SPIRE 300-mK System Delta-DDR Board Report
SPIRE-RAL-REP-001544

Meeting held: Friday 14 February 2003.
Report Issued to review panel for comment: Tuesday, 25 February 2003

Review Panel

Douglas Griffin (chair)
Anne-Sophie Goizel
Graham Coe
Eric Sawyer

Attendees

John Delderfield
Ian Walker
Chris Brockley-Blatt
Berend Winter
Peter Hargrave
John Coker

Meeting Aims (DKG)

1. To review the progress made in addressing the list of open issues raised at the DDR held last year and to compose a new list of open items.
2. Review the design changes since the previous DDR
3. Make an assessment of the state of readiness of the components for entry to the Instrument Level STM programme.

Board feedback

- Significant progress has been made since the DDR and it is the board's opinion that the subsystem is ready to be incorporated into the instrument STM programme for thermal and structural qualification.
- A series of tests have been carried out to characterise the 300-mK Strap Support and the 300-mK Stray-Light Baffle. The results from these tests were used to construct a FEA model of the system. The model predicted the RMS vibration load and the quasi-static load in the Kevlar cords in the system when integrated into the instrument FEA model. This analysis yielded a maximum force of 1.5N-rms. A safety factor of 50% and an analysis uncertainty of 20% were applied to this. The maximum force during warm testing was calculated at 5.2N-rms.
- The adequate mechanical performance of the Stray-Light Baffle and the 300-mK Support critically relies on closely following the assembly procedure that has been developed. It is critical that this procedure be fully documented and rigorously followed for all the Instrument Qualification models and the PFM. It has been noted that an Assembly Procedure has been written for the 300-mK Strap Supports. More detail needs to be included in this procedure including details of the pre-conditioning of the devices on a shaker table. A similar procedure needs to written for the Stray-Light Baffles.
- It was noted that tests on the Stray-Light Baffle so far indicate that misalignment during vibration is minimal. Nonetheless, this failure mode remains as one of the most concerning.

The board recommends that misalignment budget be drawn up with unequivocal Pass/Fail criteria that can be tested during various phases in the Instrument qualification programme.

- The design presented at the delta-DDR uses thicker Kevlar chord (increased to 0.5mm from 0.3mm). This will reduce margins on thermal performance. However, in consideration that a mechanical failure resulting in a thermal short between the busbar and instrument housing represents a single point failure for the complete instrument, the Board judges that reduced thermal margins are preferable to potential complete failure. It is currently undetermined if this change will push the system out of specifications with regard to the parasitic heat load. This is due to the fact that there are two sources of data on the thermal conductivity of Kevlar (Ventura and Duband). The Ventura data indicates that the system would be out of specification, while the Duband data indicates that the requirement would be met with some margin. It is recommended that no action be taken to measure the parasitic heat load as (i) it is a very difficult experiment that would take considerable effort, (ii) the uncertainty in the measurements are unlikely to be less than the uncertainties in the current literature, (iii) there is very little scope for changing the design. It is important however, that this design change be incorporated into the SPIRE TMM.
- It is imperative that the results from the thermal tests carried out at Cardiff be incorporated into the SPIRE TMM. A test report documenting all pertinent tests carried out at Cardiff needs to be written and sent to RAL.
- The bulk conductivity of the Copper has not been measured. It is recommended that this not be measured, as the results of such testing are not likely to change the design of the system at this point in the SPIRE programme.
- It was identified that one possible means of monitoring creep (or indeed other degradation modes) of the Supports and Stray-Light Baffles while they are integrated in the detector boxes and therefore inaccessible would be to employ a set of Witness Units. These units would be subjected to an identical set of environmental conditions as the units integrated into the instrument. The witness units could be examined periodically to determine the probably state of the integrated units.
- It was identified that there is a theoretical possibility of the Belleville springs cold-welding under a long-term vacuum environment. This would have the effect of reducing the compliance of the spring stack and would be undesirable. One possible means of mitigating this problem would be to coat the springs with MoS_2 but this would also bring contamination issues (inside the detector boxes!). This issue needs to be addressed. (See Item 9)
- The following documents need to be signed off with signatures according to Annex-1
    - SPIRE Structure Mechanical I/F
    - SPIRE Structure Subsystem Specification
    - SPIRE Structure Development Plan
    - MSSL SPIRE – Product Assurance Plan
    - SPIRE 300-mK Strap System Requirements

