SPIRE Systems Team Meeting

Saclay 4, 5 March 1999

Circulation: Attendees, Systems Team, Project Managers, Judy Long

Principal aims of the meeting:

1. Finalise the Scientific Requirements to enable System Requirements to be frozen, including trade-offs on field of view and detector numbers.

2. Consolidate the systems requirements (especially with regard to the array options) in preparation for the Technical Meeting with ESA at ESTEC on March 15th.

Agenda

Thursday March 4

1.	Plenary session on Scientific Requirements Document	Walter
2.	System Trade-offs for number of detectors	Colin
3.	Structure conceptual design and impact on budgets	Bruce
4.	Telescope design and focal plane sharing	Bruce
5.	Actions and agenda for ESA Technical Meeting	Matt
6.	FTS concept and implications for FPU & electronics	Bruce

Friday March 5

7.	Review of systems design documents for array options	
	CEA option	Louis
	GSFC option	Jim
	Caltech/JPL option	Terry
8.	Warm Electronics and on-board software	Louis
9.	Cooler system design	Bruce
10.	Review of input and questions for ESTEC meeting	Matt

Attendance:

Louis Rodriguez (LR)
Jean-Louis Augueres (J-L A)
Dominique Pouliquen (DP)
George Voellmer (GV)
Jim Caldwell (JC)
Terry Cafferty (TC)
Bill Gray (WG)
Walter Gear (Day 1) (WKG)
Bruce Swinyard (BMS)
Colin Cunningham (CRC)
Matt Griffin (MJG)
Christophe Cara (pm day 2)

1. Science Requirements Document (WKG)

SRD V0.2 should be out end next week

Still some major issue that impact on the system requirements:

- VERY strong push for enlarged FOV from many quarters.
  Science Team must discuss ramifications of this. It was a high priority for this meeting to determine the impact on the systems requirements.

- Strong desire to avoid chopping if at all possible but small-scale jiggling (drizzling/microstepping) is needed to ensure fully-sampled images, allowing for defects, bad pixels and image distortion - now incorporated in BSM (Beam Steering Mechanism) spec (1/10 beam).

- There is a push for a fourth photometer channel at shorter wavelength, but PACS have one – if it's important they should enlarge theirs. There is an overall limit on data rate and number of detectors for the payload.
  One option for getting the maximum field of view while limiting the number of detectors would be ditching the 350 micron band, and having more detectors in the other bands.
  WKG stated this was not desirable, we need three bands for the extragalactic programme.
  LR asked if we could still look at putting shorter wavelength capability in the spectrometer?
  WKG: Argument is for broad-band low-res coverage is strong and PACS doesn't do this. It is not necessarily true that we need the max possible FOV for spectrometer.
  He asked what is the "constraint" on spectrometer or photometer enhancement?
  MJG re-stated that we must not let the spectrometer design interfere with meeting the photometer specification.

  Conclusion: Need to look at long vs. short wavelength attractions for extending FTS coverage.

- Requirement on FTS to have as near as possible FOV to the photometer is a banal truism – it needs to be reworded to focus on efficiency of spectroscopy (there is no point going for greater FOV at the expense of sensitivity). MJG and BMS have action to update sensitivity numbers for FTS.

- Dynamic range requirement: MJG thought 15-bits to be an over-specification in the SRD – it applied to a small range of programmes and is probably unrealistic.
  There is a requirement for an unspecified dynamic range for PSF measurements.
  ACTION MJG/BMS/WKG/CRC Specify dynamic range of photometer

  Beware of over-specification.

- Requirement on focus mechanism? JPL are working to the goal of 6 um Wave Front Error vs requirement of 10 um, so we must design the optics to cope with the worst case of 10 um.

- Field size – going to 4'x8'
  BMS stated that there was no problem with the optical design. Worst corner is Strehl of 0.93 from Kjetil's calculation. Distortion is 5% on pupil footprint (vs. 10% requirement) for full 4 x 8 rectangular FOV.

2. System Trade-offs for field size (CRC)

These bullet points outline the impact of moving to an 8x4 arcmin field:

- **Detector numbers:**
  - Slightly more than double no of detectors for feedhorn option, in order to fill a rectangular field with hexagonally packed horns.

