SPIRE 300-mK Strap System Detailed Design Review 30 July 2002

Review Board
Douglas Griffin (RAL) - Chair
Sam Heys (RAL)
Bruce Swinyard (RAL)
Ray Carvel (PPARC)
Graham Coe (ESA)

Written comments:
Eric Clark (RAL)
Jamie Bock (JPL)
Dustin Crumb (Swales/JPL)
Lionel Duband (CEA, SBT)

Attendees:

Matt Griffin (UCF)
Berend Winter (MSSL)
Peter Hargrave (UCF)
Eric Sawyer (RAL)
John Delderfield (RAL)
Adam Woodcraft (UCF)
Iris Didschuns (UCF)
Ian Walker (UCF)
Brian Kiernan (UCF)
John Coker (MSSL)
Chris Brockley-Blatt (MSSL)

General Comments and findings

The board concluded that very significant progress has been achieved since March 2002 when the detailed design phase commenced. Despite this positive progress, there are still several open issues regarding the development of the 300-mK Strap System. Some of these open issues will impact directly on the eventual structural safety margins and need to be given highest priority.

In the light of this, all outstanding tasks in the development and delivery of the system need to be closely assessed, prioritised and scheduled bearing in mind the overall SPIRE milestone list. The board has included in the report a suggested list of Action Items noted by the board during the review that is intended to help this process to focus the development on the most important items.

The function and role of the Tiger Team needs to be reassessed as the development of the system passes into the production and testing phases of the project. This is to be assessed by the SPIRE Project Team.

Provided that the future development work focuses on the critical outstanding tasks, it is the board's opinion that there is a high probability of the system meeting the requirements. Once the major issues listed at the end of this document with an importance level of 2 or greater are resolved, the 300-mK Strap System will be ready for entry into the SPIRE STM programme. A delta-DDR should be carried out around October to review the progress of the resolution of the open issues.

Meeting Minutes/Detailed Feedback

1. Meeting/review Aims (DKG)

Presentation Summary

- Freeze the 300-mK Strap System Requirements
- Review and freeze the design for entry to the STM/CQM programme
- Review and freeze interfaces
- Review documentation

Board feedback

Review aims satisfactory

2. Development Plan (DKG)

Presentation Summary

- Brief technical overview of the system
- Review of the "Tiger Team" remit within the context of SPIRE
- Overview of the responsibility areas for the different institutions (MSSL, UCF, RAL and JPL)
- Overview of the sequence of the main tasks in the Development plan. **No Delivery dates**.
- Overview of the necessary tasks to develop the system.
  - Thermal, Structural and Optical
  - Analysis and/or test.

Board feedback

- The location of the PTC needs to be closed out [AI-1]
- Since the formation of the "Tiger Team" some responsibilities across the three institutions have become clouded. The SPIRE Project Team needs to review the role of the group in the future in order to have the most efficient structure for the production and testing of the system. [AI-2]
- There seems to be no clear detailed plan for the next stage in the development of the system. The sequence and the delivery-dates for various tasks need to be clearly defined and documented. Prioritisation and rationalisation of the list of tasks will be required given the tight budgetary and programmatic constraints. [AI-3]
- As the supports and stray-light baffles are potentially susceptible to fatigue and/or creep, life testing needs to be considered [AI-4]

3. Requirements (DKG)

Presentation Summary

- The individual requirements for the system were presented sequentially

Board feedback

- There are many TBD placeholders that need to be closed out in this document. [AI-5] The specifications on the surface roughness of the strap and the thickness of the gold coating is to be identical the components thermally tested at UCF.
- The board agrees with the Tiger Team's position that none of these open requirements are likely to significantly disrupt the development of the system.
- The Thermal Requirement on the conductance of the strap should include the operating temperature and the heat load being carried by the strap. [AI-6]
- The temperatures Level-0 and Level-1 need to be quoted in the requirement on parasitic heat loads. [AI-7]