Table 1 - Open Items at Delta-DDR

Item #	Issue
1	Re-issue the 300-mK Strap Support Assembly Procedure with more detail including details vibration preconditioning.
2	Write a 300-mK Stray Light Baffle Assembly Procedure
3	Formulate a misalignment budget for the 300-mK Support System
4	Document results from Cardiff thermal testing programme and send to RAL for incorporation into SPIRE TMM
5	Change to ∅0.5mm Kevlar for the 300-mK components in the SPIRE TMM
6	Include the Grounding Review ECR references into §5.4 of Requirements Doc.
7	Close out TBDs in Requirements Document
8	Measure Stray-Light Baffling effectiveness
9	Review potential for cold-welding of Belleville washer stack, and if necessary possible mitigation measures (e.g. sputtered MoS_2)

Table 2 – Status of the Open Items raised at the DDR. For reference only. The list is now obsolete.

AI #	Description	Status at Delta-DDR
1	Decide on a location for the PTC (taking into account the Structural, thermal and integration issues)	Closed
2	SPIRE Project Team to decide the future structure of the "Tiger Team" and to reassess responsibilities	Closed
3	The Tiger Team and the Hardware Manager are to make a detailed plan of the essential outstanding development tasks. This is to be formulated into a decision tree.	Closed
4	Consider the issue of fatigue/life testing of the strap supports and the stray-light baffles	Closed: Witness units to follow PFM
5	Close out the outstanding TBDs in the requirements document	Few still open
6	Include the strap heat load and operating temperature in Req. #1	Closed
7	Include the level temperatures in the parasitic heat load requirements	Closed
8	Perform Brazed/Welded joint tradeoff and update the DPL accordingly	Closed - using brazed
9	Determine method for axial constraint of Cu rod within Supports and Stray-Light Baffle	Closed
10	Solid Modelling of Cooler-Photometer and the Cooler-Spectrometer Straps	Closed
11	Design and thermally characterise the electrical isolation joint.	Nearing completion (new test on a 100 micron joint)
12	The method for the restraint of the Copper rod within the elbow clamps needs to undergo detailed design	Closed
13	Incorporate the provisions for bake-out of the system in view of the fact that there is a significant mass of Kevlar. This is to be included in a test plan.	Closed
14	Re-perform the FEA Analysis of the strap system including (i) mechanical properties of the Mk-III support, (ii) The mass of the electrical isolation joint, (iii) mass of the PTC, (iv) the actual routing of the strap between the Stray-light baffles and the cooler, (v) revised random vibration levels resulting from negations with ESA and/or judicial review of the vibration levels set for the system based on the SPIRE structural model.	Closed
15	Detail design of the clamped butt joints in the strap	Closed
16	Detail design of the restraining of the strap in the supports and Stray-Light Baffle	Closed
17	Detail where blackening of the SLB will be required	Drawing to be issued
18	Jig detail design for bending up the 3mm rod	Closed
19	Check specification of Belleville washers at the BDA I/F	Open
20	Determination of the optimal stacking pattern for the Belleview washers in the Supports and SLB. This will be at least partly determined by the optimal preload and compliance of the Belleville stack.	Closed: details in assembly requirements
21	Specification of the grade of Copper and annealing requirements, and coating method	Closed: on detailed drawing
22	Measurement of the SLB attenuation effectiveness (using blackbody radiation and 1mm LED)	Open
23	Measurement of the thermal conductivity of the Copper Rod	Open
24	Acceptance test plan for the SPL and TSS	Open
25	A procedure for the quantifying of the tension in the strap supports and stray light baffles needs to be produced	Closed: based on the measurement of the length of the bellevilee stack
26	Address issues raised by SPIRE PA Manager regarding the Structure FMECA, PA Plan, DML, DPL and AIV Plan	Closed: PA Documents updated
27	Include a mass dummy of the PTC system on the 300-mK strap for the STM programme.	Closed: Included
28	Incorporate the latest thermal test results and the dimensions of the system into the SPIRE TMM	Open: Data to be sent to RAL (Document to be formally issued)
29	A KIP is to be added to the SPIRE STM programme after the cold vibration test to inspect for damage and/or loss of preload in the Kevlar.	Closed: At transition between STM to CQM
30	Address issue of the sequence of gold plating, annealing and forming.	Closed

