SPIRE

Instrument Science Verification Review

Completion Review

Board Report

26-27 June 2000 (CEA/Saclay, France)

Board Members	*Signature*	*Date*
M. Anderegg **ESA/ESTEC/SCI-PS**	…………………………....	…………….
O. Bauer **MPE – Garching**	…………………………....	…………….
D. Beintema **SRON – Groningen**	…………………………....	…………….
P. Estaria **ESA/ESTEC/SCI-PT**	…………………………....	…………….
A. Heske **ESA/ESTEC/SCI-PT**	…………………………....	…………….
M. von Hoegen **ESA/ESTEC/SCI-PT**	…………………………....	…………….
T. Passvogel **ESA/ESTEC/SCI-PT**	…………………………....	…………….
G. Pilbratt **ESA/ESTEC/SCI-SA**	…………………………....	…………….

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1. Introduction

The Completion meeting of the Instrument Science Verification Review (ISVR) of the Spectral and Photometric Imaging Receiver (SPIRE) was held on 26/27 June 2000 at CEA, Saclay. This meeting completed a set of previous partial review meetings on the FPU (7/9 July 1999), the Warm Electronics (6/7 December 1999) and the detector selection meeting, held on 2 February 2000. The earlier reviews (reports are annexed) are considered integral elements of the ISVR, that is a formal review as defined by ESA for the instrument developments. The ISVR was combined with the instrument internal Preliminary Design Review as the objectives of both reviews could be covered.

The ISVR completion meeting was held on 26/27 June 2000 at CEA in Saclay and this report provides the Review Board findings, conclusions and recommendations.

2. Review Objectives

The review objectives of the Instrument Science Verification Review are defined in the ESA document “FIRST/Planck Instrument Reviews”, SCI-PT/FIN-06692, i.e.

The objectives for the ISVR are recalled below for convenience, i.e. to demonstrate that:

- the instrument conceptual design has been finalised, i.e. is compatible for achieving the instrument performance
- the instrument design will achieve the anticipated science objectives
- the overall interface requirements definition has been finalised
- the conceptual design for on-board software has been finalised
- the conceptual design for the necessary MGSE, EGSE and OGSE has been finalised.

The detailed objectives given by the SPIRE team in addition on the Instrument PDR are

- to show that instrument design has matured to a state such that it is credibly compatible with the instrument requirements
- to show that the proposed instrument can be built with the available resources and in time for launch in 2007.

3. SPIRE Instrument Science Verification Review Board

The review board for the ISVR and the Instrument PDR consisted of the board members listed below.

Name	*Affiliation*	*Function*
M. Anderegg	ESA	(System)
O. Bauer	MPE	
D. Beintema	SRON	
P. Estaria	ESA	(Operation/SW)
M. von Hoegen	ESA	(PA)
A. Heske	ESA	(Interface)
T. Passvogel	ESA	(Chair/Management/Development)
G. Pilbratt	ESA	(Science)

4. Proceedings of the Review

4.1 Documentation reviewed

The list of documents reviewed is given in Annex 1.

4.2 Presentations

Presentations were given by various members of the SPIRE team on 26 and 27 June 2000 at CEA, Saclay.

4.3 Panel Meetings

The Board members, with the exception of M. Anderegg and M. von Hoegen (both excused), attended the presentations at CEA.

5. Board Findings and Recommendations

The Board would like to congratulate the SPIRE Team for the progress made and design status reached at the ESA ISVR, respectively the PDR and considers the objectives of both reviews fully achieved.

The board was satisfied with the level of detailed design already achieved for several SPIRE assemblies or units. Items to be mentioned here are

- Beam Steering Mechanism
- Overall Mechanical Design of the Focal Plane Unit
- Optical analysis including alignment and diffraction
- 0.3 K sorption Cooler.

The Board also identified the following areas of the SPIRE instrument that need attention and asks SPIRE to consider and resolve these issues prior to the Detailed Design Review in autumn 2000:

- The Board is seriously concerned about the current size of the SPIRE System Engineering Team and supports SPIRE's intentions to strengthen this team. The Board urges SPIRE to realise this built up in the near future in order to avoid negative impact(s) on the SPIRE development, system design and analysis.

- SPIRE presented a first iteration of a bottom up development schedule. This schedule appears not yet fully validated and consistent. In several cases the schedule for subsystems, units and components seem to follow need dates defined by the SPIRE project, and consequently result in a delivery of the instrument units just in time with nearly no margin. The Board is concerned about the credibility of this schedule and its fidelity and asks SPIRE to consolidate it with all subsystem responsibles and to identify means to re-introduce margins in the planning. The board would like to ask SPIRE to specifically review the schedule of the design and manufacturing of the FPU structure. This appears to be a schedule driver and SPIRE should find ways to reduce the total duration, e.g. by freeze of subsystem interfaces and/or optimisation of the design for easier manufacturing.

- The Board takes note of the statement from SPIRE that the funding for all elements of SPIRE is secure, however, very tight. In view of the funding limits the board considers the requested actions on the system engineering team and schedule extremely important.

- An overall Instrument Design Description Document is missing for SPIRE and the board asks SPIRE to establish this document reflecting the baseline design.

- The Board notes that the SPIRE science requirements document is no longer fully in line with the actual baseline design of SPIRE and asks SPIRE to consider update to achieve consistency.

- The Board notes the large number of specifications and development plans produced for the review, and would like SPIRE to put the existing documents in context to the instrument system documents and to update the SPIRE Instrument documentation tree accordingly. It is noted that the SPIRE Instrument Development Plan was not reviewed by the Board, since not available in due time.

- SPIRE plans to issue above 100 Interface Control Documents. The Board feels that this high number will cause confusion and lead to the overview being lost. It asks SPIRE to consider rationalisation of the interface documentation.

- The Board considers the FTS mechanism a complex design and challenging development. The Board would like SPIRE to intensify the efforts put in this development. The question of μ-vibration level at the FPU and corresponding control loop should be clarified in near future.

- The Board asks SPIRE to address within the near future the failure modes of the complete instrument (FMECA) and to identify the corresponding degraded operations modes.

- The Board asks SPIRE to clarify the definition, functionality and intended use of the Instrument S/W Simulator.

- The Board notes that there exist several discrepancies in the terminology used in and contents of various documents presented. It asks SPIRE to remove these inconsistencies.

- The Board notes that no decision has been reached yet on the need to include a SPIRE parallel mode. It urges SPIRE (and PACS) to complete the investigations required to reach a yes/no decision by the end of the year.

- In the area of commonality of SPIRE with the two other FIRST instruments, HIFI and PACS, it appears that each instrument started a development on black paint. The Board would like SPIRE to explore the possibility of a common development.

- The Board would like to specifically mention the following areas where input from the spacecraft design definition or the ESA project is needed in support to the SPIRE development:

  - FIRST Telescope
  - Electromagnetic Compatibility (EMC)
  - Cryogenic Harness
  - Cryostat mechanical and thermal interfaces to the Focal Plane Unit and the JFET box
  - Structure noise (μ-vibration) for the FTS.

6. Board Conclusions

The Board recognises the significant progress made by the SPIRE team throughout the sequence of reviews over the last year that finally led to the ISVR close out review/instrument PDR and considers the objectives fully achieved.

The Board considers it very important that SPIRE find ways in near future to strengthen the system engineering team.