4. Design Description Overview (PCH)

Presentation Summary

- Listed the Design Drivers (Reliability, thermal isolation margin, Light-tightness, Stiffness, modular, compact, minimisation of residual stresses in Detector Boxes etc,)
- Descriptions were made of the following items:
  - Routing of the strap within the Photometer Detector Box.
  - Strap Support. (Compensation for creep and negative coefficient of thermal expansion, stiffness and differences between Mk-II and Mk-III design etc.)
  - The structural, thermal and handling properties of Kevlar cord.
  - The details of the Kevlar termination and capstan.
  - The hub assembly and the Belleville washer stacking options
  - The concept for a Torlon bump stop device to accommodate a soft failure mechanism into the design
  - The stray-light baffle design (temperature stages, stray-light baffling effectiveness, including discussion on the ability of the design to meet the stray-light baffling requirements)
- A brief discussion on the parasitic heat load thermal calculations was outlined. Depending on the source of the thermal data, the design either meets the requirements with margin (optimistic), or meets them with no margin (pessimistic).
- The thermal interfaces within in the system and with other systems was listed
- The requirements on the electrical isolation within the strap were presented. No details on the design of this system were available as it was only recently introduced
- The requirements on the PTC system mounted on the strap were discussed.
- The routing of the strap within the Spectrometer Detector Box presented.
- The vibration testing carried out on the Mk-II version of the support.

- A summary of the thermal interface testing that has been carried out at UCF. (Cooler, BDA, Clamp)
- Initially testing at Cardiff used 65Ncm torque but BDA ICD states 20Ncm. Initial tests at 20Ncm show little change in thermal performance.

Board feedback

- The method of making the Cu/Cu permanent joints within the system is open (welded/ brazed). This tradeoff needs to be performed in the light of contamination, thermal impedance, stress concentration, reliability, schedule etc. [AI-8]
- The method for constraining the axial movement of the ∅3 Rod within the Stray-Light Baffle and the Strap Support needs to be closed [AI-9]
- Solid modelling of the link between the Photometer Stray-light baffle and the Spectrometer Stray-light baffle needs to be performed [AI-10]
- The method for electrical isolation needs to be designed [AI-11]
- The method for the axial constraint of the Cu rod within an “elbow joint” needs detailed design. [AI-12]
- It was noted that the stray-light baffling requirements might not be completely met. Given the programmatic constraints, the potential severity of the ingress of a small portion of stray-light and the perceived scope for retro-fixes, it is recommended that no further development be performed on this aspect of the design.
- Water absorption into the Kevlar cord needs to be accounted for in the AIV (bake-out) and handling specifications. [AI-13]
- The board felt that the double stringing of the supports would introduce unwarranted complexity into the integration of the supports and stray-light baffles. If extra strength margin is eventually required, then the most favourable means for achieving this is to be the use of thicker Kevlar cords.
- It was the board’s opinion that the incorporation of a Torlon end stop to constrain the extent of the displacement of the strap in the case of Kevlar cord failure was not a favoured solution
- The amount of creep to be expected needs to be quantified and if necessary, provision for the monitoring of the strain relaxation in the supports monitored and controlled in the appropriate AIV plan/procedure handling/storage requirements.
- The jig for bending up the strap needs to be designed. [AI-18]
- The requirements for annealing, Gold plating and the achieving of the required surface finish of the various components of the strap needs to be assessed and documented [AI-21]
- The location of the high emissivity black coating needs to be established and documented. [AI-17]
- With 20Ncm the compression on the Belleville will be only~30%. Therefore may need to re-spec washers. [AI-19]
- JPL plan to use epoxy locking at BDA strap interface. This is inconsistent with use of Belleville washers. This interface requires clarification with JPL. [AI-33]

5. FEA (Structural) Analysis (BW)

Presentation Summary

- The solid model of the strap system and the corresponding FEA model was presented
- The method and results for the experimental determination and characterisation of the dynamic performance of the strap system was presented.
- The results indicate that the design based on the current SPIRE interface random vibration loads would have a negative MoS. Reducing random vibration levels (by approximately 50%) at the SPIRE/HOB interface would result in a positive safety margin.
- If the rigidity of the section of Thermal Strap between the Photometer Stray-light baffle and the first strap support within the detector box could be increased, then the loads on the system could be lowered. Increasing the rigidity would probably involve the substitution of a section of the solid strap with a section of tubular strap.
- A Mk-II device had been tested to destruction with large masses attached to the ends of the support.
- The Mk-III device that is currently in manufacture is expected to have a higher strength.
- A discussion arose as to the desirability of carrying out a subsystem vibration test prior to on in parallel with the SPIRE instrument STM programme.

