SMECm/MCU DDR Report

Bruce Swinyard
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SPIRE-RAL-REP-001655

Introduction

The Detailed Design Review for the SPIRE FTS mirror mechanism (the SMECm) and its associated electronics (the MCU) has been held in order to fulfil the following:

1. Review and sign off specification document
2. Review and close interfaces to an agreed baseline so everybody can work across them
3. Review of design to ensure compatibility with specifications and interfaces (including at system level)
4. Identification of the long lead items and approval of their procurement

To these ends a detailed set of documentation has been produced and a presentation of the design has been made to the SPIRE optical design team on the 22/23rd October 2001 at LAM Marseille.

This report will mostly follow the documentation that has been presented at the review and will make detailed comments in the context of the documentation. These comments arise almost entirely from discussion at the presentation plus e-mail exchange both before and after the presentation.

Present at the Review

Bruce Swinyard (RAL – Chair)
Thijs van der Laan (Estec)
Eric Sawyer (RAL)
John Delderfield (RAL)
Berend Winter (MSSL)
Christophe Cara (CEA SAp)

Louis Rodriguez (CEA SAp)
Jean Bruston (Estec)
Guy Michel (DESPA)
Brian Stobie (ATC)

Jean-Paul Baluteau (LAM)
Patrick Levacher (part) (LAM)
Michel Jevaud (part) (LAM)
Didier Ferrand (part) (LAM)
Dominique Pouliquen (LAM)
Pascal Dargent (LAM)

Documents Submitted to be Reviewed:
See also the "readme" documents in the SMEC_MCU_DDR folder. Drawings are not individually listed here.

Name	Author	Reference	Issue date	Submitted file name
MCU design description	Levacher Jevaud Ferrand	LAM/ELE/SPI/000619	20/09/01	MCU_Design_ description_30.doc
MCU Power Budget		LAM/ELE/SPI/011013	11/10/01	MCU_Power_Budget_1_0.xls
MCU FMECA	Ferrand	LAM/ELE/SPI/010920	20/09/01	MCU FMECA draft1.doc
MCU Flight Model Interconnection List	Travers Levacher	LAM/ELE/FTS/NTT/010314	09.2001	MCU Electrical connexions ICD 1_012.doc
MCU Grounding Scheme	Levacher	LAM/ELE/SPI/011012	11/10/01	MCU_Grounding_1.doc
MCU/ DPU Command List ICD	Jevaud Ferrand	LAM/ELE/SPI/011011	20/09/01	MCUCommandICD10.doc
EEE parts List	Levacher	LAM/ELE/SPI/QUA/000201	26/09/01	EEE_parts_list_08_0.doc
QM EEE parts list	Levacher	LAM/ELE/FTS/QUA/010201	01/02/01	QM_EEE_list_01_0.doc
Declared Material List		LAM/ELE/FTS/011008.01	08/10/01	DECLARED_MATERIAL_LIST-01.doc
Declared Process list		LAM/ELE/FTS/011009.01	09/10/01	DECLARED_PROCESS_LIST-01.doc
List of electronics drawings		No reference	09/10/01	List of electronics drawings_01.doc
SMEC Control System and GSFC prototype test report	Ferrand	LAM/ELE/SPI/010110	17/04/00	SMEC Mechanism Control System.doc
SMECm actuator Technical Specifications	Dargent Ferrand	LAM/ELE/SPI/011007	09/10/01	SMECm Motor.doc
SMEC specifications	Pouliquen	LAM.PJT.SPI.NOT.200002	12/10//01	LAM.PJT.SPI.SPT.20000208_SMEC_Specifications.doc
SMEC development plan	Pouliquen	LAM.PJT.SPI.NOT.200010	16/10/01	LAM.PJT.SPI.NOT.20000110_SMEC_Development_plan.doc
SMECm design description	Pouliquen	LAM.PJT.SPI.NOT.200008	16/10/01	LAM.PJT.SPI.NOT.20000804_SMECm_Design_Description.doc
SMECm CIDL		SPI-STM-00-LD-01-2	14/10/01	SPI-STM-00-LD-01-2_(CIDL-Mechanics).xls
ICD	Dargent	SPI-PFM-00-RI-01-A	3/10/01	SPI_PFM_00_RI_01_A.doc