The Board expects SPIRE to consolidate the development schedule with all subsystems and to identify means to increase margins.

The Board asks SPIRE to formally reply in due time to all above findings and recommendations (paragraph 5, except the last item) and does not see a need to issue separate Review Item Discrepancy (RID) notes.

ANNEX 1

1. SPIRE Specifications

#1 SPIRE Test Facility Requirements Specification Draft 1.1, CLRC, 12.06.2000 **(PT07936)**
#2 SPIRE Spectrometer Mirror Mechanism Subsystem Specification, LAM, LAM.PJT.SPT.200002 Ind 4, 09.05.2000 **(PT07937)**
#3 SPIRE Calibrators Subsystem Specification, QMWC, 03.04.2000 **(PT07938)**
#4 Subsystem Specification Document Beam Steering Mechanism, Issue 1.0,ATC, 13.06.2000 **(PT07939)**
#5 FIRST SPIRE DPU Subsystem Specification Document, Draft 2, IFSI CNR, 13.06.2000 **(PT07940)**
#6 SPIRE Instrument - Filters Subsystem Specification, Draft 1.0, QMWC, 16.05.2000 **(PT07941)**
#7 SPIRE Mirrors Specification - LAM.PJT.SPI.SPT.200007 Ind 1, 06.06.2000 **(PT07942)**
#8 SPIRE DRCU Subsystem Specification - Sap-SPIRE-Cca-25-00 Issue 0.2, CEA, 14.06.2000 **(PT07943)**
#9 SPIRE Sorption Cooler Specifications - SBT/CT/2000-18 Issue 1 rev. 2, CEA, 05.2000 **(PT07944)**
#10 SPIRE FPU Thermal Mathematical Model Specification - SPIRE-RAL-SP-xxx, Draft 1, CLRC, 24.05.2000 **(PT07945)**
#11 SPIRE Scientific Requirements - Version 2.0, W. Gear & M. Griffin, 14.06.2000 **(PT07946)**
#12 Instrument Requirements Document - 0034 Issue 020, .21, .30, .31, 15.09.99, 30.11.99, 05.2000, 25.05.2000 **(PT07947)**
#13 SPIRE Structure Subsystem Specification Document – SPIRE-MSS-PRJ-0000427 Issue 1.0, MSSL, 13.06.2000 **(PT08011)**
#14 FIRST SPIRE Bolometric Detector Arrays Subsystem Specification Document - Draft 1, JPL, 16.06.2000 **(PT08013)**

2. SPIRE Development Plans

#15 Detector Readout Control Unit and Warm Interconnect Harness Development Plan - Sap-SPIRE-JLA-xxxx-00 Issue 1.0, CEA, 06.06.2000 **(PT07948)**
#16 SPIRE Instrument - Filters Subsystem Development Plan – Draft 1.0, QMWC, 16.05.2000 **(PT07949)**
#17 SPIRE Mirrors and Alignment Tools Development Plan - LAM.PJT.SPI.NOT.200006 Ind 1, L.A.M, 13.06.2000 **(PT07950)**
#18 FIRST-DPU/ICU Subsystem Development Plan - F-13.06.00 Issue 1, IFSI CNR, 13.06.00 **(PT07951)**
#19 SPIRE Sorption Cooler Development Plan SBT/CT/2000-19 Issue 1 rev. 1, CEA Grenoble, 05.2000 **(PT07952)**
#20 SPIRE Calibrators Subsystem Development Plan Draft 1.0, QMWC, 03.04.2000 **(PT07953)**
#21 SPIRE Beam steering Mirror Subsystem Development Plan V1.0, ATC, 13.06.2000 **(PT07954)**

#22 SPIRE Shutter Development Plan - SPIRE-USK-DOC-000001 Issue 0.1 (Draft), 0.2 (Draft), 29.05.2000, 15.06.2000 **(PT07955)**
#23 SPIRE Test Facility Development Plan - Draft 1.1, CLRC, 19.06.2000 **(PT07956)**
#24 SPIRE Spectrometer Mirror Mechanism Subsystem Development Plan - LAM.PJT.SPI.NOT.20001 Ind 5, LAM, 06.06.2000 **(PT07957)**
#25 SPIRE Structure Development Plan – SPIRE-MSS-PRJ-0000426 Issue 1.0, MSSL, 11.06.2000 **(PT08012)**

3. SPIRE Interface Control Documents

#26 DPU/DRCU Electrical Interface Control Drawing - Sap-SPIRE-Cca-xxxx-00 Issue 1.0, CEA, 18.05.2000 **(PT07958)**
#27 ICD 1.1/1.5.2 Structure - SMEC-m - SPIRE-PRJ-MSS-0000298 Issue 0.1, 1.0, 13.01.2000, 14.06.2000 **(PT07959)**
#28 ICD 1.1/1.2 Structure-Optics - SPIRE-MSS-PRJ-000294 Issue 0.1, 0.2, 0.3, 1.0, 08.99, 05.2000, 06.2000, 13.06.2000 **(PT07960)**
#29 ICD 1.1/1.3 Structure/Cooler - SPIRE-MSS-PRJ-000331 Issue 0.1, 0.2, 0.3, 1.0, 01.2000, 05.2000, 05.06.2000, 13.06.2000 **(PT07961)**
#30 ICD 1.1/1.2.1 Structure - Filters - SPIRE-ICD-1.1/1.2.1 Issue 0.1, 1.0, 20/08/99, 13.06.2000 **(PT07962)**

4. Design Description

#31 DPU/ICU On Board Software User Requirements Document - Draft 3.1, IFSI CNR, 13.06.2000 **(PT07963)**
#32 Optical Design - Diffraction Analysis & Design - SPIRE-RAL-DOC-000 Issue 1.0, 14.06.2000 **(PT07964)**
#33 FIRST SPIRE: Optical Error Budgets - LOOM.KD.SPIRE.2000.002-DRAFT, LAM LOOM, 22.05.2000 **(PT07965)**
#34 SPIRE System Budgets - SPIRE/ATC/DOC/???? Issue 1.1, 14.06.2000-07-04 **(PT07966)**
#35 SPIRE Electrical System Design - Sap-SPIRE-Cca-xxx-00 Issue 1.0, CEA, 18.05.2000 **(PT07967)**
#36 Mass Budget FOB Version 1.0, 08.06.2000 **(PT07968)**
#37 SPIRE Straylight Model Update Draft Notes, 14.06.2000 **(PT07969)**
#38 SPIRE Optical System Design Description - SPIRE-LAM-DOC Draf1 1, LAM, 25.05.2000 **(PT07970)**
#39 SPIRE Operating Modes for the SPIRE Instrument - Doc. Nr. 000320 Draft 1.0, 2.0, 2.1, 2.2,12.11.99, 30.11.99, 04.04.2000, 14.06.2000 **(PT07971)**
#40 SPIRE Instrument AIV Plan - SPIRE-RAL-DOC-000410 Issue 1, 25.05.2000 **(PT07972)**

ANNEX 2

SPIRE FPU PDR REVIEW COMMITTEE REPORT

Summary Statement

The review committee heard a very detailed presentation of the level of design of the Focal Plane Unit (FPU) of the SPIRE instrument on 7-9 July 1999. This review is the first of four SPIRE instrument reviews that form the complete instrument PDR. The further reviews are in November 1999 (warm units), January 2000 (detector selection), and March 2000 (Instrument PDR completion). We were quite impressed with the state of the design at this point and with the proposed capabilities of the instrument. The development plan for SPIRE also seems well organized and likely to lead to successful completion of the instrument. There were a number of issues, though, that came up during our discussions that we think should be addressed by the SPIRE team within the instrument PDR cycle in order to minimize risk during the development. We discuss these below in the context of the three areas we were asked to consider during our review: capability of SPIRE to meet its science goals, overall compatibility with the FIRST mission, and the likelihood of the development plan to lead to a successful and on-time completion of SPIRE.