Board feedback

- As there are still a significant number of open issues relating to the detailed design and operating environment of the system, it is not possible for the board to adopt a position on the mechanical reliability of the device in service. When the details of the system become available, then the analysis needs to be re-performed. [AI-14] It is critical that the requirements on the interface loads to the BDAs and the cooler are verified by analysis here. If the loads exceed the requirements, then provision has to be made in the design (probably compliant links)
- A positive MoS can be demonstrated either by a reduction in the SPIRE random vibration environment (requiring approval by RFW - request for waiver), or by use of thicker kevlar cords to increase the strength. Therefore, studies to increase the stiffness of the strap by changing to a tube should not be continued.
- The effect of the preload on the strength of the system is unclear at the moment. This could have a high impact on the strength and dynamic performance of the supports and stray-light baffles. As such, the optimal configuration of the Belleville washer stack needs to be determined. [AI-20]
- As the mass of the PTC hardware will increase the load on the suspended 300-mK Strap System, a mass dummy of this system should be included in the STM test programme. [AI-27]
- A KIP should be added to the SPIRE STM programme where the supports are inspected for damage and loss of preload after the Cryogenic vibration test. [AI Given that the intensity and duration of the vibration loads on the instrument are likely to be significantly higher during the qualification than during flight, a successful STM programme would give a high probability of mission success.
- The board recognises that it would be desirable to carry out sub-system vibration of the 300-mK Strap System prior to the SPIRE STM vibration testing. The board asks that the SPIRE

Project team make a decision about the value of this test over and above the value of other tasks.. [AI-31]

6. Interface Control Document (C B-B)

Presentation Summary

- The structural interfaces between the components of the 300-mK Strap System and the other parts of SPIRE as contained in the SPIRE Structure ICD were outlined. This information was an update of the information presented at the SPIRE Common Structure DDR.

Board feedback

- The interfaces to be managed are relatively straightforward and no issues were found apart from a query regarding the maintenance of clearances from the optical beams within the Photometer Detector Box.

7. Strap Integration Plan (C B-B)

Presentation Summary

- Contains the sequence of operations for the integration of the straps into the detector boxes but does not include the means for attaching the straps to the cooler when the detector boxes are integrated onto the SPIRE Optical Bench.

Board feedback

- In general terms, the strap integration sequence appears to be rational
- The gold plating appears to be prior to the forming of the strap. Would the bending and/or annealing processes compromise the integrity of the Gold layer? [AI-30]
- The plan for the integration of the Detector Boxes onto the SPIRE optical bench and the connection of the Photometer Strap and the Spectrometer Strap onto the Cooler needs to be included in the MAIV plan. [AI-31]

8. Stray-Light Baffle and Strap Support Integration (PCH)

Presentation Summary

- The sequence of integration of these two items was presented.
- The critical issues in the integration sequence are (i) the repeatable and accurate determination of the preload in the Belleville washers and (ii) the alignment of the 300-mK hubs within the outer Level-0 assembly during the string-up of the Kevlar.

Board feedback

- It was generally identified that a means of measuring (indirectly if necessary) the preload in the Kevlar during and after integrations is necessary. This is so that any loosening of the cord due to slippage, creep or equilibration of cord tension could be detected. [AI-25]

9. Optical/Thermal Testing and Characterisation (PCH)

Presentation Summary

- The details of the thermal and optical testing of the components of the system were outlined.
- An outline of the schedule for this work was presented

Board feedback

- It was unclear how the schedule of testing fitted in with the overall schedule for structure and for SPIRE. [AI-3]
- The prioritisation and scheduling of the remaining tests needs to be made in light of the whole SPIRE programme [AI-3]
- High urgency should be given to the thermal testing of the design of the electrical isolation joint, as there is a relative high degree of uncertainty in this part of the design and could potentially have significant impact on either the performance of SPIRE and/or the programme. [AI-11]
- The latest I/F and component thermal test results along with the physical dimensions are to be incorporated into the SPIRE TMM. [AI-28]

10. FMECA, CIDL, DPL, DML (C B-B)

Presentation Summary

- The section of the updated SPIRE Common Structure FMECA pertinent to the 300-mK Strap was presented.
- It was noted that the PA documentation had been updated

Board feedback

- Eric Clark, the SPIRE PA manager has provided written comments on this material. They are included as an attachment. [AI-26]
- Update of the DPL based upon the results of the E-Beam Welding/Brazing tradeoff. [AI-8]

11. Action Items / Recommendations

These items have been included in the report to assist in the prioritisation and planning of the future work of the development team. As such, a nominal importance and urgency level has been assigned to each task.