31	Include the details of the sequence of the fixation of the photometer and spectrometer straps to the cooler in the Structure MAIV plan.	Closed
32	Decide on whether a sub-system vibration test of the 300-mK Strap System ought to be carried out prior to the SPIRE STM programme	Closed: Decided not to carry it out.
33	Resolve the issue of the locking of the BDA I/F screws with Epoxy while utilising Belleville washers	Open

Annex 1 - SPIRE Document Signatory List

Project Configured Documents

a) ICD
   i) Checking engineer at Authors Institution,
   ii) Local Project Manager
   iii) Project Manager at each institution with which an Interface is held
   iv) Checking engineer at each Institution with which an Interface is held, (one for each institution)
   v) SPIRE Systems Engineer, (John Delderfield)
   vi) Instrument Development Manager (Eric Sawyer)

b) PA Plan
   i) Local Project Manager
   ii) PA Manager,
   iii) SPIRE PA Manager, (Eric Clarke)
   iv) Instrument Development Manager (Eric Sawyer)

c) Specifications
   i) Local checking engineer/scientist,
   ii) Local Project Manager
   iii) PM at institutions which have requirements placed on them by the Specification
   iv) Instrument Scientist, (Bruce Swinyard),
   v) Instrument Development Manager (Eric Sawyer)

d) Development Plan
   i) Checking engineer at Authors Institution,
   ii) Local Project Manager at Authors Institution
   iii) Project Manager at each institution with joint deliverables
   iv) Local PA Manager,
   v) Instrument Development Manager (Eric Sawyer)

e) Requirements
   i) Checking engineer
   ii) Author
   iii) Checking engineer at each institution that has requirements placed upon it

Annex –2 Meeting Notes

Design Description (PCH)

List of design drivers
Brief description

- 290 (0.5mm) Tex DuPont Kevlar was 167 Tex (0.3mm). Increased since DDR
- Now using three stranded (twisted) rather than unwoven cord (procured from same manufacturer as used for Sorption Cooler).
- Went to thicker Kevlar to get more structural margin

On the 300-mK Support, minimum bend is ∅4mm

On the capstans, the surface roughness is identical between the QM and the PFM

The Lionel type knot is not used. Adjustable jam hitch will be used.

The optimal stacking pattern for the Belleville has been found. <<<>>><<<>>>

Scribing a mark on the hubs and using a travelling microscope could be a good way to monitor preload

The stack is compressed to 90% and then the capstan is torqued to 60Ncm

There is a compression of approximately 1mm in the stack

There is a theoretical possibility of the stack cold welding itself together.

Preload is 56N per run.

Stray-Light Baffle

The minimum bend radius is 2mm on the SLB
All radii are electro-polished (to reduce friction and improve equalization of pre-load tension; also reduces probability of seeing fraying of the Kevlar)

The location of the black has been specified

There is an asymmetry in the string-up of the Stray-Light Baffle. It could induce a rotation of the suspended.

It is not clear that there is indeed a 1.5mm minimum gap between the components.

Thermal

Depending on the model (Ventura/Duband); the thermal budget is either met or non-compliant.

For B/C of 1.8K, there is between 1.42 and 2.65 μW
For B/C of 2.0K, there is between 1.87 and 3.54 μW

Mechanical Testing

The first mode increased cold and returned to the original when warmed up

Thermal test data to be issued as a document in the "next couple of days"

- Brazed joints.
- Bolted copper I/F
- BDA I/F
- Brazed joints in the Spect. Det. Box
- Electrical Isolation Joint (approximately 10 times worse than Cu/Cu I/F my estimate is an 8mK temperature rise)

Life Testing

Philosophy is to have a set of supports and stray-light baffles to follow development models.

Work to be done:
Thermal tests on isolation joint
Stray-light baffling effectiveness
Thermal isolation tests

MAIV and Compliance Matrix

No E-Beam joints. All silver soldered.
Silver solder flux cleaned.

Assembly and integration

Compliance

FEA Analysis

Need to have component acceptance test.
Now have a FEA model of the entire instrument that includes the 300-mK Busbar. At instrument qual. levels (including the current notching scheme) we have a margin of safety of 2.
The first failure mode will be where the Kevlar starts to slip and cause wear of the Kevlar.

PA

Documents have been updated.