Thermal Summit
QMW 25/26 September
SPIRE-RAL-MOM-000517

Present: Alex Ellery; Matt Griffin; Peter Ade (part); Peter Hargrave; Sam Heys; Berend Winter; John Coker; Lionel Duband; Bruce Swinyard; Terry Cafferty; Geoff Gannaway (part)

Purpose of the meeting

1. Go through the thermal model, get everyone's input and refine the
2. Choice and specification of thermometers
3. Temperature control (temperature of the detectors)
4. JFET box thermo-mechanical implementation
5. Thermal straps
6. How do we document the thermal design

TMM (Sam)

Summary of thermal assumptions – see vg's

Summary of requirements on the model
- Max heat leak between FOB and 4 K stage (11 – 4.2 K) 6 mW
- Max heat leak 2K supports 1 mW
- Max Heat leak photometer 0.6 micro W
- Max heat leak spectrometer 0.4 micro W

TMM written ESATAN v8.4.2., 138 diffuse nodes; cryostat model needs to be upgraded to allow the dynamic response of the system to be modelled. Need representative thermal masses for the instruments, shields, FOB etc. at each level. The instrument level 2 shield is missing from the cryostat model? Shield 1 runs hot?

Steady state model – He cooler performance details need to be upgraded – just a boundary node at the moment – got temperature and heat flows under nominal operating conditions.

Nodal break down – see vg's.

Input parameters – copper conductivity – so far assume same as used for ISO for level 1 straps – Terry's assumed value is same as measured by Lionel. – Level 0 straps assume this high value.

300 mK busbar supports assume 6.6 mm^2 40 mm vespel for photometer and 4.4 mm^2 for spec.

300 mK straps from detectors assumed as 1mm diameter high conductivity copper wires.

The length of the little straps is too short the moment – 50 mm is more like it.

All level 0 and level 1 joints are Cu-Au-Cu. All 300 mK joints are Cu-Apeizon-Cu – some uncertainty as to what to do here – will certainly need to gold plate the copper anyway. Grease seems to be the best idea – but experimental evidence is required.

Sam is taking a 34-K shield as radiative input to the instrument at the moment. Gives 23 mW into Level 2 – this may be wrong but the total power reflects the real situation with increased JFET power.

Detector inputs given here are realistic according to Terry. The Level 2 vent line appears to be missing from cryostat model

2 K detector boxes heat input dominated by supports 1.23 mW: detector box temperature is at 1.76 K (1.73 for strap) cryostat 1.70 K.

Static model gives final detector temperature of 310-320 mK – this is driven more by the thermal impedance of the link from evaporator to the detectors than the actual total load. This in turn is dominated by contact conductance.

Transient case – at present spectrometer calibrator is switched off after 10 minutes – still leads to significant temperature increase in SPIRE OB temperature. Remodel with calibrator left on for duration of spectrometer observation (1 hour). Note Spectrometer calibrator is driving the thermal design of the spectrometer at the moment.

Cooler recycling profiles needs to be updated – but with present situation we can recycle and get back to operating within the two hours.

<u>Discussion</u>
Conductances being used are possibly conservative compared to the measurements that Lionel has made. He has measured 0.05 mK/uW with bolted greased interface – he is making more measurements. Non-greased bad; braided bad. Experiments will be repeated later with a clearly defined test set-up.

Need more definition of mechanism thermal characteristics.

<u>Cooler</u>
Situation Report
Thermal conductance to evaporator is too low at present – drives recycle time. The heatswitch has plenty of conductance but the strap does not – braided strap has low conductivity – solid strap causes thermal short in heatswitch due to imposing a mechanical load onto the heatswitch.

Heat switches are being redesigned to an inline device for various detailed reasons.

Impact of Low Margins

Cooler runs as 500 J device at present – spec. given to ESA was 860 J. How do we use this margin?
Note that the baseline is that the cooler will be recycled every multiple of 24 hours. 48 to be preferred over 24 as it is thermodynamically more efficient and will cause less operational hassle.

We need some headroom on the detector temperature - the way to this is to increase the pumping capacity – larger pipe – bigger cooler. The cooler would have to go up to 6 litre STP this will make it longer but not necessarily fatter.