There are some minor errors in the issue dates in the documents as follows:

Comparative linear FEA of two different flex pivots. Ref SPI.STM.23.RC.01.A (front page date - 15 October 2001, following pages 03 October 2001)

QM EEE component list ref LAM/ELE/FTS/QUA/010201 (page header date 01-02-2001, document change record page 05-03-2001)

MCU/DCU Command List ICD ref LAM/ELE/SPI/011011 (page header date 20-09-2001, document change record page 20-09-00 - wrong year)

MCU Grounding Scheme ref LAM/ELE/SPI/011012 (page header date 11-10-2001, document change record page 19-06-00)

Major Board Conclusions
The board concluded that, while there is much detailed work left to be done, especially with regard to the MCU interfaces; FMECA and detailed board layout for the flight model, the mechanical design of the SMECm and electronics design of MCU were sufficiently advanced to allow procurement of all long lead items.

The board has an outstanding concern about the effect on the performance of the SMEC due to microvibrations induced from the spacecraft reaction wheels. This review did not show that this problem had been solved at the sub-system level given the (admittedly) inadequate

knowledge of the spacecraft input. However, as it is not at all clear what the real status of the spacecraft input is, or whether any other design of the mechanism will lead to a significantly better performance, the board concludes, in consultation with LAM, that the optimum way forward is to proceed with the design as presented to DM stage and evaluate the design again once test data are available.

In order to complete the DDR for the MCU the following documents must be resubmitted for review and approval:

MCU/DPU Command List ICD
MCU/DRCU Mechanical and Electrical ICD
MCU FMECA

In order to complete the DDR for the SMECm the ICD must be completed by 1/12/01 and a delta review will be held in April 2002 to review the outcome of the development model testing.

Specification Document
General comments
Change lifetime everywhere from 4.25 years to 3.5 years as this is the requirement.
The changes noted here will form a new issue of the document. From now on the details of the changes should be noted in the change sheets at the start of the document and the document will be approved and set under configuration control.

Page 5 Section 2: AD/RDs
Systems Budgets Document is now issue 3.4
Replace spurious interface documents with real ones
Replace interconnection note with SPIRE Harness Document.

Page 9 Section 4
SMEC_P6: It is noted that the velocity requirement for the SMEC should be from 0 – i.e. include “step and look” – the IRD should be updated to reflect this.

SMEC_P10 Change words “fiducial” to “with reference to an absolute position”

Action SMEC-DDR-01: Update IRD to include 0 velocity – BMS – for next issue of IRD

Page 10 Section 5
SMEC_Tm4: Delete figure for actual CoG – change to requirement on location accuracy of the CoG

SMEC_Tm5: The mass is now quoted as 1650 grms against an allowance 1300 grms. A non-conformance must be raised for this

SMEC_Tm7: Emitted microvibration is not specified; the detector specification is less than 0.1 mg, so we should use this as the specification for the SMECm

SMEC_Tm9: Although the EMC requirement is not clear an EMC test shall be made and this should be added here

SMEC_Tm13: There is a new stray light requirement from Cardiff; this will be incorporated into the SMEC specification. (1.2 microwatts total emitted radiation)

SMEC_Tm14: Change to 2 nominal and 2 redundant thermistors to match electronics redundancy

SMEC_Tm17: Note: Ensure that position of the corner cube is located on the ICD with respect to the global co-ordinate system.
SMEC_Tm17: An additional constraint of the accuracy of the motion is that the optical encoder must still function correctly at all points in the travel.

Action SMEC-DDR-02: Non conformance on mass of mechanism to be raised against System Budget Document v3.4 – DP – 1/12/2001

Action SMEC-DDR-03: Analyse the quality of the motion required for the encoder to give acceptable results – GM – 1/12/2001

Page 11 Section 5.2.2
SMECm_OL3/OL4: Acceleration of life test criteria is not clear. (see mechanical splinter). An accelerated test is to be done at 20K. (see mechanical splinter)

Page 11 Section 5.4
Design rules should be those referenced in the IID-A.