- **Opto-mechanical design:**
  - Not easy. Arrays might be difficult to accommodate and mirrors are very big, although probably doable.

- **Signal wiring:**
  - Inside FPU – OK, as under our control
  - ESA harness: They will specify requirements to industry, who may be conservative, preferring ISO-type stainless-steel harnesses.
  - Feedhorn option: need ~ 1000 wires 0.3 – 4 K and 15-300 K (this is about same number as in the CEA option)
  - WKG: need to specify surface roughness of antenna to put a spec on the electrical crosstalk (as less than optical crosstalk) – question for ESA to put to JPL/COI, but we'll be lucky to get any hard information before summer.
    Requirement is dictated by galactic survey programme – need to get views of Phillippe André on what's required.
    ACTION to outline calculations on crosstalk – interwiring capacitance – needs for 1% or 0.1% crosstalk (CRC)
  - LR: QMW results imply that can increase multiplexing by factor of two, and hence minimise wire count

- **Connectors:**
  - Feedhorns: Better to use 100-way MDMs (question on Jamie's list)
  - Will be v. difficult if we have to use 37-way connectors
  - Termination of Kapton ribbon cables to connectors is not easy and may be expensive
  - TC: NASA have used 51-way MDM connectors, and there is much experience of 100w MDMs in ground-based instruments.

- **Data rate:**

Extension to 4x8 should be OK if we have increased data rate (by X-band transponders) and may even be possible with current data rate.

- **Mass of array assemblies & Thermal loads:**

  - Array mass will increase, but not double; optics mass up; JFET box mass up; BAU mass up. Corresponding thermal loads may not increase very much, for instance TC noted that, for the Horn Option, Kapton conductance dominates 0.3 K

LR noted no difference in power dissipation at 0.3 K for the CEA option, where extra multiplexing means little increase in wire count, and the modular array design means that 4'x4' is made up from 4 16x16 repeat arrays and 4'x8' from 8 16x16 repeats, so the mass will be little different.

Action all array groups: Provide tabulation of thermal loads for 4 x 8 option in addition to 4 x 4 baseline.

- **Warm electronics power:**
  - Will double for the horn option.
  - JC: for GSFC looking at around 100 W for 4'x4', with little increase for 4'x8'
    - TC: total warm power capacity of s/c dominated by need to heat telescope for decontamination (1 kW)
  - CEA option will have very small increase if higher speed double multiplexing is possible.
  - CRC: Riccardo says DPU does not provide power conditioning – has to be done by DRCU (&SPU)– this will up the power required by the DRCU by around 1.3 - 1.4.

- **Cost to consortium:**

  Increased hardware costs may not be high (except maybe for horns), but increased array fabrication and testing would be significant and should be estimated.

CONCLUSION : major systems cost of increased FOV will be opto-mechanical structure, and may even preclude the option of 4 x 8 arcminutes. It is urgent that we tie this down as soon as possible.

3. Structure conceptual design (BMS)

- Initial concept study OK on eigenfrequency and thermal load margin but not much margin on eigenfrequency.
- Mirror sizes up with 4 x 8 field size - BMS now thinks 2-plate system looks problematic, due to large overhanging masses of mirrors.
  DP, CRC thought it may not be so bad, as the mirrors are stiff and need no low-conductance supports, unlike the plates.
- Problems with array accommodation but some room to push spectrometer out sideways to make room.
- WKG: Do we need a box at 2 K – in principle we don't need it from the point of view of baffling, but it may be needed to provide a double wall to prevent ingress of stray light
  Mounting detectors at 4 K makes it more difficult to effect 2-K level – could be easier to revert to 2-K mounting.
- Action on MJG to look at actual need for a 2-K box.
  Need realistic version of 4 x 8 mechanical envelope of array assemblies – Dustin Crumb working on this at the moment for the horn option.
- Optical design makes it difficult to fit things in: discuss on Monday 8th March structure meeting.

- CRC suggested that the only way to make the necessary rapid progress on the opto-mechanical design was to get optical design and structure teams together for a week or so until it is done!

4. Telescope design and focal plane sharing (BMS)

- PACS wants spot diagram to fit inside one pixel, which seems to be an over specification.
- HIFI still want to take a corner of our box, but it is not looking feasible for us to give up that corner, which may be needed for our structural supports.
- We cold bulge out in Y direction on HIFI side too – e.g. push the cooler out.