Kevlar Tensioning
There is a problem with knowing what tension has been applied to the kevlar support system and, once it has been tensioned, how to measure it after prolonged storage and temperature cycling. Dustin is working on the same problem for the detectors.

Heatswitch Redundancy
Lionel does not like having redundant switches. As he has now found that the link to the evaporator is critical. When he used a solid copper link it put some force on the switch and caused a thermal short. This makes him uncomfortable about the prospect of having two switches. The heat load is 5 uW per extra switch into 300 mK. To accommodate this we may need the bigger cooler anyway.

Temperature control
Methods:
i) Cooler pump heating method only needs on board software and no further electronics.
ii) We could also use the heatswitch sorption pumps to change the thermal conductance of the heatswitches. (Note this requires variable current supplies for the heatswitch sorption pumps.)
iii) Heaters on the evaporator and use cooler thermistors. This cannot be the default for the active thermal control 'cos the basic cooler thermometry won't be accurate enough. It needs to be measured through an AC bridge type circuit probably with a cold pre-amp. Anyway we should put heaters onto the evaporator for at least the CQM for diagnostics.

The JPL worry is short term temperature fluctuations (minute scale) this may very well require thermal control for each detector separately if needed/possible at all. Anyway the strap plus detector acts as a low pass filter and should damp any rapid thermal variations.

Decision: Suck it and see on the CQM – if necessary we will have to implement something for the PFM.

300 mK architecture
Start at evaporator and work towards detectors.
Lionel will provide hard mount point for thermal connection on the outside of the cooler structure.
There would then be a flexible link to the hard point mounting of the bus bar itself at the wall of the photometer detector box and the bar from the spectrometer. The nature of the

link will depend on the results of tests on an annealed copper braided link being done by Lionel.

Lionel states that there will be a box around the cooler and MSSL will be interfacing via the wall of this box. There will be flexible links inside the box (copper braids) to accommodate external structural loads.

Thermal Finishes

At present MSSL are assuming that the SOB will be allochromed and this is the only thermal finish it will have. Need confirmation that this will be ok.
The QMW black-1 epoxy with rough surface will be applied around apertures and at other TBD critical surfaces.
It is possible that QMW black-2 anodising could be used as the standard surface finish inside the detector boxes (TBC)

300 mK architecture.

Straps need to be designed (material choice, cross sectional area, length)
Support for the straps need to be designed
Concepts need to be verified, engineering tested (cold, vibration)
Concern about various connections number should be minimised.

Division of work:

QMW will do some thermal contact testing gold/copper/grease/braid etc. Together with CEA/Lionel. This could be wrapping up measurements already performed and additional measurements.
QMW for some raw material testing at 0.300 K. copper, vespel, torlon
QMW will do concept design
QMW will do the concept testing (cryotesting)
MSSL will assist in concept testing (vibration testing)
MSSL final design, + interface
MSSL responsible for final design of straps and procurement
QMW responsible for final design testing

Testing:

- Realistic representative tests needed:
  - Bakeout
  - Lifetesting
  - Thermal cycling
  - Etceteras
- Busbars and straps
  - Conductivity (reliable supplier)
  - Interface –thermal conductance for different config.
- Busbar supports
  - Semi rigid at detector strap interface
  - Knife edge snubbers (TBC)
  - Kevlar (aramid/dynema) support at light trap

- Test materials, Vespel, Torlon Kevlar, proto type
- Light trap – test concepts in Bac(h)us Dewar.
- QMW needs a dedicated He-3 system for these tests available by mid October. (Tests will be done in QMW cryophysics dewar – no need to buy a new one at QMW.**)**
- Routing of bus-bars in SPIRE needs final definition soon – affects conformation of JPL 300 mK strap – CQM array tests starting Jan 2001
- Volume envelopes for the components needed. MSSL to make the latest model available to QMW.
- STM components needed soon (see milestone list)

Day 2:

<u>Wiring</u>

1.7 to 300 mK: Constatan in kapton – line spacings 50/50 microns – 75 way. 25/25 microns looks very possible – need 225 leads for the highest population. Then pull bond wires out for connections – JPL has this capability.