Importance Levels

0 Diversionary
1 Potentially useful task (I.e. If problems crop up later, then this work will assist in resolving the issue)
2 Useful task to help meet requirements
3 Essential task in meeting requirements

Urgency Levels

0 Low
1 Medium
2 High
3 Very High

AI-#	Description	Importance	Urgency	Resp.
1	Decide on a location for the PTC (taking into account the Structural, thermal and integration issues)	2	3	MSSL (BW)
2	SPIRE Project Team to decide the future structure of the "Tiger Team" and to reassess responsibilities	2	2	SPIRE PT (Matt Griffin)
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.	2	1	Tiger Team (DKG)
4	Consider the issue of fatigue/life testing of the strap supports and the stray-light baffles	1	1	Tiger Team (MSSL)
5	Close out the outstanding TBDs in the requirements document		1	Tiger Team (DKG)
6	Include the strap heat load and operating temperature in Req. #1	3	1	Sam Heys / Doug Griffin

AI-#	Description	Importance	Urgency	Resp.
7	Include the level temperatures in the parasitic heat load requirements	3	1	Sam Heys / Doug Griffin
8	Perform Brazed/Welded joint tradeoff and update the DPL accordingly	2	3	MSSL
9	Determine method for axial constraint of Cu rod within Supports and Stray-Light Baffle	2	1	MSSL
10	Solid Modelling of Cooler-Photometer and the Cooler-Spectrometer Straps	2	1	MSSL
11	Design and thermally characterise the electrical isolation joint.	3	3	
12	The method for the restraint of the Copper rod within the elbow clamps needs to undergo detailed design	2	1	MSSL
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.	3	0	UCF
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.	3	3	
15	Detail design of the clamped butt joints in the strap	3	2	
16	Detail design of the restraining of the strap in the supports and Stray-Light Baffle	3	2	
17	Detail where blackening of the SLB will be required	3	2	
18	Jig detail design for bending up the 3mm rod	3	2	
19	Check specification of Belleville washers at the BDA I/F	3	2	
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.			
21	Specification of the grade of Copper and annealing requirements, and coating method	3	2	
22	Measurement of the SLB attenuation effectiveness (using blackbody radiation and 1μm LED)	2	2	
23	Measurement of the thermal conductivity of the Copper Rod	2	2	
24	Acceptance test plan for the SPL and TSS	3	1	
25	A procedure for the quantifying of the tension in the strap supports and stray light baffles needs to be produced	3	1	
26	Address issues raised by SPIRE PA Manager regarding the Structure FMECA, PA Plan, DML, DPL and AIV Plan	2	1	
27	Include a mass dummy of the PTC system on the 300-mK strap for the STM programme.	3	2	
28	Incorporate the latest thermal test results and the dimensions of the system into the SPIRE TMM	2	1	

AI-#	Description	Importance	Urgency	Resp.
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.	3	1	
30	Address issue of the sequence of gold plating, annealing and forming.	2	3	MSSL
31	Include the details of the sequence of the fixation of the photometer and spectrometer straps to the cooler in the Structure MAIV plan.	3	1	
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	2	3	SPIRE Project team (Eric Sawyer)
33	Resolve the issue of the locking of the BDA I/F screws with Epoxy while utilising Belleville washers	3	2	

Hi Doug
Revue of MSSL documents as requested. As stated before as long as the following points are raised I do not think I need to be at the DDR.

- Can Eric Clark (Spire PA manager) be added to the distribution list on the CIDL.

The Following declared lists are incomplete:-

- **Materials list**

1."Use & Location" the majority not completed.
2. Approval status not completed, i.e. is the material ESA approved etc
3. Although some materials appear to Quote commercial parts, the materials I checked are referenced on ESA PSS-01-736 Issue 1 But no outgassing information is available.