## *I.	Capability of SPIRE to meet its science requirements/goals*

The SPIRE instrument as presented to us appears very well suited to meeting its science goals. The large focal plane coverage with simultaneous imaging at three wavelengths will be an excellent tool for both the prime science goal of deep extra-galactic surveys and many other science goals in extra-galactic, galactic, and solar system astronomy. The Fourier Transform Spectrometer (FTS) portion of the instrument is clearly important to be able to determine redshifts of interesting objects found in surveys as well as to perform astrophysical analyses of the state of the matter in any of the objects studies.   There are several issues relevant to meeting the science goals that need further study or consideration, however.

(1) It was not completely clear to the committee how the science data from SPIRE would be analyzed to achieve the desired levels of performance given the realities of the FIRST telescope and spacecraft. In particular, the pointing performance of the spacecraft may affect the ability to perform the desired drift-scanning method of surveying. Modeling of this problem with expected spacecraft performance and SPIRE characteristics could be very important in planning the use of SPIRE (as well as in final design details of the detector modules and data acquisition electronics). A second issue in this category is the method of extraction of astronomical spectra from the FTS. Since the FTS essentially takes a difference of the SKY+TELESCOPE and an on-board "blackbody", the derivation of the true source spectrum clearly requires some kind of sky-differencing and removal of the calibrator spectrum. The committee was unsure how this would be accomplished and thought that some analysis and modeling of this issue is likely to minimize risk in the design of the FTS.

(2) SPIRE will be operating in a very high background environment relative to the natural sky background limit because of the telescope temperature relative to the wavelengths of operation. Therefore, stray light is clearly a VERY significant issue. The SPIRE team presented a detailed first analysis of this issue during PDR, but it is clear this must be an on-going issue. This stray-light analysis should continue through the entire instrument design and should be coupled with measurements as soon as possible on real optical models.

(3) Although improvements in spacecraft specs are always possible in the future, the promised data rate at this time of 100kbs is clearly less than optimum for SPIRE. The team should continue to examine the effects of this on all aspects of the instrument design (e.g. data compression) and operations planning.

(4) As mentioned later, the committee was somewhat worried about the level of design of the FTS at this point, and this issue is related to that concern. It appeared to us that the R=1000 goal on the FTS may be driving the design in a different direction than simply meeting the R=100 requirement would do. Although there are obvious scientific advantages in the higher resolution goal, there are clearly tradeoffs in FTS mechanism size, stage design, controller design, and even optics that are being made to achieve the higher resolving power. We recommend that the SPIRE team re-examine these tradeoffs relative to the science gain afforded by R=1000. Of course, this also depends strongly on completing the FTS design to the same level as the remainder of SPIRE.

(5) The cooler system for SPIRE is obviously a very critical single-point failure possibility that could completely eliminate SPIRE from operation on FIRST. The committee believes that some redundancy in the cooler

system is essential. This could involve either of several possibilities. A second cooler could be added either in parallel with the first one or better yet in a mode where one cooler was used for some of the arrays and one for the remainder of the arrays. Another possibility would be to use redundant heat switches, two in series and two in parallel. The various alternatives should be thoroughly studied, including all relevant parameters, i.e. design complexity, failure modes, resources (mass and thermal), level of achieved redundancy (protection against cooler failure). The decision on implentation of the selected redundancy concept should be based on this tradeoff.

II. Compatibility with the FIRST mission

The SPIRE instrument design at this point seems quite compatible with the FIRST mission as a whole. The continuing refinement of the design is unlikely to reveal any unexpected incompatibilities, but clearly issues like, thermal loads, pointing requirements, and EMI, must continue to be studied.

III. Development Plan

The development plan for SPIRE that was presented to us appears quite appropriate for completion of the instrument on time with relatively low risk. Aside from the natural evolution of the development plan to a greater level of detail, specific areas of development that appear to require further work during the "Delta-PDR" stage, i.e. up to completion of the instrument PDR cycle, are:

(1) Structural Design – The structural design at this time is very preliminary and almost no details of components and subsystems exist as far as we can see. We suggest that the issue of accessibility and replacement of subsystems (especially detector modules) without affecting the instrument alignment should be made a requirement. A similar issue that needs further analysis is the change in alignment of the instrument during cooldown, given the number of different materials proposed as structural components.

(2) FTS Design – For a system that is roughly half of the total SPIRE instrument, the details of this system are clearly critical to define as soon as possible, both the mechanical and control system design. This is one of the most important items requiring significant additional effort as soon as possible, since the committee felt that the current level of design was not at the "PDR" level. Early prototyping of the mechanism will be essential and should not wait for the design to finalize.

(3) Beam Steering Mirror (BSM) – We were presented only with estimates of the BSM performance and design details based on the ISOPHOT

chopper. It is now certainly appropriate to perform detailed design and modeling of the proposed SPIRE BSM system.

(4) Thermal Design – The thermal model of the FIRST focal plane and its interfaces to the cryostat require continued development, in line with the structural design work, since this feeds directly into issues like straylight, alignment, and basic instrument mounting, e.g. the possible mounting via "blades". This will presumably be an iterative process with the other instruments and the spacecraft.

(5) Shutter – The committee was convinced of the need for a "shutter" to perform functional testing on the ground at reasonable background levels. A design for such a shutter should be developed as soon as possible and tradeoffs between such a shutter versus a low-background "lid" on the cryostat should be examined.

(6) Detector Options – Although the SPIRE project has tried hard to develop the instrument design with 3 possible detector options, this committee strongly supports the choice of a date no later than Jan '00 for the detector selection in order to proceed with the detailed instrument design on an appropriate time scale. The CEA option appears to be resource-limited at this time, so the addition of further resources is likely to improve its chances of success, both at the down-select time and for CQM delivery.

ANNEX 3

Board Report

The SPIRE Warm Electronics Review (part II of the ISVR) took place on Dec 6/7 at IFSI, Rome. Taking into account that this review should be seen as a review internal to SPIRE, no RIDs will be raised. The RID system will be applied to the final ISVR meeting in March and those comments that will not have been answered by than will be transformed into RIDs.

The Board would like to thank the SPIRE team for their detailed presentations and for the open and fruitful discussions.

Statements and comments from SPIRE have been included wherever available.

Comments to the SPIRE Warm Electronics Review:

#1: Sorption Cooler Recycling
- It is not clear whether the sorption recycling is planned to be performed autonomously, ground controlled or any other way and which parameters are to be monitored. The impact of recycling of the cooler on the system operation need further to be clarified.
- How would SPIRE see the scenario if a recycling of the sorption cooler would be missed, i.e. one of the parameters to be monitored would indicate the cooler not being ready?

#2: S/C pointing accuracy during line scanning
- The pointing accuracy during the line scanning to be defined/specified by ESA.