1.7-4-K: Detectors – two options – Tekdata need good RF shielding – does this work? JPL are looking at an alternative approach – 38 gauge stainless STP. 12-ax has 6 sets of twisted pairs within one shield – shield dominates thermal characteristics. Supplier Cooner Wire (Ken Mullin 818 882 8311).

Thermal conductivity $3.1\text{x}10^{-6}(T_H^{2.19} – T_C^{2.19})$ W/mm

450 Pairs/6 for number of wires needed from detectors to JFET boxes.

Questions on the detector wiring:

How do the wire bundles get mounted?
What is space qualification status – what plastic is the insulation?
How does one make off the connectors?
What is impedance per unit length?

All mechanisms are isothermal with external connectors so can use conventional (Al or Cu) wiring.

Wiring routing

What about RF shielding outside the box?
What are the lengths of the cables?

<u>JFET Boxes:</u>

SiN films do not work as expected – hence the increase in power. Dustin has new designs for modules – what is the development status of the SiN films?

What is required in terms of electrical isolation of the JFET structure? JPL suggest electrically isolated. How does the heat load get transferred to Level 2?

JD suggests looking at having intermediate temperature stage within the JFET box. There is no point in pulling the JFETs down to 12 then warming it up to 110 K.

Level 0 level 1 straps

Requirements on three straps to level 0:
Two straps for the cooler – separate thermally isolated straps direct to tank. Efficiency of cooler depends on temperature of the evaporator. If only one strap then recycling power will raise the evaporator temperature. Don't care about temperature of pump strap we do care about the temperature of the evaporator strap.

Lionel will provide FTP details to get information on cooler design.

Interface – Lionel will provide tabs on the bottom middle of the cooler structure. Short straps will then bolt to these and the light trap will slide over the top.

Possible problem with Ti tube that isolates the 2 and 4-K on heat switch. May need to beef up this to support load.

What is specification on average power dissipation for cooler. LD thinks it should be 5 mW for the cooler cycle. Interfaces baseline as Cu-Au-Cu.

2-K box strap will be continuous piece of copper – hard mounted to 2-K box – probably the spectrometer. All straps will be coupled to 4-K via support/light trap.

Need i/f drawing with positions of straps for 11/10 meeting at ESTEC.

Level 1 Straps on cooler end of bench.

Thermometers:

It is agreed to use the Lakeshore Cernox thermistors.

Number and placement of thermometers needs serious thought and revision. It would be desirable, but not essential, to have all structure thermistors as part of the other sub-systems and the wiring sent out through the sub-system harnesses rather than having a separate structure harness.

Resolution required

0.1 mK for 300 mk (CX-1030)
1 mk for 2-K (CX-1050)
2 mK for 4-K (CX-1070)
Check that this is compatible with ADC resolution.

STM Definition

Basic use is for mechanical testing. However, the need for a thermally representative model during the STM test has been identified.

When do we see a cooler? Detailed drawings of 4-Litre now being done – if 4 litre is chosen will build unit this spring and deliver autumn 2001. The ESA TRP unit (EM) will be at SAp?
If go to 6 litre unit then there will be a possible 2- month delay.

Working cooler (CQM) will be fitted to the STM – will be qualified before delivery.
Mechanical use of STM is for vibration test on mechanically representative sub-systems.

