From Jan 2004	No need date

Detailed planning in file SMEC_DevpPlan_20011015.mpp.

7. Description of deliverables

7.1. Deliverable models

7.1.1. MCU models

Model	Flight representativity	Difference with flight	Deliverables	Delivered to
QM1	Dimensions, interface, functions	No redundancy, flight equivalent components	1	CEA-SAp
QM2	Dimensions, interface, functions, redundancy	Flight equivalent components	1	CEA-Sap
PFM	100%	None	1	CEA-Sap
FS	100%	None	1	CEA-SAp

7.1.2. SMECm models

LAM will deliver the BSMm at the same time as the SMECm models (Not applicable to the STM)

Model	Flight representativity	Difference with flight	Deliverables	Delivered to
STM	Mass, CoG, Stiffnesses	No active components, only mass dummies	1	RAL
CQM	100%, except…	… no redundancy, only mass dummies and non vibrable	1	RAL
PFM	100%	None	1	RAL
FS	100%	None	1	RAL

7.2. Associated equipment

The associated equipment is for integration and alignement.

Model	Use/Function	Associated with	Deliverable
MCU SIM	Controls the MCU/DRCU interfaces Simulates the MCU as seen from the DRCU	Any SPIRE WE model	1 to CEA-SAp
MECm SIM	Simulates the electrical interfaces of the SMECm and BSMm during MCU integration into DRCU	Any deliverable MCU	1 to CEA-SAp, 1 to RAL
SMECm EGSE	SMECm control and monitor during integration and before and after transportation	Any deliverable SMECm	1 to RAL
SMECm MGSE	SMECm integration in the SPIRE Structure	Any deliverable SMECm	1 to MSSL (for the STM) and 3 to RAL (1 with the CQM, 1 with the PFM, 1 with the FS)
SMECm OGSE	SMECm alignment after integration in SPIRE structure	Any deliverable SMECm	1 to RAL

The CCA tool is deliverable, listed in the optics and alignement tools deliverables.

7.3. Associated documentation

The documentation to be delivered to RAL is defined in AD5.