#3: Safety switch off
- It is proposed by SPIRE to switch off safety parameters during commissioning and calibration. Since this is expected to be relevant for only a small subset of parameters, could SPIRE provide further information.

#4: Definition of modes
- Could SPIRE further elaborate on the difference between the standby and the observing mode, also, especially w.r.t. the system.

#5: Peak up mode
- In the case of the peak up mode SPIRE will feed back information into the AOCS, is this already defined properly.

#6: Compression of data
- The compression approach obviously depends on the detectors selected and is important for the warm electronics design. However, no approach is defined yet. Could SPIRE provide the plan to implement data compression in the instrument design.

#7: Burst Mode (?)
- It was not clear from the discussion whether there is a need from SPIRE of a burst mode or not. SPIRE to clarify the data transfer philosophy.

SPIRE:
The details of the data rate budgets (average and burst mode) are in need of clarification. SPIRE is assuming that an average data rate (science + H/K) of 100 kbs over 24 hrs is available. The value of the burst mode and the period for which it applies are not fully clear at present, and some definite specifications will be needed soon to allow the SPIRE electronics and OBS to be designed.

Action: Bruce Swinyard/Ken King to write a note explicitly detailing how the instrument is to be operated and how the data transfer occurs.

#8: Partner Mode

- The scientific benefit of the partner mode of SPIRE with PACS is not evaluated yet, could however affect the S/C and GS interfaces and resources. SPIRE should, together with PACS, perform an evaluation of the scientific benefit of the partner mode.

SPIRE:
The feasibility and desirability of this mode are still uncertain. ESA would prefer to keep the operating modes as simple as possible and avoid this mode if possible. Neither the SPIRE nor PACS instruments are being designed with partner mode observations in mind. Its feasibility will depend on observing modes, sensitivities and compatibility with FPU power dissipation and data rate budgets, and presumably on ground segment/scheduling constraints.

SPIRE recommends keeping it as a possibility for now and making a decision once the instrument designs are finalised. In the meantime, Matt Griffin will consult with Albrecht Poglitsch to provide an up-to-date assessment of the viability of Partner mode to the next FST meeting.

#9: Model Philosophy

- The use of the different units for the different tests appear not yet optimum and should be reviewed with ESA, i.e. use of QM1 instead of the AVM for the CQM tests?

SPIRE:
We accept that more clarity is needed from SPIRE on the purpose and specification of the various units and on the kind of parts to be used.
ESA also need to be clear on what they need each of the instrument models for and what the test philosophy will be with each of the instrument models – this will help SPIRE to clarify what functionality and tests are required for each of the models and simulators.

Action: Bruce Swinyard/ESA to consult and clarify the requirements on the CQM and AVM.

It was noted that the first model of the DPU must be built before the appointment of a spacecraft contractor. This will pose potential problems with interface definition, and may limit the subsequent design flexibility on the spacecraft side.

#10: Harness capacities

- One of the detector options requires a maximum capacity (and knowlegde in advance ?) on the cryo harness wires. It is not yet clear what system impact this requirement has (ESTEC to evaluate).

#11: Delivery of PFM instrument

- The delivery of the PFM instrument is, according the presented planning 5 months after the need date. This seems driven by the warm box electronics. SPIRE to provide detailed planning for the warm boxes and propose ways to recover the delay.

SPIRE:
Potential schedule delay is building up. A slip in the launch date is to be avoided at all costs. Once the instrument development plans are complete, it will be useful to revisit the issue of the PFM instrument development and the spacecraft AIV schedules with the aim of optimising the overall AIV schedule consistent with an early 2007 launch.

There is a lack of homogeneity in the subsystem development plans which is difficult to avoid at this stage as the detector selection has not yet been made, and the overall AIV flow is still not certain. Much attention will need to be paid to this in the immediate aftermath of the detector selection.

Action: Bruce Swinyard/Ken King to review the AIV plan and make it all more realistic and coherent.

#12: Document control

- The documentation referred to in various SPIRE documents are not in all cases at the last status. SPIRE to correct/update the document references in their documents. (ESA to consider a central document status lists)

SPIRE:
It was noted during the meeting that there is a need to ensure the availability and use of up-to-date versions of key documents. Some thought on how best to do this is needed on the part of ESA and the instrument teams. Having documents deposited on DMS is insufficient as updates may pass unnoticed. A better scheme might be to maintain a well-publicised web page with the current versions of all key documents.

#13: Temperature measurements

- SPIRE requires the s/c to measure temperatures at various locations in the SPIRE units. Nominally the s/c would control interface temperatures only. Could SPIRE clarify the needs for temperature monitoring by the s/c inside their units, also considering that the baseline is that all instrument warm units will be on all time.

#14: SPIRE Budgets

- The presented budgets for the different units of SPIRE are not always compatible. Could SPIRE assure consistency?

SPIRE:
No definite figures are available from ESA for the instrument teams to work to.
The SPIRE DRCU box may need to be split in two for thermal/mechanical reasons.
The table summarising the SPIRE power dissipation for each option needs to be filled in.
The accounting for power converter efficiency should be uniform for the different detector options so that their warm electronics power requirements can be properly compared.

Action: Christophe Cara or Jean-Louis Augueres to write a document explicitly laying out the expected system design of the DRCU; grounding scheme; subsystem interfaces; power distribution etc. and the array groups to take this as their starting point (the information exists it just needs clarification and collation).

#15: DRCU Nominal operation

- In the nominal operation modes of SPIRE the DRCU dissipates different amounts of power. This will affect the SVM temperatures. It is expected that SPIRE goes to one single dissipation mode, when non prime, to be in line with the needs of HIFI. The rule that should apply is that only the prime instrument is allowed to change its power dissipation (warm units and FPU).

#16: Detector Selection

- The three detector options of SPIRE do have different needs of resources from the spacecraft. SPIRE to summarise the resource requirements for the three detector options and elaborate with ESA the corresponding attribution of needs to the selection.

#17: OBDH interfaces

- It appeared from the presentation that SPIRE needs further information on the interface to the OBDH. SPIRE to provide questionnaire on information needs.

#18: Component quality level

- The proposed component quality level for the different units are not consistent within SPIRE and not in line with the ESA requirements. SPIRE to clarify.

#19: DRCU to DPU high speed communication link

- What is the reason to implement a high speed communication link between DRCU and DPU if the compression is already performed in the DRCU, i.e. the data rate should be compatible with the 1553B?

#20: Microprocessor selection

- Two different microprocessors are planned to be implemented for SPIRE. In view of the commonality with the other four instruments of FIRST and Planck and the fact that a separate microprocessors will be very costly, from procurement, development tools and maintenance point of view, SPIRE should revisit the selection. SPIRE to clarify why the DSP 21020 cannot be used in the DRCU.

  SPIRE:
  The SPARC has been identified as a good solution for SPIRE, and is close to being space qualified. Although SPIRE is the only one of the five instruments using the SPARC, and this is a departure from total commonality, SPIRE does not see this as a major issue.

#21: DRCU Conceptual Design Completion

- The presented design concept of the DRCU exclude the detector readout part since the detector selection has not yet been performed. However, it is considered that this element of the unit will require considerable effort. SPIRE to initiate work on the conceptual design of the detector readout part of the DRCU, especially w.r.t. sharing of tasks and control between DRCU and DPU, OBSW, and data compression.

