SPIRE-QMW MOM-000051.10

SPIRE Bolometer Array Technology Meeting

NASA GSFC

September 17, 18 1998

Minutes of 3rd SPIRE Bolometer Array Group Meeting
NASA Goddard, September 17, 18 1998

Matt Griffin
6 October 1998

Note: 1. These minutes should be read in conjunction with the viewgraph package from the meeting, which contains most of the information.

2. The topics are ordered here as on the original agenda, not as actually presented at the meeting.

3. Actions are tabulated in Section 16.

4. Reports and action lists from three of the four splinter meetings have not yet been produced – they will be circulated when made available (splinter chairmen please note).

1 List of attendees

Peter Ade	QMW
Patrick Agnese	LETI
Bob Baker	GSFC
David Bergman	GSFC
Jamie Bock	JPL
Christophe Cara	CEA
Terry Cafferty	JPL
Colin Cunningham	UKATC
William Duncan	UKATC
Jason Glenn	Caltech.
Bill Gray	JPL
Matt Griffin	QMW
Erich Grossman	NIST
Hien Nguyen	JPL
Peter Hargrave	QMW
Ken King	RAL
Andrew Lange	Caltech
Bruno Maffei	QMW
Phil Mauskopf	Umass.
Harvey Moseley	GSFC
Christopher Paine	JPL
Carl Reintsema	NIST
Louis Rodriguez	CEA
Juan Roman	GSFC
Rick Shafer	GSFC
Bruce Swinyard	RAL
Anthony Turner	JPL
Laurent Vigroux	CEA

For contact details see viewgraph.

2 Review of SPIRE status and aims of meeting

Matt Griffin presented some introductory viewgraphs.

(a) The current status of FIRST

(i) The carrier option is now favoured by ESA, but budget problems remain for both the spacecraft and payload funding.

(ii) Confirmation of the mission implementation and payload approval is planned for early 1999.

(iii) European FIRST and Planck payload funding status was reviewed at a special meeting convened by ESA in July, and another such meeting is planned for October.

(b) The current status of SPIRE

(i) A double-FTS is being considered as an alternative to the classical Martin-Puplett FTS described in the SPIRE proposal. This would recover the 50% of the light lost at the input, but would involve increased mass and complexity. A decision will be made in January.

(ii) The wisdom of the choice of an imaging FTS for SPIRE has not been endorsed by the FIRST Mission Scientists.

(iii) The critical Structure and Systems Engineering work-packages are currently unfunded in the UK. The funding status of SPIRE in the UK will be clarified by the time of the October payload funding meeting.

(iv) The first technical meeting between SPIRE and ESA took place on July 29, and generated many actions on SPIRE, most of which have to be completed by October 10.

(v) The SPIRE project is now formally established, and the lines of communication and reporting must also become more formal.

(c) The main aims of this meeting

(i) Review the schedule and requirements for SPIRE detector array selection and qualification.

(ii) Establish the system design for each option.

(iii) Plan the testing and evaluation programme.

(iv) Review progress on array development since the Saclay meeting in May.

(v) Mid-term assessment of how well the array programme is going: are we being realistic?

The emphasis is very much on making it clear that array selection requires more than proof of detector performance – because of the short time available between selection and CQM manufacture, thorough systems designs and qualification programmes and credible fabrication schedules must be available for all of the options so that the chosen one can be rapidly implemented.

One of our most urgent needs is to produce first drafts of the systems design documents for the various options. These should include all firm information currently available, and TBDs, TBCs and questions for SPIRE or for ESA as appropriate, so that problems can be identified and sorted out before it is too late. It is the responsibility of the array groups to ensure that they do not de-select themselves by failing to raise critical issues before it becomes too late for us to deal with them internally or in consultation with ESA.

3 Schedule for detector evaluation, SPIRE PDR, CDR and CQM

Ken King presented the current SPIRE schedule, which is driven by the delivery date for the PFM (mid. 2004).

ESA will issue the ITT to potential spacecraft contractors in October 1999 and will require that all major spacecraft interfaces are frozen about six months before then (or if there are options, their spacecraft interfaces must be separately detailed)

Although CQM deliver to ESA has been delayed until early 2003, this makes no difference to us as we have to build and test the CQM before starting PFM manufacture. This results in a very tight schedule for detector array selection and subsequent detailed instrument design. If there is any slip in the schedule in the future (e.g., from a delay in the PFM delivery date) this will not be used to defer detector selection.

The schedule for Systems Design requires that the first draft of the Scientific Requirements Document be produced in the very near future, for which the Project Scientists are responsible. In particular, the decision on the FTS choice in January requires it.

A detector selection plan must be produced and available for ESA endorsement by the time of payload approval in early 1999.

4 Actions from the Saclay meeting

Bruce Swinyard reviewed the status of actions from the Saclay meeting. An up-to-date summary is given in section 16 below, together with a summary of new actions arising from this meeting.

5 Qualification programme

Bruce Swinyard presented the requirements and schedule for qualifying the detector arrays for SPIRE. This is a critical requirement for selection, and the schedule is worryingly optimistic. It is vital to carry out as much of the qualification work as possible before array selection.

See the viewgraphs for more details.

6 Systems design and array interface specifications

6.1 TES-Pop-up option

Mechanical design (Michael Amato):

The detector mechanical assembly and mounting scheme will be based on the design for the SOFIA HAWC instrument. It can be adapted for SPIRE, and it should be possible to accommodate it within the existing envelope (perhaps even a bit smaller).

It was agreed that the structure as presented could be employed for the purposes of array selection tests. A detailed description of the proposed design for SPIRE will have to be made available at the same time. Some characteristics (e.g. volume envelope, mass, connectors) need to be defined much earlier.

It may also be feasible (and would be highly desirable) to use a near-identical structure for the feed-horn option.

Some concerns were raised about the light tightness of the back of the assembly.

Electronics design (Bob Baker and David Bergman):

Important points which will need to be addressed are the readout rate, power dissipation and whether the electronics can be built with approved components. These questions need to be addressed as soon as possible, through provision of a first draft systems design document.

For the purposes of selection, the readout must be representative in that it should faithfully represent the impact, if any, of the readout on overall sensitivity and performance. Whatever is proposed for the flight instrument must at the same time be fully described in the systems design document.

6.2 Feed-horn option (Jamie Bock)

There are good prospects for employing the same basic mechanical configuration for either the TES pop-up or feed-horn options, and this will be investigated further by Goddard and JPL

It may be possible to bend the leadout wires into the perpendicular plane to reduce the area taken up by an array.

The noise specification form the JFETs is not very stringent because the detectors will be strongly photon noise limited (~ 20 nV Hz^{-1} for 5 MΩ operating resistance)
Considerable progress has been made on the FET box design since the last meeting, and a scheme for mounting the FETs on a silicon nitride membrane is being examined, which could provide a large reduction in the heat loads. It may be possible to avoid having any connection to the 30-K shield, which would greatly simplify the interface with ESA. The viability of this concept is still to be demonstrated in practice, so we should not rely on it too much at this stage. An outline design (summary of mechanical an thermal properties) will be prepared for ESA including both options will be provided to ESA for their comments.