- **Processes List**

Points 1 & 2 Above

- **FMECA**

Not acceptable the comments raised by ESA on the previous FMECA have not been addressed. see attached.

- **PA Plan**

4.8.4 Reporting of NCR's And Figure 4.8.5 State ESA is informed of Major NCR's this should include SPIRE project Manager and PA manager.
SPIRE PA Plan SPIRE-RAL-PRJ-000017 should be added to the Applicable Documents.
There is no indication in the plan on how ECR's (Engineering Change Requests) or RFW's (Request For Waiver/deviation) are to be controlled.

- **AIV Plan**

It is an ESA requirement that "MIP's" & "KIP's" (Mandatory and Key inspection points respectively) are scheduled, this is normally included in the AIV plan.
Where are these Scheduled?.

- I have not reviewed the remaining documents.

Regards

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Comments on SPIRE – FMECA MSSL/SPIRE/PA005.1 29.11.2001

The title is misleading since it is not the FMECA for the whole instrument bur for the structure.

The functional diagram or drawing is missing in this analysis. A unique reference number for each failure mode and cause is also missing in the analysis sheet. Each failure mode and cause shall have its own unique id number so that it is possible to refer to each row in the analysis sheets. The traceability between the failure modes in the analysis sheets and the drawings is required in the analysis and it shall be unambiguous.

§ 3 Category 2: Loss or degradation. Loss and degradation should be separated into different severity categories, according to ECSS-Q-30-02A. Thus there would be 4 severity categories.

§ 3. Failure modes considered. The failure modes listed are not corresponding to the failure modes in the analysis sheet. The listed failure modes are basically applicable to electronics and mechanics and not to structure. To be corrected.

A description of the columns in the analysis sheets is missing.

The critical items (severity category 1 and 2) shall be summarised and followed up in the report. There is no visibility on how the critical items are treated and what design provisions are taken to remove the criticality or how to control it. The ECSS-Q-30-02A describes how this shall be done, and the standard is available for download at the ECSS homepage http://www.estec.esa.nl/ecss/. Critical items shall be entered into the critical items list and analysed appropriately, if necessary through a process FMECA.

Analysis sheets

In this analysis some failures will occur during ground operations and some during flight. It should be clearly visible for each failure mode/cause if it is analysed during ground tests or during flight. The objective is to identify failures that can occur during flight and how to correct or control these. When other phases are included in the analysis it shall be clearly visible. An additional column shall be added with “Mission phase/Operational mode” stating in which phase or mode a failure occurs.

The “provisions” column. Compensation provisions are design provisions or operator actions, which circumvent or mitigate the effect of a failure. This means provisions that are to be taken when a failure occurs in flight. Design provisions are for instance: redundant items or alternative modes of operation that allow continued and safe operation, and safety or relief devices which allow effective operation or limit the failure effects. For most of the items here there are no provisions if a failure occurs in flight and in the column it should then be stated “None”. The provisions described in this column now (such as sufficient design margin, visual inspection, etc.) are ways to control a critical item and minimise the risk of it occurring and should be entered into the corrective actions column or a remarks column.

The corrective actions are actions that are taken to render a critical item non-critical, or if that cannot be done how to control the criticality. This shall be followed up in the critical items list, and traceability shall be kept between the FMECA and the CI list.

The sheets refer in several cases to sufficient design margin. What is a sufficient margin and has a stress analysis been performed to obtain this margin? If an analysis has been performed it shall be referred to and the values of the margin shall be given.

Actions such as “training”, “qualification tests”, “engineering tests” are referred to. Are the plans and procedures available, and are such provisions as “sufficient design margin” known?

Page 7. Why are the three first failure modes SPFs but not the three following? A single point failure is according to ECSS-Q-30-02A: failure of an item which results in the unrecoverable failure of the analysed product. The three last failures fall under these criteria too. This comment is also valid for the other failure of severity 1.

Id 9a refers to provision as “careful handling”. Are the handling procedures available or will they be written?

Id 13 refers to “sound engineering practice”, which is something that is expected in any case and not a corrective action. Please refer to correct mounting or handling procedures, stress analysis etc.(Quote relevant document number)

There should also be a column in the analysis sheet for remarks for clarifications.