  SPIRE:
  A proper description of how the detector data stream is generated is needed for all options. The JPL design is not currently compatible with the requirements or the proposed interfaces to the DRCU.
  As noted above, a document is needed clearly setting out the DRCU system design, as noted above. The contents exist in various viewgraph presentations, notes and e-mails - it just needs to be brought together. The sub-systems can then design against this.
  Complete FPU sub-system specification documents are needed so that the design of the warm electronics can proceed.
  Detailed system operation must be defined shortly after detector selection.
  The overall AIV plan contains a number of inconsistencies and is incomplete: it must be defined in more detail and made to be internally consistent.

#22: Buffer amplifier unit

- Is it correct that the BAU will be requested by all three detector options?

#23: FTS preamplifier

- It appears that is a potential need for a preamplifier of the FTS at the level of the CVV. Could this be clarified by SPIRE?

  SPIRE:
  The location of the 100-K ampifiers for the FTS position sensing system should be clearly specified.

  Action: Didier Ferand/Bruce Swinyard to confer and make the specification.

#24: DRCU compatibility with the needs from the FTS

- It was not clear from the presentation that the DRCU is compatible with the needs of the FTS. Could SPIRE further elaborate on the implementation?

#25: Thermometry

- It is noted that the inner temperatures of the SPIRE FPU will not be measured during cryostat bake out at around 80°C.

#26: Shutter Specification

- There is no specification on the SPIRE shutter existing at present. SPIRE should provide an outline of the requirements and needs from electronics (DRCU).

  SPIRE:
  The warm electronics to drive the shutter is in the DRCU for two reasons:
  (i) operation of the shutter in flight is still, under consideration;
  (ii) this is convenient for ground testing.

#27: Instrument Operation

- The actual instrument operation will to some extent depend on the selected detector option. How and when will this be included in the SPIRE definition?

#28: On-board Software

- It was noted that the on-board software was not addressed in detail during this review.

  SPIRE :
  The OBS was not included in this review, for a number of reasons:
  - A common framework for instrument commanding is not yet defined (a paper has been produced by Ken King and is under review).
  - The SPIRE detector selection in early February will have implications for the OBS.
  - We intend to split the OBS requirements into two separate URDs (respectively for the DPU and the DRCU) and a DPU/DRCU ICD. A first draft of the DPU/ICU OBS URD has recently been produced by IFSI, and needs to be reviewed and revised if necessary to take into account the sharing of tasks between the DPU and the DRCU which has not fully defined yet.

  The OBS will be covered in Phase 4 in April.

Additional comments from SPIRE:

#29: Grounding scheme, cryoharness definition and EMC
- We need electrical definition of the FPU + cryoharness for the grounding scheme definition. The final grounding scheme for SPIRE will therefore need to be defined after detector selection. A working group involving ESA and the instrument teams is needed to address grounding and EMC issues.

#30: RF filtering
- This is customary for sensitive bolometer instruments, and is only specified as a requirement for the NTD germanium detector option. The reasons why it is thought not to be required for the other options need to be clarified, or else it should be baseline for them also. Note that the RF filter box is specified as a deliverable for the array-providing group in the *SPIRE Product Tree*.

#31: DC-DC converter synchronisation
- SPIRE wishes to have the option of synchronising the DC-DC converters and expects to receive the necessary synch pulse from the spacecraft. This shold be included in the relevant section of the IID-B.

#32: Cooler thermal control
- It is not clear who is actually responsible for this – there is an inconsistency between the presentations by Bruce Swinyard and Louis Rodriguez.
  Better resolution on the temperature control will be needed.

  Action: Bruce Swinyard to consult with array groups to define specification for required temperature resolution.

#33: BSM control system
- PACS are planning to carry out the real time control of their chopper using the CPU in the DEC/MEC (the equivalent of our DRCU). The possibility of doing the same for the SPIRE BSM should be analysed as it may avoid the need for dedicated control electronics.

  Action: ATC to check their control system processing requirements against the performance of the SPARC chip.

#34: BSM flex pivots (not really a subject of this review but noted in passing):
- The reliability of the commercially available flex pivots proposed for the BSM needs to be verified.

Garching, Dec 23, 1999
O.H. Bauer

ANNEX 4

SPIRE Detector Array Selection Meeting
RAL February 2 2000

This meeting took place at the end of the two day meeting of the SPIRE Detector Array Group at which the three detector options were presented and discussed. This document is intended as a purely factual account of what was said at the meeting.

Attendance:

External advisers:	Paul Harvey	
	Erick Young	
	Göran Pilbratt	
	Thomas Passvogel	
The Selection Team:	Jean-Paul Baluteau	Project Scientist
	Jamie Bock	Caltech/JPL
	Walter Gear	Project Scientist
	Matt Griffin	PI
	Ken King	Project Manager
	Harvey Moseley	Goddard
	Bruce Swinyard	Instrument Scientist
	Laurent Vigroux	Co-PI
Technical experts:	Peter Ade	QMW
	Kent Irwin	NIST
	Louis Rodriguez	CEA

Apologies from: Jean-Michel Lamarre (external adviser)

1. Introductory remarks

Matt Griffin made some introductory remarks, emphasising the following points.

- If we made the right decision, we would all be winners in the array selection.
- Although individual members of the selection team might be biased one way or another, collectively, the group should be able to come to a rational and fair decision.
- The advisers and each member of the selection team would be expected to argue strongly and courteously for whatever option they considered to be the best for the scientific success of SPIRE and FIRST, and all such views should be respected.
- An important question was the reality of the FIRST schedule and the credibility of the launch date to which the instrument teams were working.

  He asked the ESA project team members present to comment on the solidity of the current project schedule. Thomas Passvogel and Göran Pilbratt confirmed ESA's intention to launch in early 2007. If anything, an earlier launch might be favoured, if S/C AIT and/or launch campaigns do not need all allocated time or the contingency. ESA had some concerns about the ability of some of the instruments to deliver in time. A letter to the PIs was in preparation asking them to confirm the instrument teams' ability to meet the schedule. However, an important caveat was that the ESA budget beyond 2001 will depend on the outcome of the next ministerial meeting. The agency's ability to implement FIRST and Planck on the current schedule is therefore not yet guaranteed.

The following order for the advisers and selection team to make their comments and recommendations was proposed by Matt Griffin and unanimously approved:

Advisers	Paul Harvey Erick Young Jean-Michel Lamarre Göran Pilbratt Thomas Passvogel
Selection Team	Jean-Paul Baluteau Walter Gear Ken King Bruce Swinyard Laurent Vigroux Harvey Moseley Jamie Bock Matt Griffin

It was agreed that the speakers would make their comments in turn without discussion until everyone had spoken.

2. Statements

Advisers and members of the selection team were invited to make any statements that they felt might be relevant to or important for the decision

Erick Young said that the work carried out by all the groups in the course of the array programme was very impressive, and that it would be important to maintain unity within the consortium after the selection.