It is important to examine the constraints on the number of detectors that can be fitted into the focal plane in the case of the feed-horn option. It may be feasible to enhance mapping speed by using more of the focal plane area. Using dc-stable detectors (little or no 1/f down to ~ 30 mHz) slow scanning modes (either using the telescope or the SPIRE chopper) could be used to modulate the signal.

Data rate and FPU mass should not be a problem – the limit may be set by the number of wires and connectors. This should be included as questions in the first-draft systems design document.

RF filtering is regarded as a potential problem, and an RF filter box (inactive) should be baselined for location at the outside of the CVV feedthrough (mechanically similar to the BAU for the CEA option, but with zero internal dissipation).

The first-cut electronics design incorporates 18-bit resolution, which is not feasible with current standard components. It is desirable that a baseline be identified which is consistent with current ESA requirements. At a later stage, it can be enhanced depending on what we are allowed to fly. The requirements on SPU memory and processing power should also be estimated.

6.3 CEA arrays (Louis Rodriguez)

This presentation included an update on technical progress since the last meeting (item 8). Measurements on absorption efficiency and bolometer characteristics were reported (see viewgraphs for details), Some problems have arisen with the grid structure, the implanted thermistors and power dissipation per array.

The combination of $R > 10^{10}\ \Omega$ and $C \sim 3$ pF results in a time constant of > 30 ms (< 5.3 Hz). Assuming that this time constant dominates the speed of response requirement (switching transients in multiplexing may also need to be considered), this is consistent with the photometer specification but may require the FTS drive to be slowed down. It was agreed that the combination of bolometer resistance, preamplifier noise and input capacitance needs to be carefully optimised for the CEA option.

While the thermal load does not need to be in spec. for the array evaluation tests, the proposed flight system must be demonstrated in a separate experiment to meet the allowed load.

The internal time constant of the absorber might influence the limiting speed of response, and should be calculated in a manner similar to what Jamie Bock has done for the spider-webs.

6.4 Summary of progress on systems designs and interface specifications (Bruce Swinyard)

See viewgraphs.

7 Evaluation criteria and plan for future meeting schedule (Matt Griffin)

A brief summary of the evaluation criteria was presented, based on the draft note circulated before the meeting (and attached to these minutes).

In discussion, it was agreed that the required array performance should be assessed by a complete analysis of the scientific performance of the arrays in the SPIRE instrument, with observing/mapping speed for faint point-like objects being the main figure of merit. Placing requirements on the detector parameters will not be enough. The response of the whole system must be modelled through simulations of SPIRE observations, adopting an approach similar to the one used in the note by Aussel, Vigroux and André on *Confusion noise in SPIRE surveys* (attached to these minutes). The splinter group on sensitivity (Splinter Meeting 2) would make a start on this.

Future meeting schedule (viewgraph is now out of date):

January 1999	QMW	Dates: Jan. 21, 22
May 1999	Caltech	
September 1999	Saclay	
January 2000	RAL (formal selection meeting: full documentation to be provided by mid-Dec. 99)	

The main aims of the January meeting will be:

(i) review and planning of the array testing programme;

(ii) review of the array selection criteria based on simulations of SPIRE observations for the various options;

(iii) review of the systems design documents for the various options and identification of further work needed before PDR. (Comment: it is assumed that these documents will be in a fairly mature state by January. An option for which this is not the case cannot be regarded as a serious candidate for selection.)

8 Array development progress reports

8.1 TES pop-up arrays (Harvey Moseley)

This report covered

- Detector electronics
- Test cryostat
- Mechanical design
- Squid multiplexer
- Detector tests
- Schedule for October - December

See viewgraphs for full details

8.2 Feed-horn arrays (Jamie Bock)

This report covered

- Problems encountered with Al/Ag film (degradation due to heating above 100 °C during sensor manufacture
- Results of measurements on TES sensors with Ti films
- Array design and development for feed-horn + NTD Ge option
- Related development of BOLOCAM
- Procurement and plans for the SPIRE test dewar

See viewgraphs for full details

8.3 CEA arrays (Louis Rodriguez)

See item 6.3.

9 BACUS status and array test plan (Peter Hargrave)

This report covered

- Design of BACUS module
- Cryogenics
- Optics
- Illuminators
- Connectors
- Summary of BACUS capabilities
- BACUS schedule

- Array test schedule

See viewgraphs for full details.

Note: The schedule and array test plan and schedule were discussed in the splinter meeting on the following day - see report below.

10 Presentations on technical issues

10.1 TES detector optimisation for SPIRE (Matt Griffin)

This presentation was a summary of the note *Specifications for TES-ETF bolometers for SPIRE* (SPIRE/QMW/NOTE/0043.20) by Matt Griffin and Peter Hargrave. The main conclusion, that for TES bolometers the thermal noise NEP should be designed to be around half of the photon noise limited NEP, was in agreement with the assessment of the Goddard/NIST team.

The need for having a cold shutter ($\leq$ 4 K) in SPIRE was also discussed. It was concluded that this would be highly desirable and possibly essential for ground testing at spacecraft level, given that the background level in the cryostat would be far higher than in orbit.

10.2 Simulations of SPIRE observations (Laurent Vigroux)

This presentation summarised the methods and initial results of the Saclay group study of simulated SPIRE deep survey observations and the relative performance of the different array options in terms of faint point source detection in a crowded field (Aussel *et al.*, attached).

It was agreed that this approach was the correct one for evaluating array performance. Various technicalities about the assumptions and methods should be discussed and agreed.

See the report on the Splinter Meeting 2.

11 Discussion following day 1

12 Summary of day 1

Due to pressure of time, these were conducted over drinks and dinner. Many wise and insightful things were said but nobody was taking notes.

13 Agenda review

14 Splinter meeting organisation

The four splinter meetings identified on the original agenda were retained.

15 Reports from splinter meetings

15.1 Array test programme (Peter Hargrave)

- 3 x BACUS scenario agreed (QMW/GSFC/JPL)
  - QMW to supply drawings & filters
  - RAL may supply some engineering effort

- Schedule: See revised schedule below
  - CEA prototype to QMW Oct. '98 for optical tests - retain 1 He-3 fridge (GSFC or JPL) until Jan. '99 for this purpose.
  - CEA iterative tests through '99.
  - NTD pixel to QMW early Dec. to characterise BACUS stray light environment.
  - Jan. - Feb. BACUS testing (QMW)
  - US BACUS modules to QMW Feb. '99 for verification.
  - Single pixel TES from JPL/CALTECH end '98
  - Expecting final arrays from all providers at QMW between Aug. '99 and Nov. '99
    - Phased delivery of US dewars in Sept. '99 and Oct. '99 - GSFC and JPL/CALTECH to decide between themselves who will have which delivery date.
    - Array groups to supply additional staff effort during QMW tests

- Interfaces/Tests: to be defined via template document between QMW and array providers within 1 month of Goddard meeting

List of actions arising from array test programme splinter:

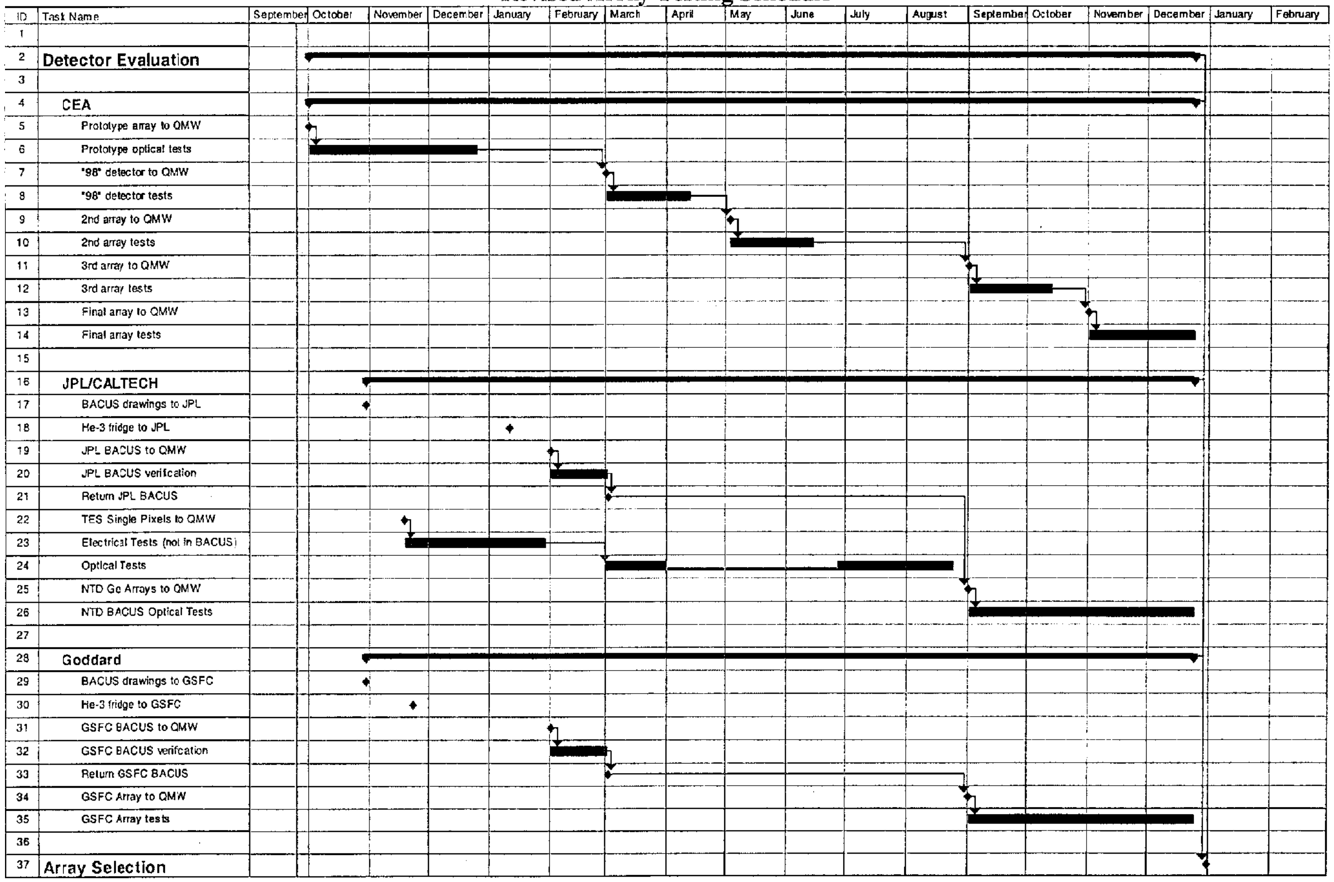
- QMW
  - supply BACUS drawings to GSFC and JPL/CALTECH (Oct. 23)
  - distribute interface/test document (Oct. 23)
  - QMW/RAL to perform stray light/baffling analysis on BACUS module
  - complete FIR illuminator tests (Oct. 23)

- CEA
  - supply prototype to QMW for optical tests Oct. '98
  - '98 detector to QMW March '99
  - next array to QMW May '99
  - next array to QMW Sept '99
  - final array ready for QMW tests Nov. '99

- GSFC
  - build GSFC BACUS and deliver to QMW for verification by Feb. '99
  - deliver final array in test dewar to QMW Sept./Oct. '99
  - supply illuminator modules for all three BACUS modules by Jan. '99

- JPL/CALTECH
  - TES single pixel to QMW mid November '98
  - NTD pixel to QMW early Dec. '98 for BACUS testing
  - build JPL BACUS and deliver to QMW for verification by Feb. '99
  - deliver final array in test dewar to QMW Sept./Oct. '99

Revised Array Testing Schedule



15.2 Array sensitivity and operating modes (Laurent Vigroux)

To follow.

15.3 Feedhorn option (Jamie Bock)

To follow.

15.4 Front-end electronics for US options (Louis Rodriguez)

To follow.

16 Summary of actions

The tables below show the status of actions from the previous meeting at Saclay and from this meeting. Actions which are closed or have been superseded are in the lighter typeface.

Summary of actions from Saclay meeting May 28, 29 1998				
No.	**Action**	**Responsible**	**Deadline**	**Status**
1	Provide template document describing common 2-K interface and circulate to the array groups for completion.	Swinyard	June 30	Closed (issued Aug. 28)
2	Provide detailed description of cryoharness for SQUID/TES options (detail required as in the IID-B).	Moseley, Bock	June 30	Superseded by Action TBD.
3	Co-ordinate further study of capabilities of filled and feed-horn arrays, especially for point source extraction (report to be presented at next meeting).	Gear	Sept. 17	Superseded by establishment of SPIRE Observations Sensitivity Group chaired by Laurent Vigroux
4	Define power and mass budgets for warm electronics and produce baseline functional description.	Rodriguez, Moseley, Bock	June 30	Superseded by Action TBD.
5	Define all the mechanical, electrical and thermal interfaces for BACUS	Maffei, Hargrave, array groups	July	Closed
6	Define detailed test plan for technology evaluation.	Maffei, Hargrave, array groups	Sept. 17	Superseded by Action TBD on Ken King to produce test plan
7	Send to Kent Irwin the details of the temperatures of the SPIRE interfaces with the FIRST cryostat	Griffin	July	Closed: as reported at meeting with ESTEC on July 29, Collaudin and Passvogel paper has latest available information from ESA (but these are not definitive numbers).
8	Specify ^{3}He cold stage temperature requirements for SPIRE and BACUS.	Rodriguez, Moseley, Bock	July	Open. Revised deadline October 7.
9	Specify which FPGA is being considered for the Goddard array control and readout electronics.	Moseley	June 30	Superseded by Action TBD.
10	Define how and by whom the back-up option will be developed in the US (using BOLOCAM and Planck design concepts where possible).	Moseley, Lange	Sept. 17	Superseded by actions from Feedhorn Option splinter meeting.
11	Define a draft schedule for future Array Group meetings, including formal selection meeting.	Griffin	Sept. 17	Closed.
12	Define the quantitative performance requirements and the make-up of the array selection team.	Griffin	Sept. 17	Open. New draft to be circulated by October 30.
13	Provide monthly reports on progress on the development programme to Matt Griffin, copied to Ken King	Rodriguez, Moseley, Bock, Hargrave	End of each month	Continuing. Future reports should include technical and schedule information separately.