Action List

No. AI-SYS-000517-xx	Actionee	Description	Priority	Need and Date	Status
01	BMS	Contact ESA to ask for details on thermal masses for cryostat.	High	Needed for accurate thermal transient analysis Raise at tech meeting 11/10/2000	Open
02	LD	Provide experimental data for each part of the cooler as Power vs Temperature curves for each of the operating modes.	High	Needed for accurate thermal transient analysis 16/10/2000	Open
03	TC	Provide mass and temperature breakdown for all parts of the detector modules.	High	Ditto	Closed at meeting
04	SH	Do sensitivity analysis on a poor quality strap to the 2-K box and how important is the insulation of the 2-K to 4-K	High	For systems review Report by 27/10/2000	Open
05	BMS	Clarify positions and temperatures of shields in cryostat with ESA.	High	At Tech meeting 11/10/2000	Open
06	BMS	Ask Thomas why the level 2 ventline is not explicitly present in the cryostat model. (Well how it is implemented anyway)	High	At Tech Meeting 11/10/2000	Open
07	BW	Ask Ian for info on thermal conductance measurements on oxygen free copper. To be distributed to Lionel, Terry and Sam	Medium	16/10/2000	Open
08	JC	Update required thermal strap length as a result of this meeting. That is strap length inside the detector boxes and from the box to the cooler.	High	Needed to complete thermal model 16/10/2000	Open
09	BMS	Contact mechanism suppliers to get present thermal configuration of their sub-systems.	Medium	Needed to complete thermal model 16/10/2000	Open
10	LD	Study impact of going to bigger cooler and report back.	Urgent	Need to inform ESA at tech meeting. 30/9/2000	Closed (Note Appended)
11	BMS	Write report for ESA on use of 6 litre cooler. BMS – following receipt of Lionel's report. Iteration to be done	Urgent	For tech meeting 9/10/2000	Open

		with BW; BMS; SH.			
12	TC	Ask Dustin Crumb to send Lionel details of the tensioning system used on the detectors and his tension measurement device.	Medium	For cooler final design 27/10/2000	Open
13	BMS /MJG	Raise redundancy of cooler with ESA at tech meeting	High	At Tech meeting 11/10/2000	Open
14	LD	Send MSSL draft sketches of 6 litre cooler	High	To ensure 6-litre cooler is compatible with structure design 16/10/2000	Open
15	BW	Check dynamical response of larger cooler	Medium	For system review 27/10/2000	Open
16	BMS /MJG /BW	Write requirements document for STM	High	For systems review 27/10/2000	Open
17	BW	Specify parasitic load into 2-K straps from support	High	To complete thermal model 16/10/2000	Open
18	JC	Update and re-issue interface drawing	Urgent	For tech meeting 9/10/2000	Open
19	TC	Confirm details of proposed wiring as specified in minutes	High	For systems review 27/10/2000	Open
20	BMS	Chase Dustin on number and location of connectors on back of detector modules	High	For routing of wiring 16/10/2000	Open
21	JD/BMS/ SH	Come up with concept for wiring routing	High	For systems review 27/10/2000	Open
22	JD/SH	Study options for reducing the thermal load from the JFET modules	High	For systems review 27/10/2000	Open
23	LD	Define requirements on level 0 thermal straps	High	To complete thermal model (And IID-B) 9/10/2000	Closed (e-mail of 27/9/2000 – appended)

Lionel's e-mail for action 23

Bonjour again again,

This is what I wrote in June (e-mail 14/06/2000):

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As for numbers, as a first approximation you can assume that on average for CSTR1 (evaporator + shunt strap) there will be 50 mW flowing. What we want for sure is that at the end of the condensation phase the temperature is as close as possible to T cryostat (1.8 K or less). Since I don't have the exact power dissipation profile, I would say with 50 mW the temperature should not raised more than 1 K (0.05 W/K conductance).

For CSTR2 (sorption pump) it is less critical. We could use a similar strap, but one with say 10 mW/K should do.

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In the light of our recent measurements:

* CSTR1 - if you look at the temperature profile you see that at the end of the recycling phase there was still about 20 mW flowing to the cold plate. Of course we could have waited longer until the temperature of the evaporator dropped close to 1.8 K (and in this case the flowing power would obviously be less) but we wanted to show we could recycle in less than 2 hours.
In any case for now to assume 20 mW and a • T not in excess of 0.2 K seems reasonable. This turns into a conductance at 2 K of 100 mW/K (or 0.01 K/mW).
If one assume k = 5 T W/(cm.K) (they can probably do better) and 40 cm long, it corresponds to a 40 mm2 strap.

* CSTR2 - here we have more flexibility, however I think we do not want the temperature at the end of this strap to raise too high, since it will probably be close to the other one (conductive path), it will radiate, etc....
So let's assume it will not go higher than say 8 or 10 K at the peak power.
Let's assume this peak is 400 mW, then we end up with about 50 mW/K.

Then there are all the contact conductance, so I suggest it is better to oversize a little bit the strap.

How does this sound ?.