3. Comments and recommendations of the external advisers

Paul Harvey:

- The CEA detectors appear to be limited by 1/f noise at low frequency and speed of response at higher frequency
- The GSFC detectors can work within a wider range of parameter space, but are also subject to 1/f noise
- A major consideration is the lack of heritage in either of the filled array options
- He had been contemplating a situation in which one or other of the filled array options would have demonstrated good system performance at this stage.
- The fact that further development was needed would place a heavy burden on the filled arrays even though there was an advantage to be gained
- Overall, in the case of the filled array presentations, there had been too many statements of the form "we don't quite understand that yet". This might be acceptable for a PI instrument such as SOFIA but not for a major satellite instrument such as FIRST-SPIRE
- He had been impressed by the quality of the BOOMERANG data and its proof that the feedhorn technique can work

- Recommendation: Feedhorn option

Erick Young:

- Having participated in around six space projects, an important lesson he had learned was that even that which is "easy" and based on well-established technology is hard to implement.
- Two major issues for the selection were technical readiness and complexity. To assure success, it was wise to go for a system as simple and ready as possible.
- The CEA option was simple in principle, with its monolithic fabrication and simple control electronics
- The GSFC option was more complex relative to that. It required high data transfer rates, many FPGAs, and a lot of signal processing.
- The JPL option was complex in that many individual channels had to be implemented
- These factors also had to be considered in the light of the balancing requirement for technical readiness.
- Some concerns with the CEA approach were:
  The performance was not well characterised by theory.
  There were concerns about the low-frequency performance of the MOSFETs
  The production of the cold MOSFET readout electronics was not simple. (In the case of SIRTF-MIPS, several production runs (even though based on well established technology) had to be undertaken, and the yield had been low. This emphasised the point that "even the simple is difficult".)
- The JPL arrays were best in terms of technical maturity.
- The basic system performance of the JPL arrays was the best demonstrated: they had been used many times in real instruments and produced excellent data. The detector performance parameters were well controlled and theoretically well understood.
- In terms of system resources, both of the filled array options stretched the available data rate. The GSFC option also put pressure on the mass, power and volume.
- In order to develop and build the instrument on schedule, the feedhorn option was best.
- Recommendation: Feedhorn option

Jean-Michel Lamarre:

Jean-Michel Lamarre was unfortunately unable to attend the Array Selection meeting. He had provided some comments by e-mail. These were circulated to the attendees and read aloud by Matt Griffin at this point. The comments are reproduced below.

> *The most mature solution is surely the Caltech array. It is proven and spider web bolometers have demonstrated performances that I could measure myself.*
>
> *I know (nearly) nothing about the Goddard array.*
>
> *I have looked at CEA array with some care. I consider that*
>
> *1) It is hardly ready now for competition in the announced terms.*
>
> *2) It is very promising. In particular, pixels seem to work as very sensitive bolometers.*
>
> *3) Significant work has still to be done for optimal operation. This is especially true for the readout scheme. Improving the scheme of the cold electronic end and adding a J-FET stage at intermediate temperature would help getting a low noise, EMI immune array. This may be also true for other*
> *aspects, as the choice of several parameters for the array fabrication.*

4) If CEA can commit themselves to implement these improvements in a (reasonably) short delay this solution should be looked at with great attention. The advantage for SPIRE, and especially for its camera would be very significant.

5) The delays in industrial phase B may open the opportunity of choosing a more risky solution, while keeping the Caltech option as a back-up. Especially, we have learned that FIRST and Planck would not have to be integrated as a single satellite, due to the increased launch capability of ARIANE V, that allows to use the SPILMA interface. I expect from this change a later integration of both satellites. Although nothing is official now; one should ask for more information.

Al this thinking is done with only part of the story in mind. It comes mainly from the difficulty I have to accept that SPIRE, to be launched in 2007..., will not benefit from the advantage of filled arrays that seems to be at reach.

A discussion followed about the possibility noted in Jean-Michel's e-mail that with the enhanced lift capacity of Ariane V, the option of delivering FIRST and Planck as separate spacecraft could now be considered. An important question was whether this could lead to some saving of time in the spacecraft-level integration. This might allow a relaxation of the instrument schedule providing some more time for detector development. Thomas Passvogel made the following comments. The main advantage of this approach would be simpler interfaces, and the main disadvantage would be higher mass. The ITT for the spacecraft contract will not specify that the Carrier option has to be adopted. The current spacecraft AIV schedule include a system-level vibration which would be eliminated if FIRST and Planck were completely separated. This could save something on the order of three months. ESA might press for this to be used to speed up the schedule and have an earlier launch. The aim would be to complete the AIV in as short a time as possible and then launch. In his view, this issue was not a major consideration for the SPIRE detector selection.

Göran Pilbratt:

- The decision on which detector option to go for could be approached in two ways. A simple approach would be to look at the selection criteria as laid out in the meeting documentation. In that case at most one option was selectable, with the JPL feedhorn option coming closest.
- One must also consider however, the anticipated science return. On considering the relative performance of the filled arrays and feedhorn arrays, he had realised in the last few days that the potential advantages of the filled arrays were not as great as he (possibly naively) had previously believed.
- Putting these two considerations together, one must ask what potential gains are achievable through adopting a filled array option and what are the risks involved in so doing, compared to the scientific performance of the clearly more mature feedhorn option.
- He was not convinced that the potential gains outweighed the risks that would be introduced (schedule/heritage/developments needed, etc.).
- Recommendation: Feedhorn option

Thomas Passvogel:

- The filled array mapping speed advantage was 2-3.
- Looking at the technical level reached by each of the technologies, he believed that neither of the filled array options was ready to be implemented in FIRST.
- It was a pity that only one option could be selected, but the only viable one was the feedhorn option
- Recommendation: Feedhorn option

4. Comments and recommendations of the Array Selection Team

Jean-Paul Baluteau:

- He would concentrate on the spectrometer only
- Two worries were:
  (i) The required dynamic range was reaching the 16-bit capacity for the feedhorn option without compensation.

  (ii) The spectrometer might suffer from "stitching" problems associated with detectors having different fields of view. He was not sure which of the two options was best to address this problem - this will depend of the operating mode(s) effectively in use, which will be defined later. However he had the feeling that the filled arrays should give a possible significant advantage from the fact they are more correctly sampling the field of view. For low resolution spectra, it would be very important to be able to combine the sub-spectra from the two bands.

Walter Gear:

- He noted a consensus in the earlier discussion in the main meeting that one should not take major risks for a factor of two or so.
- The imager had dominated the analysis and discussion leading up to the selection, at the expense of the spectrometer
- The CEA detectors had good potential and amongst the three options, this technology had the unique possibility of extension to very large formats. The future for such applications lay on the ground and with SOFIA. For SPIRE, the uncertainties over the readout and the detector parameters meant that selection was not an option.
- The GSFC detector concept was beautiful and elegant. It was closer to being able to demonstrate the required sensitivity. Again, however, consideration of systems issues led one to conclude that it was not ready for selection.
- The JPL feedhorn option had almost demonstrated the necessary performance. The heritage of this technology was tremendous. One could be confident that it could be successfully implemented and that it would work. It was the only feasible choice.
- Recommendation: Feedhorn option

Ken King:

- He would confine himself to programmatic issues only.
- Given the schedule, a huge amount of work would be need to implement *any* of the options.
- He noted the point made by several people that the benefit of a potential factor of 2-3 in observing time might not justify the risk involved. This would favour choosing the option with the most heritage/least risk/least required development.
- An important issue not raised by others was the implications for operations and the ground segment.
- It was generally true that being able to get all the data down to the ground in the rawest possible form was a big advantage.
- Having fewer detectors could also make calibration and testing simpler
- The feedhorn option was less dependent on the BSM for proper performance.
- All these considerations led him to recommend the feedhorn option.
- A notable disadvantage was that the feedhorn option was more reliant on good telescope pointing.
- Recommendation: Feedhorn option