5. Actions and agenda for March 15 (MJG)

- Nature of PDR
  - Concentrate on requirements/specifications/interfaces/budgets/risk analysis
  - Problem with CNRS funding – no money this year for FTS development

  Action: MJG to sort out with LV
- Status of System Requirements Document (SRD)

  - Keep it concise and as an overview
  - It must translate scientific requirements into technical requirements

  Action on BMS to send out revised draft (two weeks)
  - Internal SPIRE model philosophy
    - IS DPU part of CQM
    - Is the SPU needed? DPU can be more powerful.
    - On-board memory requirements may not be as high as before.
      - J-L A has action to compare solutions in draft document in preparation for meeting on the subject on March 24/25 at Saclay.
    - LR: We need scientific requirements on number of bits for the photometer.

    Action: 15 bits probably overkill. MJG/BMS/WKG/CRC to address this (two weeks)

    - More questions for ESA:
      - Cryovibration facility
      - At what temperature must subsystems be qualified before integration into the FPU?
      - What are microvibration levels produced by the spacecraft?
      - Telescope:
        - Change in back-focal length
        - Thermal gradients and effect of petal design (5^o roll)
        - Late telescope design prevents optical design from being finalised

6. FTS Status (BMS)

- Need to test effect of using powered mirrors in interferometer
- System requirements nearly complete
- LVDT may not be good enough (DP not yet sure)
- 16 bits dynamic range would be needed for no compensation

LR stated we must compensate at least 70% by using the FTS calibrator, and MJG put requirement at 80% (TBC); FTS calibrator requirements need drawing up , eg Temp TBD; How it fills the pupil TBD

Action: BMS and MJG to draw up FTS calibrator spec.

- Aside: CRC: Need requirements for photometer calibrator also
- Data rate:
  Feedhorns: can transmit all interferograms to the ground fully sampled.
  Filled arrays: decimate and average 6 scans
  Solution: slow down FTS a bit? Observe for some of the time with lower data rate?
  LR working on report on sampling scheme.

7. Review of System Design Documents

7.1. CEA Option (LR):

- **New pixel design:**

680 um active pixel dimension with 750 um pixel side
Modular array concept with 16 x 16 array (x 4 for 32 x 32)
Cross gap equivalent to one pixel when four butted together
Easy to extend to 64 x 32.

- **Wiring:**

32 signal outputs + clean biases on one 37-way MDM
256 pixels with 8:1 multiplex factor
Clocks, mux phases etc. on another
851 wires for 4 x 8 arcmin FOV (assuming FTS FOV doubles also, so overestimate). With FOV remaining at 2x2', then total is 783 wires.
If increase mux factor by 2 (which looks feasible) then back to 489 wires

DP: ESA regulation on maximum pin occupancy of 70%? – check with ESA on March 15.

- **Operation:**
  MJG: How sensitive to 1 pW per pixel? Preamp noise limited if background too high?
  LR: Not very sensitive – can use electrode to control the bolometer resistance.

- **Power:**

Conduction 5 μW per array = 25 μW (10 μW at detectors is guaranteed figure)
Would require 2 μW per array to be consistent with the current ^{3}He fridge design unless the re-cycle time is reduced to ~ 24 hrs.
At 2 K, 1-2 mW depending on whether spectrometer or photometer.

- **Mechanical design:**

There is confusion over provision of mechanical mounting for arrays. The array systems document template makes it clear that the requirement is for array groups to provide modules that bolt to 2 K or 4 K, and provision is made for connectors and harness for electrical connection to 15K, and an interface to a 300 mK thermal strap.

- **Power consumption:** Need update from Christophe

- **BAU design:** No update

8. GSFC/NIST option

- **Concept (GV):**

  George Voellmer described how the 4 x 4 baseline array could be extended to 4 x 8, either by increasing the number of strips of pop-ups, or increasing the number of detectors in a strip. He noted that either way we would have 1 mm sq. pixels with few μm gap in both dimensions

- **System design (Jim)**

  - **Cold Power:**
    Max power dissipation on 300 mK 5 μW for three photometer arrays on at same time

    We need clarification as follows for both options (4 x 4 and 4 x 8):
    Photometer on: Dissipation 0.3 and 2 K and parasitics 2 K – 0.3 K
    Spectrometer on: Same

    JC/GV will clarify within a few days

- Warm electronics power: 9 W per row driver now – working to reduce this to 4 or less. Figures don't include power conditioning efficiency. Assume negligible warm power increase if go to 8 x 4 by increasing number of rows of detectors.
  If change to 4 x 8 arcmin: Increase rows – increase address lines – more wires
  Increase columns – power doubles – won't do this

- Wiring: Still working on requirements for impedance of harness. Very difficult to be specific now. Info will be required for May detector meeting.