Summary of actions from Goddard meeting, Sept. 17, 18 1998				
No.	**Action**	**Responsible**	**Deadline**	**Status**
14	Remind Project Scientists of urgent need for scientific specifications document	King	Sept. 25	Closed (E-mail of Sept. 23)
15	Produce draft array selection plan	King	Oct. 10	Open
16	Define ^{3}He fridge stability requirements for BACUS	Hargrave		Open
17	Attach the list of test that ESA will carry out on the various instrument models to minutes of this meeting	Griffin	Sept. 28	Closed (see viewgraph package)
18	Provide summary of FET box options to Thomas Passvogel based on input from Jamie Bock	Cunningham	Sept. 28	Open (deferred to Oct. 9)
19	Circulate expanded Interface Specification document template to include warm electronics, and re-name Systems Design Document	Swinyard	Sept. 25	Closed (E-mail of 24 Sept.)
20	Provide first-draft of Systems Design Document	Bock, Moseley, Rodriguez	Oct. 7	Open
21	Provide recommended volume envelope for detector arrays	Swinyard	Sept. 29	Open
22	Provide document describing proposed Spanish SPU capabilities to Caltech and Goddard	Swinyard	Sept. 25	Closed (E-mail of Sept. 24)
23	Provide written comments on existing draft of array selection criteria document to Matt Griffin	All	Oct. 30	Open
24	Revise array selection criteria document	Griffin	Nov. 13	Open
25	Ask Lionel Duband to provide cooling power vs. temperature curve for baseline ^{3}He fridge	Swinyard		Open
26	Copy ESA's Rosetta Parts List to array groups	King	Oct. 7	Closed
27	Define limiting resource dictating maximum permitted number of detectors in the focal plane for feedhorn option	Systems team	Nov. 13	Open
28	Investigate creation of new SPIRE workpackage for a cold shutter	Griffin	Oct. 9	Open
29	Array splinter meeting actions	QMW, CEA, GSFC, Caltech/JPL	Various	To be monitored through monthly progress reports and reviewed at January meeting

17 Summary of the meeting (Griffin)

Below are some comments (written after the meeting) assessing the outcome of the meeting with respect to the aims.

(i) Review the schedule and requirements for SPIRE detector array selection and qualification.

Success: all groups should now have a good understanding of what work needs to be done to meet the schedule.

(ii) Establish the system design for each option.

Very limited success: first draft system design documents have yet to be produced and are urgently needed and must be turned into comprehensive and detailed designs in the coming months.

(iii) Plan the testing and evaluation programme.

Limited success: The programme has been specified in more detail but there are still many uncertainties and potential problems with the success-orientated schedule particularly the fact that the evaluation tests for all of the options are scheduled so late in the programme.

(iv) Review progress on array development since the Saclay meeting in May.

Success: Progress has been reviewed.

(v) Mid-term assessment of how well the array programme is going: are we being realistic?

Success: it is now clear that an enormous amount of work needs to be done to fulfil the aims of this array programme. At present it is barely realistic, and any serious delays from now on will make it infeasible.

- Array development: good progress is being made in the lab., but not always as quickly as one would like.
- Systems designs: progress has been much too slow up to now and this must be rectified well before the time of the next meeting.
- Array test and evaluation schedule: this is very tight, and there are worries that the options will not have been properly developed and tested by the time of selection. In these circumstances, the only realistic choice will be to select the most conservative option.

SPIRE Bolometer Array Technology Meeting
NASA GSFC, 17, 18 September 1998

PROVISIONAL AGENDA

Day 1: Thursday September 17

1.	09.00	Welcome, logistics	Moseley
2.	09.15	Introduction • Review/revision of agenda • Status of FIRST and SPIRE • Aims of the meeting	Griffin
3.	09.30	Schedule for detector evaluation, SPIRE PDR, CDR, and QM manufacture	King
4.	10.00	Actions from Saclay meeting	Swinyard
5.	10.30	Qualification programme	Swinyard
6.	11.00	Systems design and interface specifications • Goddard/NIST • Caltech • Saclay	Array teams (30 min. each)
7.	12.30	Evaluation criteria and plan and future meeting schedule	Griffin
	13.00	**Lunch**	
8.	14.00	Array development progress reports and qualification plans • Goddard/NIST • Caltech • Saclay	Array teams (30 min. each)
9.	15.30	BACUS status and array test plan	Hargrave
10.	16.00	Presentations on technical issues:	
		• TES and semiconductor bolometer design for uncertain photon background	Griffin
		• Simulations of SPIRE observations	Vigroux
11.	17.00	Discussion following day 1	All
12.	17.45	Summary of day 1	Griffin
	18.00	End of day 1	

Day 2: Friday September 18

13.	09.00	Review of agenda; splinter meeting organisation	Griffin
14.		**Parallel splinter sessions**	
	09.30	1. Array test plan Hargrave, Maffei, Irwin, Rodriguez, Caltech, Goddard, Ade, Swinyard + others	Hargrave
	09.30	2. Array sensitivity and operating modes Bock, Vigroux, Griffin, + others	Vigroux
	10.30	3. Feedhorn option Cunningham, Bock, Duncan, Swinyard, Ade, + others	Bock
	10.30	4. Front-end electronics for US options Rodriguez, Caltech, Goddard, NIST, + others	Rodriguez
15.	11.30	Reports from splinters (~ 10 min. each)	
		1. Array test plan	Hargrave
		2. Sensitivity and operating modes	Vigroux
		3. Feedhorn option	Bock
		4. Front-end electronics	Rodriguez
16.	12.30	Review of actions from this meeting	Swinyard
17.	12.45	Summary and conclusions	Griffin

- Mid-term assessment of progress and likelihood of
  - (i) meeting the performance requirements on schedule;
  - (ii) establishing the systems design on schedule;
  - (iii) meeting the requirements of the qualification programme and the CQM schedule.
- Division of effort on the different options between now and selection
- Details of test plan
- Other issues . . . .

13.30 End of meeting

1

List of attendees

SPIRE DETECTOR ARRAY MEETING GSFC 17 Sept. 98

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29)			

2

Introduction

Status of FIRST and SPIRE
Aims of this meeting

Matt Griffin

Status of FIRST and SPIRE

FIRST

- Carrier is favoured option of ESA's SPC

  But ESA still have to fit FIRST and PLANCK into something not much more than 650 MAU

- Final mission confirmation and payload approval in February 199~~8~~9

- Funding status was reviewed at special meeting in July

- Another one planned for October

SPIRE

- Double-pass FTS option being studied as alternative to classical MP as in proposal
  - Decision in January

- Still need to convince Mission Scientists of wisdom of FTS choice

- Funding problem in the UK (Structure and Systems Engineering) needs to be sorted out by October

- First formal meeting with ESTEC project took place on July 29 – many actions on us to be completed by October 9 ⇒ not long after this meeting

- SPIRE project now needs to establish more formal and reliable lines of communication and reporting