Bruce Swinyard:

- To choose filled arrays there would have to be big scientific benefits.
- The CEA detectors appeared to be "boxed in" in terms of parameter space for their optimisation.
- The GSFC option was worryingly complex
- Both filled array options posed problems of data compression which in his view had not been satisfactorily solved.
- Recommendation: Feedhorn option

Laurent Vigroux:
- Prior to dealing with technical matters, he would make some comments on political issues.
- The funding situation for CEA and the French participation in SPIRE: The array development had been supported by CEA and CNES because of the link with FIRST as a space project. This support would be terminated in the case of the CEA arrays not being selected. This was not the case for the other two array types.
- It is unfair to say that the feedhorn option is better because it is more mature at this stage of the process. This was known from the very beginning. If it is the only selection criteria, this should have been said 3 years ago. We would have avoided to start an expensive development. It was surprising that people were taking this attitude. Because of this attitude, the work done over the last three years was being negated.
- FIRST is a European mission. If the JPL option were selected, then the two largest European missions (FIRST and Planck) will both be flying American detectors.
- Space projects were a good way of promoting detector technology.
- ESA's record in promoting detector development for FIRST and Planck had been very poor.
- If a non-European option were to be chosen for SPIRE, this would be a very bad situation for the future of FIR/submillimetre astronomy in Europe.
- The BOOMERANG data shown at the meeting were very impressive. He recalled the selection of ISO in 1983, when the presentation of fresh IRAS data at the key meeting had been a big factor in the decision. But nobody at the time was suggesting that the IRAS-type detectors should be flown: the intention was to fly more advanced detector arrays. This showed that even if BOOMERANG is a success, that does not mean we should fly the same technology.
- It had been said that the BSM is a single point failure for the filled arrays. This was not true. The 1/f noise could be reduced by the electronic chopping technique, as had been demonstrated for the CEA arrays. The preferred mode for the CEA detectors would be not to use the BSM but to raster and scan.
- The point about filled arrays needing more time for calibration/flat-fielding due to the larger number of detectors was not valid - it would need around the same time.
- His own assessment of the technologies under consideration was
  CEA had made a working 16x16 array
- The CEA option was the best in terms of what had been tested and compares most closely with the flight version.
- The high responsivity needed to overcome the MOS noise was demonstrated. It had been claimed by some people that this could never work.
- The noise was still high, even though the last test at QMW showed an NEP in static mode of 6E-17 W $Hz^{-1/2}$, with a dynamic mode performance about a factor of two worse.
- Many aspects of the detector performance were not yet completely understood.
- Electronic chopping was a very promising method of reducing the 1/f noise below the limit needed.
- Overall, the performance was very close to the specification.
- Many prototype detector arrays were available to test, and he was confident that the next generation would show improved performance.
- In the last year, 1-2 arrays per month had been produced. None of the other technologies were capable of doing this. A typical batch would involve 40-50 different arrays and readouts. The

technology involved no "hand-made" elements - it was fully integrated and controlled using mass production techniques.

- In terms of system complexity, the CEA option was simpler than the other solutions.
- Stray light is a potential problem, but careful optical design looks to have solved this.
- The thermal dissipation levels are now acceptable, and there are no unusual requirements on the cryoharness. The readout electronics are conventional.
- Overall, the CEA option was very close to being proven
- It would be difficult to understand another option being selected on the basis of perceived greater maturity
- For the FTS, there would be an advantage in terms of the required dynamic range.
- He was convinced that filled arrays offered better image quality for SPIRE.
- Filled array technologies will be implemented in other facilities, and we must consider the situation seven years from now.
- It had always been assumed up to now that a single array technology should be used for both the FTS and the photometer. There was a definite time constant constraint in the case of the FTS, but no such constraint in principle for the photometer. One could consider having different detector types for the spectrometer and photometer. It would be necessary in any case to have different readout electronics even with the same detector type. Such an option could satisfy all of the constraints that need to be considered (technical and political). It would also involve having a back-up solution and be less reliant on continued NASA funding. The danger of relying totally on only one detector procurement opportunity should not be ignored. But if such an option were considered, CEA would not be satisfied with just being the back-up solution.
- Recommendation: CEA option

Harvey Moseley:

- The TES programme had started out three years ago with good ideas and concepts It had now progressed to the stage where very good detectors had been built.
- It was true that the electronics for the GSFC/NIST option were more complex than for the others.
- It was unsurprising that the feedhorn option was being favoured for SPIRE, with the project taking a risk-averse approach.
- The GSFC/NIST team were very happy to have had the opportunity to develop the TES technology, and would continue to do so.
- The level of talent and dedication that had gone into this work were extraordinary. It was a pity not to be selected but it was a fact of life.
- The CEA detector architecture and system design were very elegant, but the device physics posed problems and the optimisation was in a performance corner with not much room for manoeuvre.
- He noted that the XRS instrument was a factor of 13 away from the specification when selected and was about to be launched. this showed that it was possible to take and to manage risk.
- He understood many of the points expressed in this meeting, and the conservatism they embodied, but believed that alternative approaches could lead to improved performance.
- In the event of a delay to FIRST, the instrument capabilities should be reviewed - there was a danger of being scooped scientifically.
- All in all, he was proud of his team and what they had achieved.

Jamie Bock:

- As a scientist who is enthusiastic about technology, he had enjoyed the detector array programme and
- the interaction with all the other participants.
- The CEA detectors had a good format and impressive fabrication techniques.
- The GSFC/NIST option was based on a concept with a proven fundamental advantage

- Ultimately, NTD Ge technology would be superseded.
- All space missions fly out-of-date technology but must be able to make big scientific advances in spite of this fact.
- In the US, NASA funds technology as a generic activity, and this policy ensures that the US is strong in that area.
- He was looking forward to the time when FIR/submillimetre arrays will be available in the same way as InSb arrays are today.
- Recommendation: Feedhorn option

Matt Griffin:
- He felt it inappropriate to abstain on this issue.
- He favoured the feedhorn option mainly because the potential benefits of the filled arrays were not enough to justify the amount of effort needed to realise them and the risks of various kinds involved.
- To achieve a mapping speed advantage of a factor of 2 or less, it would involve introducing a number of problems which must then be solved nearly perfectly to avoid cumulative degradation of the advantage (e.g., 1/f noise, data rate, stray light). Realistically, the advantage might be lost in practice.
- He would have no hesitation in arguing for a filled array option if he though that this were best for the scientific impact of SPIRE and FIRST, but felt that this was not the case.
- Recommendation: Feedhorn option

At this stage, Matt Griffin invited each speaker in turn to add to or modify their comments, having had the benefit of listening to what everyone else had to say. The order would be as before.

Paul Harvey:
- He would have liked to have chosen filled arrays. Perhaps if the gain had been a factor of 10 or more, this would have been justified.

Erick Young:
- The possibility of cooling the FIRST telescope to a temperature much lower than the currently envisaged 80-90 K should be seriously considered. the NTD Ge or TES detectors would be able to take advantage of the lower background.

  Comment by Laurent Vigroux: This is also true for the CEA detectors because the responsivity goes up as the detector operating temperature decreases.