Question: TES/FTS integration issue (thermal vs. electronic) – need to discuss the question with Harvey and Rick Shaffer.

- Warm electronics parts: Looking at this now. Need fast ADCs which are power hungry.

- Connectors: GSFC Electronics people don't like small connectors

8.1. Mechanical (George)

Comment: TC: If go to 4 x 8 need to reduce volume/area occupied by connectors. E.g. take ribbon cables all the way to 15 K. This could be very beneficial, and may be important in expanding the fov.

9. Feedhorn option (TC)

- **Wiring**

Kapton part of the ribbon cables suggested for 0.3-2K use dominates parasitics. 1 μW per array.
15-K to shell is the important harness for ESA
If wiring after the JFETs does not need inter-signal pair common ground for cross talk reduction, then the number of conductors would decrease eg for the 250 um array, it would be 122 conductors not 183.
We cannot decide on a commoning factor for shields until the cross-talk spec is set and modelled.
Is resonant freq. > 1 kHz really needed on low impedance side? – TC will check.

10. Warm Electronics (Christophe)

- **Synchronisation scheme:**

Current scheme	:	5 sequencers (one per array) FTS sequencers: position sampling triggered by FTS clock Photometer sequencers free running
Option 1	:	Three arrays in total (sharing between photometer and spectrometer) Three sequencers triggered or free running
Option 2	:	For CEA option, base on nine 16 x 16 arrays in total Advantage: only one sequencer (probably redundant)

- Chopper control electronics

Assumes synchronisation controlled by the chopper clock (similar to FPU)
Question for Jamie: Does AC bias need to be synchronised to sampling? Best to have one master clock from which the various other clocks are derived.

Aside: Note that GSFC may want to build some parts of the readout electronics.

- Important inputs still needed:
  FTS operation
  Chopper operation
  Peak-up mode with AOCS: ESA organising commonality meeting on communication between AOCS and instruments (in April).

- On-board processing details
  Final frame rate for photometer = 1.5 frames per second for photometer with 40 Hz image sampling rate
  With 200 kbits/sec we're close to being able to transmit the average of every chop ½ cycle to the ground when chopping at 5 Hz
    - No on-board deglitching and reduces on board memory requirements

  LR: If low number of glitches and no memory effects then just reject data for photometer, but can't do this for spectrometer

  Goal should be not to have to do any coaddition on board if we can possible manage it either for photometer or spectrometer.

But deglitching/coaddition needed anyway for GSFC

Action: Decide soon whether or not the level of on-board data processing we need to have can be accommodated totally outside the DRCU.

- Input data rates:

CEA : DMA not needed in SPU (1 data acquisition every 160 microproc. Cycles)
Feedhorn : DMA is needed (1 data acquisition every 4-5 microproc. Cycles)
TES : DMA is needed (1 data acquisition every 4-5 microproc. Cycles)

Do we need the SPU? Important to decide soon on this: action on WEOBS Group

Need preliminary list of housekeeping parameters to set H/K rate.
For each thermometer: accuracy, readout rate, etc.

- Questions/comments:
  RF shielding requirements for all options.
  TBCs OK now but need pretty good idea by PDR (i.e., May meeting for arrays)
  RF filtering - can we use a common kind of filter for each array type?
  Magnetic field shielding – specify by May.
  Action on PH from array meeting at QMW to specify the tests to be carried out – very important to do this soon.

- Data rate: Raw rate = 640 ksamples/sec. = 625 images/sec.
  Need to average to 10 frames per second (about 60 images)
  LR: New figure on limit to data rate is 200 kbits.

Question: Do we need filter at 300 mK? – There is an outstanding Action on Peter Hargrave/Peter Ade to define filtering scheme for SPIRE.