Page 13 through 16 Section 6 MCU requirements

General Comments
An EMC Frequency plan is to be supplied by LAM
Note that the reliability requirement has a thermal implication – two coils would use half the power if we can use them in series or parallel - however the electronics design does not permit this at present. FMECA will be done to assess impact of extra switches in electronics to allow this.

Page 13 Section 6.1
MCU_Tm1 to 5: Physical size of cards not defined in detail – this table must be completed with next issue of document.

MCU-Tm6: Power is 15.5 watts average, SAp is assuming about 13 watts – this budget will be set by SAp and any non-conformance reported against it.

Operating modes to be reviewed by RAL.
MCU to DRCU interface document to be created by SAp
Protection of static sensitive components to be considered by LAM and Sap.

Action SMEC-DDR-04: LAM will estimate the mass of the electronics cards and add to specification document – DP – 1/12/2001

Page 14 Section 6.2.3
SPIRE Project will check operating modes table from this document contains what is required.

Action SMEC-DDR-05: SPIRE Project to assess operating modes of MCU and comment – BMS – 1/12/2001

Page 15 Section 6.4.2
Design rules should be those referenced in the IID-A.

Page 16 Section 6.6.2

TBDs in the Operating Environment must be closed by LAM and SAp in the next issue of the document

SMECm Interface Control Document
Page 5 Section 6
Shims are not desirable here. It is noted that shims are a last resort and that no special thermal interface is required.
MSSL will provide the torque requirement for the bolts
No specification is given on the interface flatness

Action SMEC-DDR-06: LAM to analyse how sensitive the SMEC is to interface misalignment and place a requirement on the flatness of the interface – PD – 1/12/2001

SMECm Design Description
Here are notes on the presentations given on the day – the design description is not a configured document so no formal notes are given on the documents.

Mechanism
History lesson
Prototype I had wrong length arms and was designed to work with LVDT
Prototype II used TRW pivots and needed making more rigid in order to control it; the motor slung was underneath

Flight Design
Based on experience with the prototypes the design was changed to allow beams to pass around the structure and a study by BE Systems also suggested use of much large diameter pivots to achieve the specification. TRW pivot will not allow the degree of movement required to meet the design goal. The pivot diameter goes up to 11 mm from 6.35 mm. They have a much higher load capacity: 300 N cf 14 N but the mass is 15 grm per pivot.

The mechanism has to be latched so the shear force goes directly into pivots which cannot rotate so they have to be able to support this force during launch.

Mass of mechanism increases are because of larger pivots and increase in structure mass. Plus some increases due to motor and bits and pieces. However, the analysis has not been done to show that the increased mass for the mechanism is justified – LAM will commission a new study with BE systems and the new design.

LAM wish to change the belt material from CuBe as in the prototype to an Al alloy (see materials list). No fatigue study has been done on the belt material to date – this will be done.

The alignment of the encoder is critical – the stiffness of the carriage is set to some extent by the need not to lose the encoder fringes under different orientations under 1-g. A specification will be set on the required accuracy of the movement (see specification document section above)

Thijs v.d. Laan suggests adding a moving sheet to the plate to suppress the rotational modes. LAM do not want to change the design this radically – they will study quickly whether the inversion of the motor is at all possible to reduce the moving mass.

Guy Michel has a high sensitivity accelerometer and vibration table – he has offered to lend this to LAM – only has one axis. LAM need to make some measurements on the new design – may be do this on the Prototype II as well.

An analysis of the impact of the new design on the microvibration sensitivity can only be done once the development model is built and tested for the transfer function This will be done by April 2002 and a further review will be held then. Meanwhile the Project will look at what the actual science impact will be of induced position error using simulations.

Action SMEC-DDR-07: Send vibration table to LAM – GM – 1/12/2001

Action SMEC-DDR-08: Assess impact of microvibrations on scientific performance of FTS – BMS – 1/12/01

Optical Encoder

The commercial Heidenhain device will be modified by changes to the grating support and replacing the focal plane with a custom built one. The photodiode (PD) will be replaced with a Hamamatsu SN2386K (a pure Silicon diode) and the LED with an OD8890-C GaAs type.