Göran Pilbratt:
- He originally thought he would be arguing for a filled array option at this meeting, but still did not feel that the risks were justified, given the level of potential scientific performance gains that could be expected as presented in the observation speed comparison document. He noted that - despite specifically asking for comments - nobody challenged the actual calculations presented in this document. The notion of reconsidering the instrument capabilities in the event of a delay was not appealing - he could still see no reason to change from the feedhorn choice.

Thomas Passvogel:
- There were some questions of detail that had arisen in the comments made by others that he wanted to understand, but these were not major points and could be addressed off-line. He did not favour the option of having different detector types. His view on the selection were unchanged.

Jean-Paul Baluteau:

- It was very difficult to make an assessment. He was worried that we may be missing something in having to make a selection now.

Walter Gear:
- It was very unfortunate that a European option could not be chosen. But the European members of the consortium had a very good relationship with the Caltech/JPL group. Politics should not over-rule science.
- At the October 1997 meeting, he had argued in favour of the feedhorn option, more from intuition than from detailed analysis. Jamie Bock had started the analysis and that work was then extended and refined by himself and Matt Griffin. Had the results of that analysis been available in 1997, it is unlikely that the same decision would have been made then.

> *Comment by Laurent Vigroux: A factor of 3 in mapping speed is not to be dismissed. The FIRST surveys will take a long time. The real benefit from SPIRE will be the selection of objects from the survey to follow up. Faster surveys will therefore allow more time for the all-important follow up observations. It is the same order of magnitude which is provided by moving from a 4-m class telescope to an 8-m class telescope. If such a gain is negligible, why people have been so keen to built GEMINI or the VLT, which are far more expensive than an old 4-m telescope.*

On the question of mixed array technologies (feedhorn for spectrometer/CEA arrays for photometer), the argument would be stronger the other way around. He could not support this proposal.

Ken King:
- He was concerned that the time needed for CEA detector development would be too long.
- Having two technologies would make the instrument and its interfaces more complicated

Bruce Swinyard:
- His main worry was still the "performance corner" of the CEA detectors.
- In the case of the TES detectors, the system complexity was the main drawback.
- He agreed with Walter Gear that if a two-technology option were to be considered it would make more sense to have filled arrays for the spectrometer rather than for the photometer.
- The feedhorn detectors had the major advantage of low 1/f noise.

Laurent Vigroux:
- The option of having filled arrays for the spectrometer and feedhorns for the photometer could be considered.
- To keep the CEA technology alive, it would be necessary to link it with a space project
- Considering the factor of 2 increase in noise for the CEA option, this compensated for the factor of two mapping speed advantage, making the CEA and feedhorn options comparable in terms of performance. According to Criterion 2 in the Array Selection Criteria document, the CEA option should therefore be selected.

Harvey Moseley:
- The TES detector technology is well suited to implementing a filled array for the FTS.
- An alternative approach could be to have a small filled array of NTD spider-web bolometers for the FTS, thereby having a common technology.

Jamie Bock:
- If a much larger fraction of the FIRST focal plane were available for SPIRE, the optimum choice might be different.

- On the issue of filled arrays vs. feedhorns for the spectrometer, this depended on the relative importance of spectroscopy of diffuse emission vs. point source spectroscopy. In his view, sensitive spectroscopy of distant galaxies would certainly be an important objective for FIRST

Matt Griffin:
- The CEA detectors did not appear to be able to meet the speed of response requirement for the FTS.
- He viewed the additional complexity and workload that would be introduced by implementing two different detector array types would made this option very unattractive.

At this stage the meeting was interrupted for a lunch break.

5. Selection decision

When the meeting reconvened, Matt Griffin summarised the morning session as follows:

The feedhorn option had been recommended unanimously by the four external advisers who had attended the meeting. Jean-Michel Lamarre had expressed some support for the CEA option in his written communication before the meeting. The selection team had supported the feedhorn option with the exceptions of:

Jean-Paul Baluteau:	undecided
Laurent Vigroux:	opposed; favoured the CEA option.
Harvey Moseley:	opposed but unsurprised at the views of others

On the basis of the majority view which had been expressed by the advisers and the Selection Team members in favour of the feedhorn option, Matt Griffin then proposed that the Array Selection Team vote formally on the resolution that the feedhorn option be adopted for SPIRE. The voting was as follows:

Jean-Paul Baluteau:	Expressed reservation concerning the feedhorn option for the spectrometer. Expressed no view either way concerning the photometer.		
Walter Gear:	In favour		
Ken King:	In favour		
Bruce Swinyard:	In favour		
Laurent Vigroux:	Opposed	(a)	See comments below
Harvey Moseley:	In favour	(b)	See comment below
Jamie Bock:	In favour		
Matt Griffin:	In favour		

(a) Laurent Vigroux also made the following comments at this point:
- He opposed this proposal not just because he favoured the CEA technology.
- He was not convinced the there was any less risk in adopting the feedhorn option.
- The JPL test array had been damaged at QMW and not all performance requirements had been met.
- The need for craftsmanship in manufacture involves risk. With mass production techniques, reliability is better.
- The CEA system is simpler than the feedhorn system mechanically, electronically and optically, and the fabrication is under control.
- On-board data compression remains a problem but one that can be easily managed.

- There is therefore less risk in adopting the CEA option, and this is one of the main reasons for voting against the feedhorn option.
- His favoured option was to share the risk by adopting the feedhorns for the FTS and the CEA filled arrays for the photometer. That way both technologies are kept alive and one could move from one to the other in the future..
- He was not convinced that the filled arrays could be used with the FTS because of the need for fast detectors.

(b) Harvey Moseley also made the following comments at this stage:
- He still believed that the TES detectors could be produced with the necessary performance and within the schedule.
- The unwillingness of the project to take on a perceived risk might itself prove to be a risk.

Conclusion: The resolution was agreed

6. Discussion of related issues

There followed a discussion of the background to this decision, in which the following points were made.

Matt Griffin: This decision could be seen as a consequence of low investment in FIR/sub detector technology by ESA and the European Space agencies in recent years.

Laurent Vigroux: ESA TRP support had been given for HIFI and PACS technology but nothing for bolometers.

Göran Pilbratt: This point should be emphasised when the outcome of this meeting is reported.

Laurent Vigroux: CNES will find it difficult to accept the decision of this committee

Harvey Moseley: In contrast to FIR/sub groups, the X-ray community in Europe is active and well supported.

Laurent Vigroux: In the case of X-ray detectors, there is strong ESA support of the ESTEC group and PPARC has supported the UK community and its work with EEV.

Laurent Vigroux:
- CEA is not an organisation that is inclined to support fundamental R&D. The prospects for continued funding of the CEA arrays were not good.
- The provision of the SPIRE warm electronics by CEA would be carried out as agreed
- Some extra costs may be incurred to implement the JPL electronics design. This will not be a problem as long as the funding support is available.
- The money which supported the CEA detector programme will be lost to the project
- CEA is pushing for high tech development and applied research. With CEA not being selected, there may be some impact on the funding support for the warm electronics. Although he hoped personally that this would not be a problem, it was impossible to guarantee that, and this meant there was considerable risk.

Walter Gear expressed thanks to all the participants in the array development programme, especially the groups who were not selected. Matt Griffin echoed this on behalf of the whole team.

The meeting then ended.