- Warm Power: 4 x 4: 25 W photometry ; 7 W spectroscopy
  8 x 4: Double

9. Cooler BMS

Thermal stability requirement: 150 nK $Hz^{-1/2}$ needs to be checked by GSFC and Saclay
Drift over timescale of 1 min.:
What's heat capacity of an array?

10. Questions:

- **Jamie's questions**

  Important point: 1Fλ horns no longer option for photometer –if we go for more detectors we will try to fill the FOV with approx. 300 2.F.Lambda horns in 4 x 8 arcmin field. Spectrometer TBD.

1. **Can 4 K or 15 K shield serve as RF faraday cage?** Yes, we will aim for 15K RF shield.
2. **What are the characteristic frequencies to block?** Not yet known, question for the FIRST EMC working group
3. **Any space qualification issues with passive RF filters?** Question for ESA meeting.
4. **Can the warm electronics box be electrically isolated from the spacecraft?** Not yet known, question for the FIRST EMC working group

- **BAU**

1. **What is the max dissipation on the dewar shell?** 2.5 W at present, but dependent on thermal design of the BAU.
2. **Can we assume placement of passive RF filters at the shield is allowable?** We'll ask ESA

- **Mechanical**

1. **Do we have a spec for the mechanical envelope?** BMS will send out sketch next week with proposed interface
2. **Which structure will be mechanically referenced to focal plane?** As above
3. **Light tightness of 2 K shield.** Light tightness is the requirement BMS will specify equivalent hole size

- **Electronics**

1. **Any feedback on the choice of A/D converter (see below)?** No. 16-bit ADCs may be approved (Burr-Brown ADS7807 or 09) – ask ESA to confirm. Maxim MAX 195 will be used on INTEGRAL.
2. **Any feedback on use of SPU for demodulation?** Looking at need for SPU. More info next week
3. **We need to know details of power supply lines.** We have no information on quality of power supply lines, allowable switching frequencies etc.
4. **A guideline on acceptable power dissipation.** Will be covered on March 15

- **Connectors** We strongly urge qualification of 51- and 100-pin MDM connectors. We'll include on parts list for approval
- **Optics** What are the current prospects for the 4 x 8 arcmin FOV? Baseline = 4 x 4. VERY DESIRABLE goal = 4 x 8.

Date of next meeting: 19 May (the day before the Detector Array Group Meeting in Pasadena)

SPIRE Systems Team Meeting March 4, 5 1999

Actions

AI-ST-0399-1	GSFC + JPL	Provide updated thermal numbers (don't include margin)	10 March
AI-ST-0399-2	MJG/BMS	Generate updated FTS sensitivity model	31 March
AI-ST-0399-3	CRC	Outline calculations on crosstalk – inter-wiring capacitance – needs for 1% or 0.1% crosstalk	31 March
AI-ST-0399-4	MJG/BMS	Look at actual need for a 2-K box	8 March.
AI-ST-0399-5	MJG	Check status of Fr funding/resources for 99/00	15 March
AI-ST-0399-6	BMS	Circulate revised SSRD (2 weeks)	20 March
AI-ST-0399-7	J-L A	Compare solutions in draft document in preparation for meeting on the subject on March 24/25 at Saclay.	15 Apr
AI-ST-0399-8	MJG/BMS/ WKG/CRC	Specify number of bits needed for photometer (15 probably overkill)	31 Mar
AI-ST-0399-9	MJG/BMS	Provide draft spec for calibrators	31 Mar.
AI-ST-0399-10	PH	Specfy in detail the tests to be carried out in BACUS	15 Apr.
AI-ST-0399-11	TC/JJB	Clarify whether or not 1 kHz resonant freq limit necessary for low impedance side of JFETs	8 Mar.
AI-ST-0399-12	PH/PARA	Write note on filtering scheme for SPIRE	15 Apr.
AI-ST-0399-13	BMS	Specify additional items for V1 of ASDDs	7 Apr.
AI-ST-0399-14	Array teams	Wiring systems etc in V1 of ASDD: Redundancy philosophy	May1
AI-ST-0399-15	Sys. Team	Decide whether or not the level of on-board data processing we need to have can be accommodated totally outside the DRCU.	15 May
AI-ST-0399-16	WEOBSG	Address the issue of whether the SPU is needed	24 Mar