Main aims of this meeting

1 Review the schedule and requirements for SPIRE detector array selection and qualification

2 Establish the system design for each option

3 Plan the testing and evaluation programme

4 Review progress on array development since the Saclay meeting in May

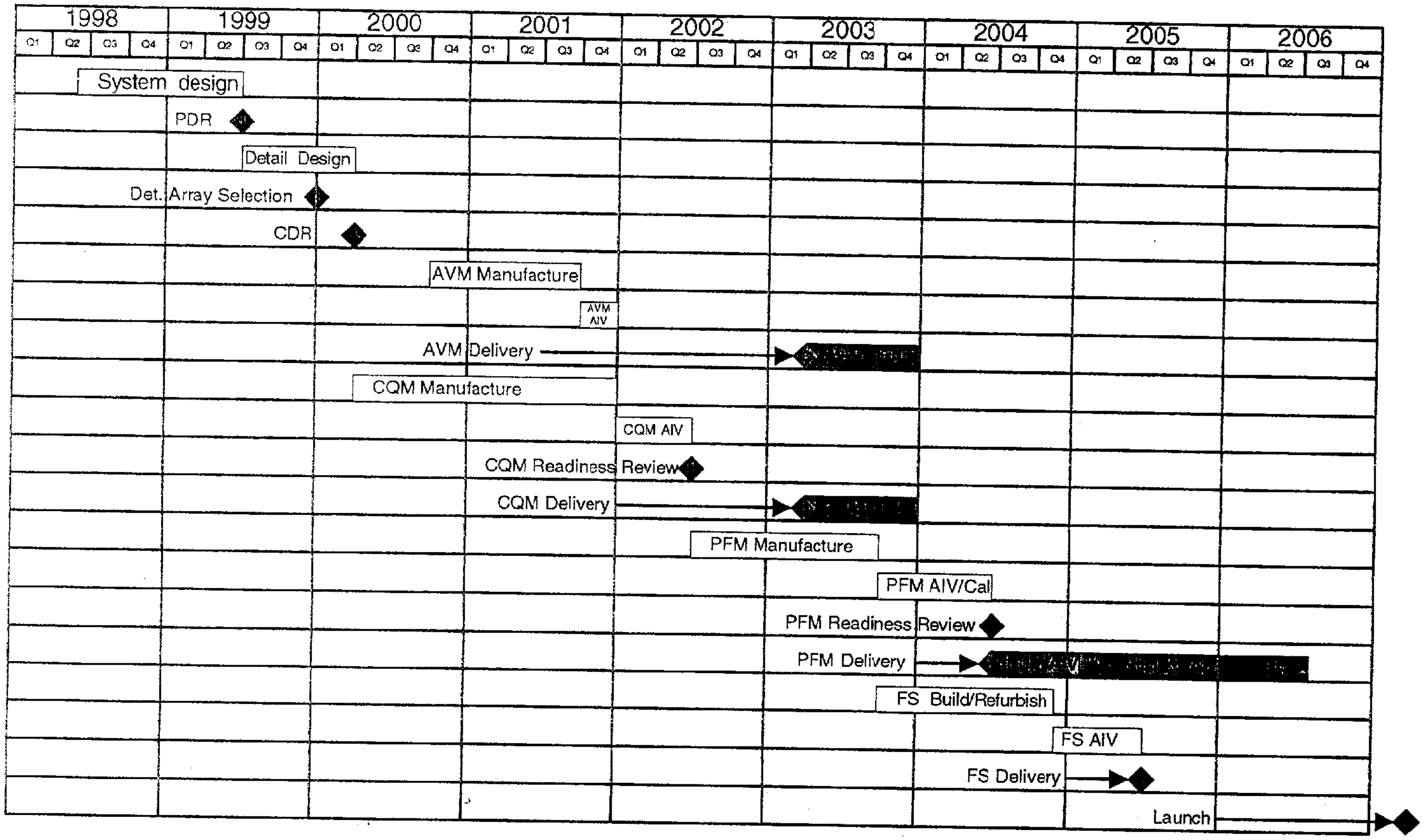
5 Mid-term assessment of how well the array programme is going: are we being realistic?