At present GRP is used for mounting the PDs. It is recommended that ceramic mounting would be better. However Louis Rodriguez points out that the company that does the flex-rigid technology does not use ceramic and it will be expensive to change.

Pre-amplifier has been built and tested at 4-K and appears to work o.k. - improvements are required to give better electrostatic protection and solve possible oscillation problems

A test that allows the raw signals to be sent out to monitor the fringe contrast directly is required at sub-system and instrument level testsing. This will need to be repeated to monitor the effects of instrument orientation. The average voltage from the PD system is monitored as a housekeeping value and gives indication of the output of the LEDs.

An analysis and/or test is required to check what happens to the amplification chain when the PDs get a big signal such as from a cosmic ray hit.

MCU Electrical connexions ICD

Page 43-44 Section 8 (and SPIRE Wiring Harness Document)
These tables must be verified for compatibility against Wiring Harness Document.

The resistance of the harness is set on the basis that the mechanism needs to be driven at room temperature – if the requirement is relaxed to allow only +/-3.2 mm then the requirement on the harness goes from ~few Ohms per side to ~100 Ohms per side.

The requirement on the launch latch is not relaxed however. Required drive current for coils 300 mA therefore RT impedance 83 Ohms – 4-K impedance 830 milliohm.

Command List Interface Control Document

This document is not complete or ready for detailed review. A RID will be raised on this document.

RID: Command List Interface Control document is incomplete. A complete version shall be submitted by 1/1/2002.

MCU Design Description.

Again this is not a configured document. The notes made here are a call to action to check that the DRC/DPU and the commanding of the instrument are correctly specified.

Telemetry/Command Interface

No size limit is set on the “trace mode” packet. The size needs defining as a command parameter in the MCU Commanding ICD

The mechanism can go at up to 5 mm/s in theory but can the data keep up? This needs to be checked.

Confirmed from DRCU ICD that there is a frame that has both optical encoder and LVDT position present – these will be sampled 10 usec apart due to multiplexing.

SPIRE project to check what formats are defined and whether these are adequate. Another format is needed for backup mode operations and testing with encoder and motor current/back emf.

It is noted that the DPU will need to read back the SetParam with a GetParam in order to verify that a parameter is set correctly.

The commanding of the SMEC to "ON" needs to be carefully thought through. There are two ways this could be done – either the DSP looks after it or we do it by command sequence from DPU to the SCU. For Christophe it would actually be easier if the DSP did this task – however the FPGA is also problematic here. Christophe suggests using some form of soft start on the DACs. SAp and LAM will define a secure method of switching on the MCU.

LAM will detail the nominal boot sequence for the MCU and what happens if the boot doesn't work when booting – perhaps define a "safe on" and a "nominal on if anything goes wrong then off" sequence.

Action SMEC-DDR-10: LAM to specify step by step switch on and boot sequence for the MCU – DF – 1/12/01

Action SMEC-DDR-11: SPIRE Project to assess data interface implications of MCU design and define required telemetry contents of frames – BMS – 1/12/01

Electrical Design

The grounding scheme appears to be compliant with the system level grounding scheme.

JD will consider requirement on balancing of differential drives into RF filters in order to prevent injection of EMC.

LAM will add a paragraph describing how SEU's are handled in the control loop.

The power consumption is based on estimation using the maximum power for each component and summing them. Recommended that typical values are used with added margin. LAM will re-assess power consumption based on actual from the prototype. This will be the same at all temperatures.

All critical parts are 10 ppm per ^{o} (resistors etc).

Mass estimate – standard electronics boards – CEA will design board stiffeners but have not sent out the mechanical ICD yet.

Development Plan

Page 5 Section 2.1

It is noted that the BSM Development Plan has not been made available on Livelink by the SPIRE Project.

P 6 Section 4 and hereafter

Lifetime requirement should be changed to 3.5 years from 4.25 years.

Page 9 Section 4.3
There is an extra risk due to the pivot development. Pivot delivery time from BE systems is quoted as 11 weeks for 20-off but they are not actually in production. In case of not having the correct pivots the STM will have plain "PTFE" bushes. This will give the wrong mechanism response but should be o.k. for the structure response – see page 11 of document.