3

Schedule for detector evaluation, SPIRE PDR, CDR and CQM

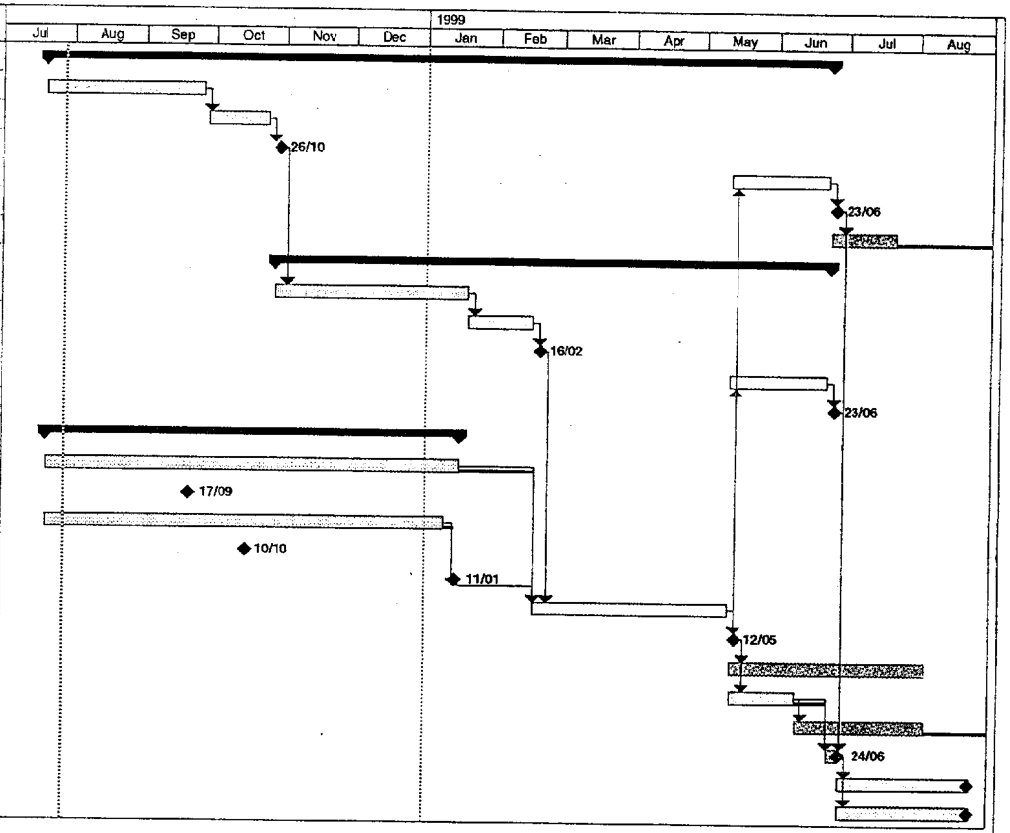
Ken King

SPIRE Instrument Development Schedule



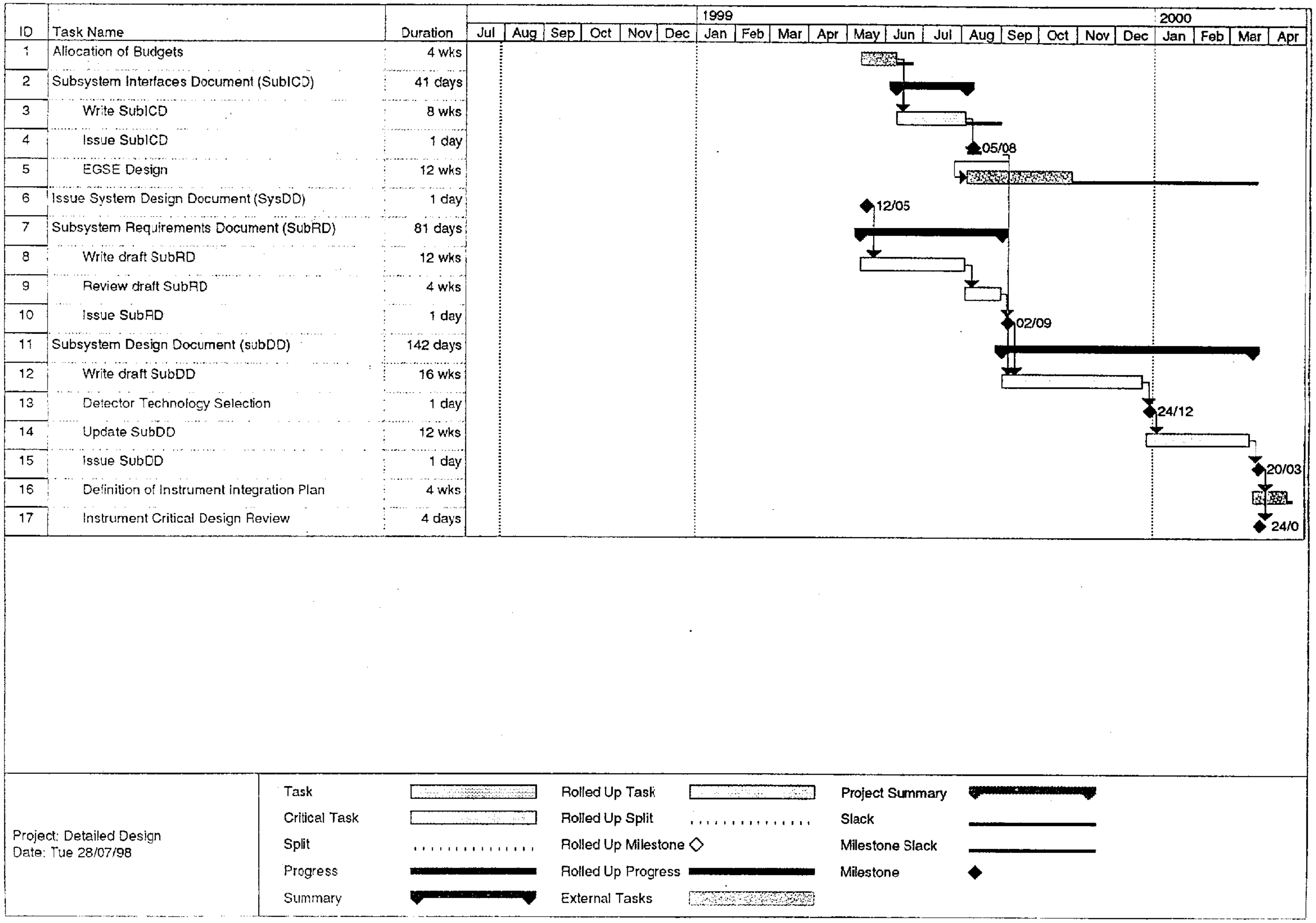
29th July 1998

ID	Task Name	Duration
1	**Science Requirements Document (SciRD)**	**243 days**
2	Write draft SciRD	10 wks
3	Review draft SciRD	4 wks
4	Issue draft SciRD	1 day
5	Update SciRD to Issue 1	6 wks
6	Issue Scientific Requirements Document	1 day
7	Definition of Scientific Calibration Requirements	4 wks
8	**Engineering Requirements Document (EngRD)**	**172 days**
9	Write draft EngRD	12 wks
10	Review draft EngRD	4 wks
11	Issue draft EngRD	1 day
12	Update EngRD to Issue 1	6 wks
13	Issue Engineering Requirements Document	1 day
14	**System Design development**	**130 days**
15	Detector design development	26 wks
16	Detector Meeting	2 days
17	FTS design development	25 wks
18	FTS meeting	1 day
19	FTS Design Selection	2 days
20	System Design Definition	12 wks
21	Issue System Design Document (SysDD)	1 day
22	Write draft SubRD	12 wks
23	Allocation of Budgets	4 wks
24	Write draft SubICD	8 wks
25	Instrument Preliminary Design Review	3 days
26	Provision of Mathematical Optical Model	8 wks
27	Provision of Mathematical Thermal Model	8 wks



Project: System Design
Date: Tue 28/07/98

Task	▨	Summary	▬	Rolled Up Progress	▬	Milestone Slack	—
Critical Task	☐	Rolled Up Task	▨	External Tasks	▨	Milestone	◆
Split	....	Rolled Up Split	....	Project Summary	▬		
Progress	▬	Rolled Up Milestone ◇		Slack	—		



ID	Task Name	Duration
1	Allocation of Budgets	4 wks
2	Subsystem Interfaces Document (SubICD)	41 days
3	Write SubICD	8 wks
4	Issue SubICD	1 day
5	EGSE Design	12 wks
6	Issue System Design Document (SysDD)	1 day
7	Subsystem Requirements Document (SubRD)	81 days
8	Write draft SubRD	12 wks
9	Review draft SubRD	4 wks
10	Issue SubRD	1 day
11	Subsystem Design Document (subDD)	142 days
12	Write draft SubDD	16 wks
13	Detector Technology Selection	1 day
14	Update SubDD	12 wks
15	Issue SubDD	1 day
16	Definition of Instrument Integration Plan	4 wks
17	Instrument Critical Design Review	4 days

Project: Detailed Design
Date: Tue 28/07/98

4

Actions from Saclay meeting

Bruce Swinyard

[see minutes]

5

Qualification programme

Bruce Swinyard

Detector Qual Programme

- Assumption is that at least one dedicated model of the complete detector sub-system will be passed through a qualification programme - this is to be termed the "Type Approval Model".

- In a "classical" space project this will have happened BEFORE the instrument CDR. [OR WITH A DEDICATED QM]

  Not possible for the detector sub-system. [ON SPIRE]

- As much as possible of the detector sub-system qualification must be done before the CDR

  Freeze interfaces as early as possible

- The arrays and cold readout electronics qualification programme won't really start until after array selection.

Detector Qual Programme

- Need to identify:
  - What is to be done
  - When it is to be done in the qualification programme
  - How representative the components need to be for the test in question
  - Who is going to do it

Detector Qual Programme

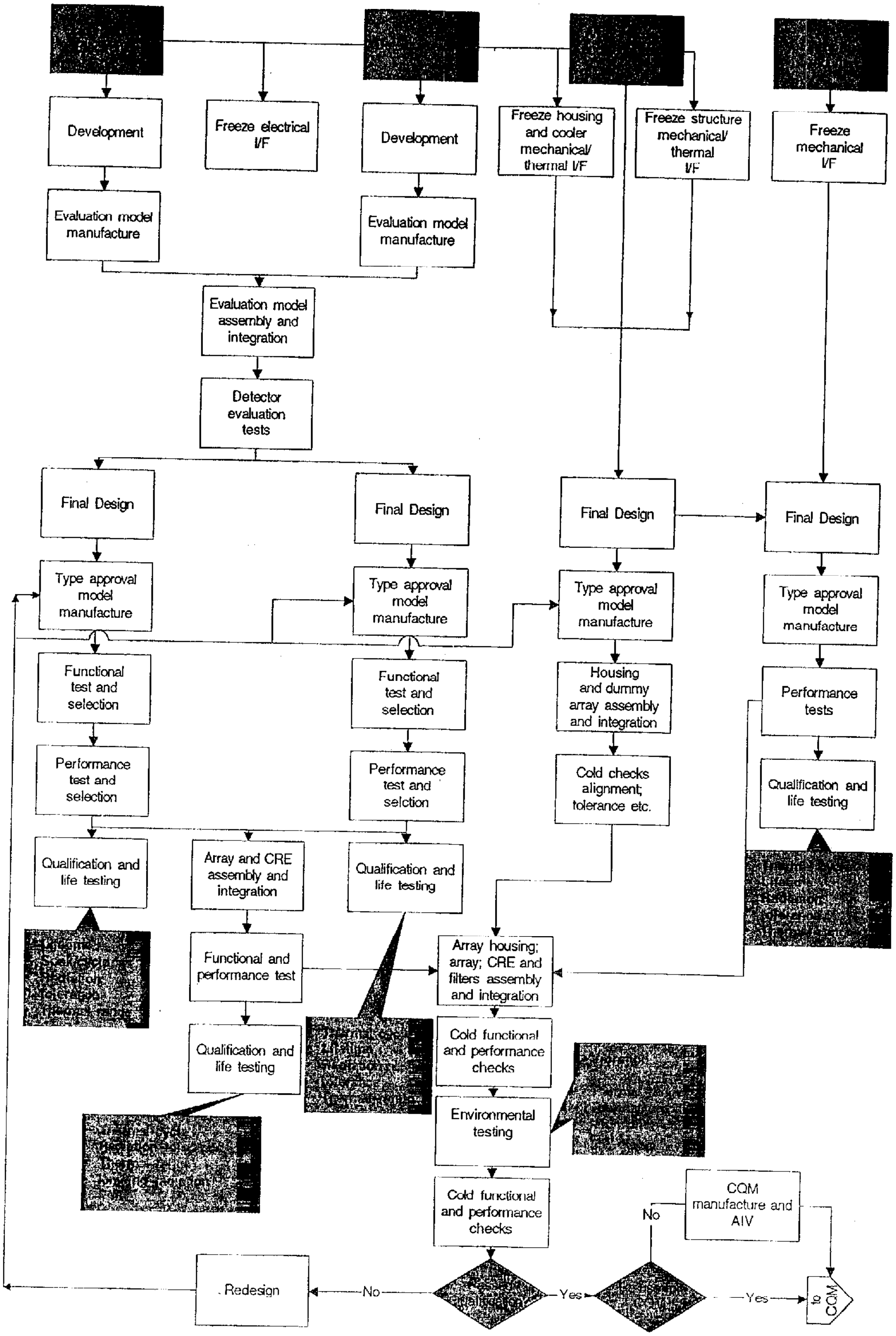
- What:
  - Vibration
  - Thermal Cycle
  - Vacuum Cycle
  - Lifetime
  - Soak and operationally cycle
  - Radiation tolerance
  - Thermal range
  - Thermal stability
  - Microphonics
  - Ionising Radiation
  - EMI
  - EMC
  - Materials conformance

Detector Qual Programme

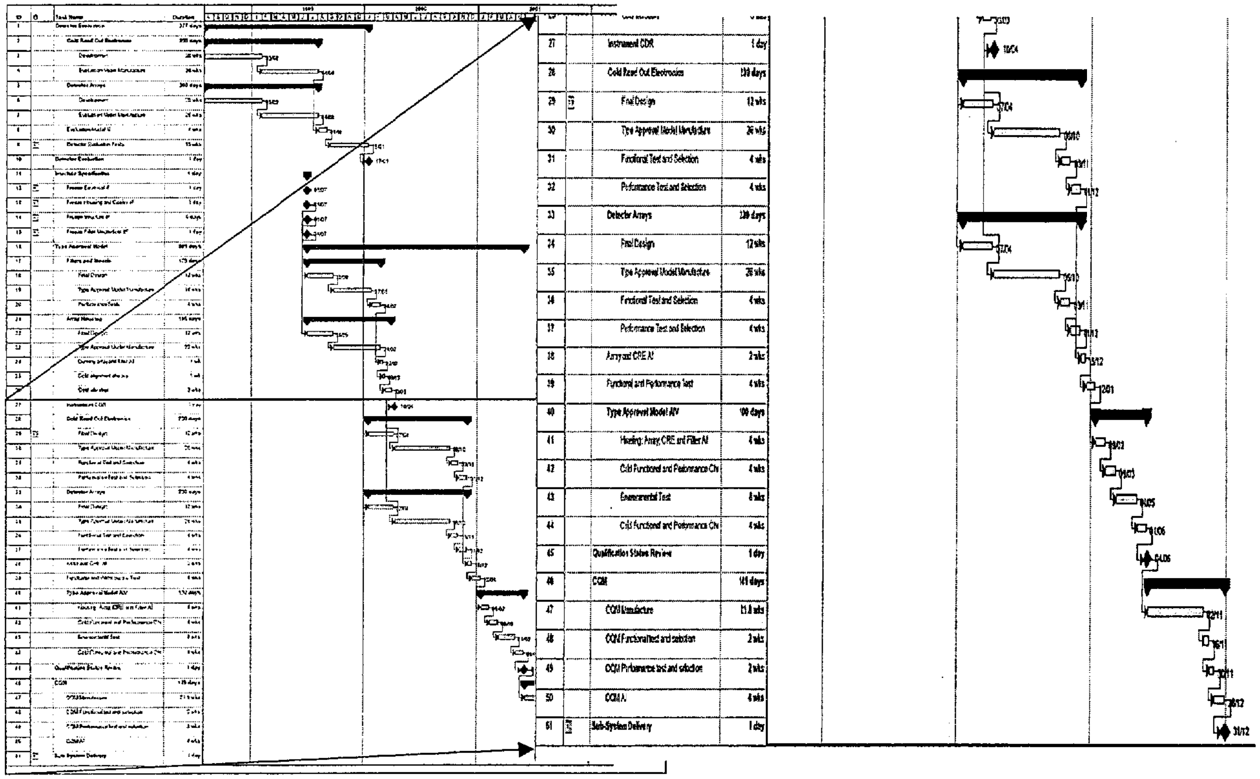
- When:
  - Flow chart…………...
  - Schedule…………….

Detector Qual Programme

- When:
  - Flow chart………….