Page 11 Section 5.1.3.1
The type of thermistor is confirmed as Lakeshore Cernox type CX-1030

Page 11 "Lifetests"
Some component level testing might be envisaged for (for instance) the belt material.

Life testing duration is problem – a method of externally stiffening of the mechanism has been proposed to allow this to be done in a few weeks.

Page 12 "The MCU QM1"
QM1 – sequencing problem between testing both BSM and SMEC with this unit and the required date for the delivery to CEA.

QM1 is only functionally representative as they didn't have the drawings. That is the QM1 MCU will NOT be form and fit compliant – this is a change to what SPIRE Project expected. The boards have been delivered so it's all too late now! The FPGA software for the interface has not been delivered from CEA – therefore LAM have developed their own and are still waiting for the SAp version.

RID: Non-conformance with Instrument Development Plan – QM1 DRCU was intended to be form and fit - this would appear to prevent that. CEA-SAp to respond on whether this is acceptable and how the QM1 DRCU will be affected by this situation.

Page 12 "MCU QM2"
QM2 must be started well ahead of the end of the testing of QM1 with the SMECm and BSM – this represents a significant risk.

Page 13 Section 5.2
It is confirmed that the RAL cold vibration facility will be available if LAM wish to use it.

Page 17 Section 6
No delivery dates for actuators or launch lock yet. This represents a schedule risk and should attended as soon as possible.

MCU FMECA
This document is in a very preliminary state and is not accepted for review.

RID: MCU FMECA not complete. LAM to complete by 1/1/2002.

Long Lead Items
Electronics parts identified and on order with CPP via CNES – LAM budget has been reduced accordingly.
Pivots for DM and CQM will be ordered as soon as possible.
Launch latch and actuator are outstanding items – plan is to sub-contract the individual parts and assemble at LAM

Annexes

Notes on Microvibration Specification

Torsional oscillations of the SMECm are a potential problem. The passband of the control loop is governed by the position of the eigenfrequency of the SMECm structure. Domique has calculated the velocity induced from a single frequency acceleration. A fixed amplitude of 0.1 mg in acceleration equates to 10 um/s at 20 Hz (ish). With an eigen frequency at 30 Hz (present design) there is no roll off in the control loop at 20Hz so this is where the requirement comes from. Only by moving the eigenfrequency up the problem really be solved.

The new design has an eigenfrequency at ~90 Hz from FEA so it might be alright – by reducing the mass of the moving stage by inverting the motor they can gain rt(3) on this again. The plan is to go ahead with the design as it stands and measure the response in the meanwhile looking at whether it is feasible to invert the motor – if necessary they will implement the motor inversion but not if not. LAM will assess the susceptibility for the Flight design when the QM hardware is available in April and the specification on the microvibration will be revisited as necessary.

Mechanical Splinter

The rolling band idea was discussed some first cut analysis showed it like it is not going to work. Tests will be done on the prototype as it stands to see what the sensitivity looks like.

Factor on lifetest has been discussed – needs clarification. LAM will have to accelerate the lifetest which they can do this by raising the natural frequency of the moving part. This could be achieved by making it lighter by “inverting” the motor at the cost of have moving wires.

Need to define the stroke over which the fatigue test will be done – 22 to 32 mm – small stroke over one end of the range? Agreed that 20-K testing is valid for mechanical testing.

Action SMEC-DDR-12: ESA Project to clarify what the lifetest factor should be for the SMECm – TvdL – 1/12/01 (closed see appended)

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>From: Thijs.van.der.Laan@esa.int
>X-Lotus-FromDomain: ESA
>To: bruston@xep0.estec.esa.nl
>Date: Thu, 1 Nov 2001 13:56:15 +0100
>Subject: Test factors
>
>Jean,
>This is to confirm, that the lifetime test factor of 1.25 (for 100000
>cycle.
>or more) has a bearing on trigological issues only.
>To prove that fatigue failures do not occur, a factor 4 on the number of
>cycles is highly recommended. ECSS-doc states it as a design factor and
>stipulates that the mechanism shall not structurally fail during its life.
>If flex-pivot fatigue tests have been performed under representative
>environment, such a test would be unnecessary.
>
>                          Thijs.
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