[redacted]
[redacted]
[redacted]
[redacted]
Development
Freeze electrical I/F
Development
Freeze housing and cooler mechanical/ thermal I/F
Freeze structure mechanical/ thermal I/F
Freeze mechanical I/F
Evaluation model manufacture
Evaluation model manufacture
Evaluation model assembly and integration
Detector evaluation tests
Final Design
Final Design
Final Design
Final Design
Type approval model manufacture
Type approval model manufacture
Type approval model manufacture
Type approval model manufacture
Functional test and selection
Functional test and selection
Housing and dummy array assembly and integration
Performance tests
Performance test and selection
Performance test and selction
Cold checks alignment; tolerance etc.
Qualification and life testing
Qualification and life testing
Array and CRE assembly and integration
Qualification and life testing
[redacted]
[redacted]
Functional and performance test
Array housing; array; CRE and filters assembly and integration
Qualification and life testing
[redacted]
Cold functional and performance checks
[redacted]
[redacted]
Environmental testing
Cold functional and performance checks
CQM manufacture and AIV
No
Redesign
No
[redacted]
Yes
[redacted]
Yes
to CQM

Detector Qual Programme



27		Instrument CDR	1 day
28		Cold Read Out Electronics	130 days
29		Final Design	12 wks
30		Type Approval Model Manufacture	26 wks
31		Functional Test and Selection	4 wks
32		Performance Test and Selection	4 wks
33		Detector Arrays	130 days
34		Final Design	12 wks
35		Type Approval Model Manufacture	26 wks
36		Functional Test and Selection	4 wks
37		Performance Test and Selection	4 wks
38		Array and CRE AI	2 wks
39		Functional and Performance Test	4 wks
40		Type Approval Model AIV	100 days
41		Heating: Array, CRE and Filter AI	4 wks
42		Cold Functional and Performance Ch	4 wks
43		Environmental Test	8 wks
44		Cold Functional and Performance Ch	4 wks
45		Qualification Status Review	1 day
46		CQM	141 days
47		CQM Manufacture	13.8 wks
48		CQM Functional test and selection	2 wks
49		CQM Performance test and selection	2 wks
50		CQM AI	4 wks
51		Sub-System Delivery	1 day

Detector Qual Programme

- How representative:
  - For type approval detector assembly - fully flight like in all mechanical; thermal and electrical properties with at least one working pixel!
- All other tests - subject to negotiation.

Detector Qual Programme

- Who:
  - Good question! No point in duplicating effort during array development and some facilities are very expensive.....
  - Some large facilities required:
    - ☹ Cold vibration
    - ☹ Proton beam capable of taking cryostat (without making it radioactive or melting the electronics!!)
    - ☹ Cryostat(s) and calibration facility for array evaluation before/after each test
    - ☹ Facility for evaluation of microphonic response
  - Some facilities needed for a long time:
    - ☹ Cryostat for lifetest
    - ☹ EGSE for soak; operational cycle and lifetest
    - ☹ Folk to carry out and monitor the tests

Detector Qual Programme

- What now:
  - Draw up agreed list of tests - array groups to respond to list given here and fill in pro-forma test sheets (1 month/next meeting)
  - Systems team to specify levels for qualification tests - prompting information from ESA as appropriate (next meeting)
  - Array groups to identify what tests can be done before array selection and/or CDR (next meeting)
  - Array groups to identify level of component representation required for all tests (next meeting)
  - QMW to identify level of component representation required for filter and housing tests (next meeting)
  - QMW(+BMS) to draw up proper qualification plan (1 month before PDR)

☺ Remember ☺

A qualification plan is a requirement
for detector technology selection

☹

6

Systems design and array interface specifications

6a

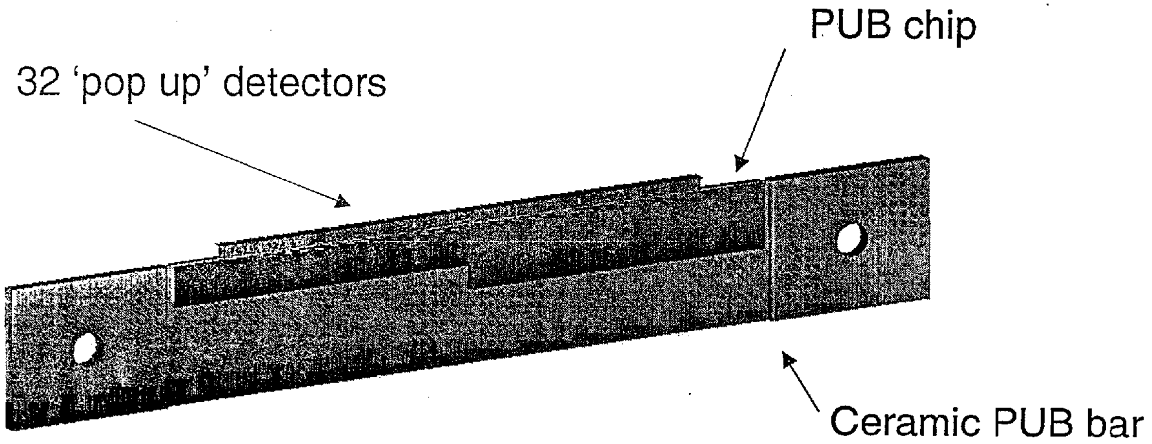
Systems design and array interface specifications

TES Pop-up option

Harvey Moseley et al.

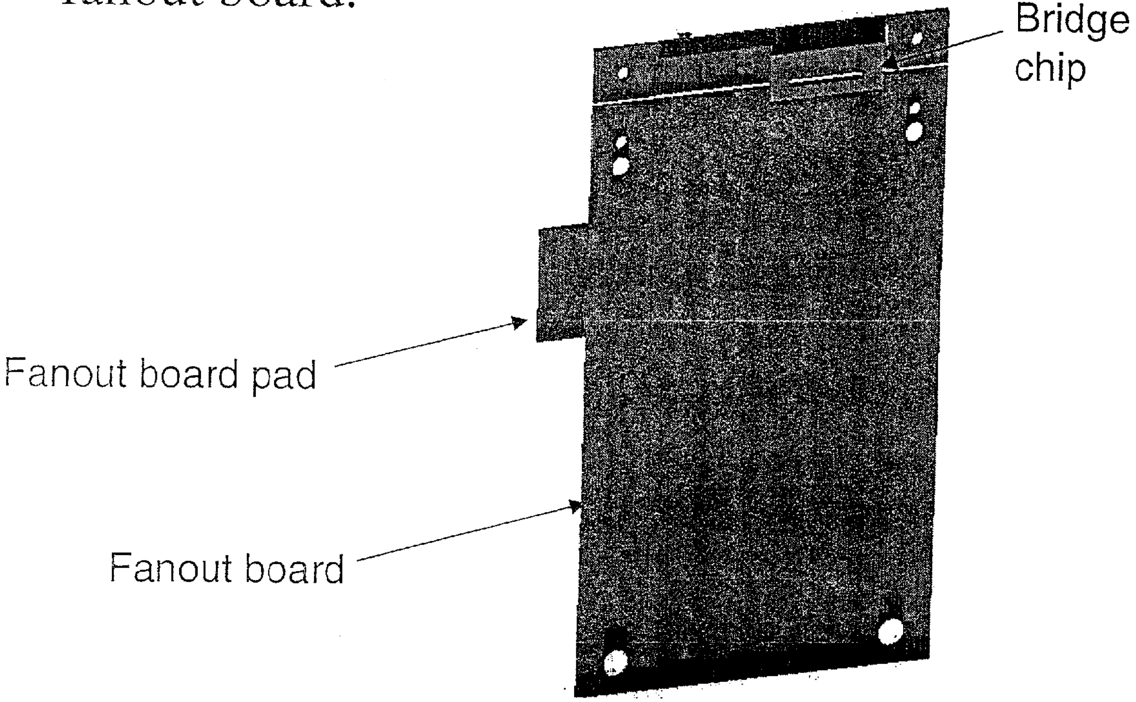
Detectors

- The PUB chips are folded and epoxied to the PUB bars.



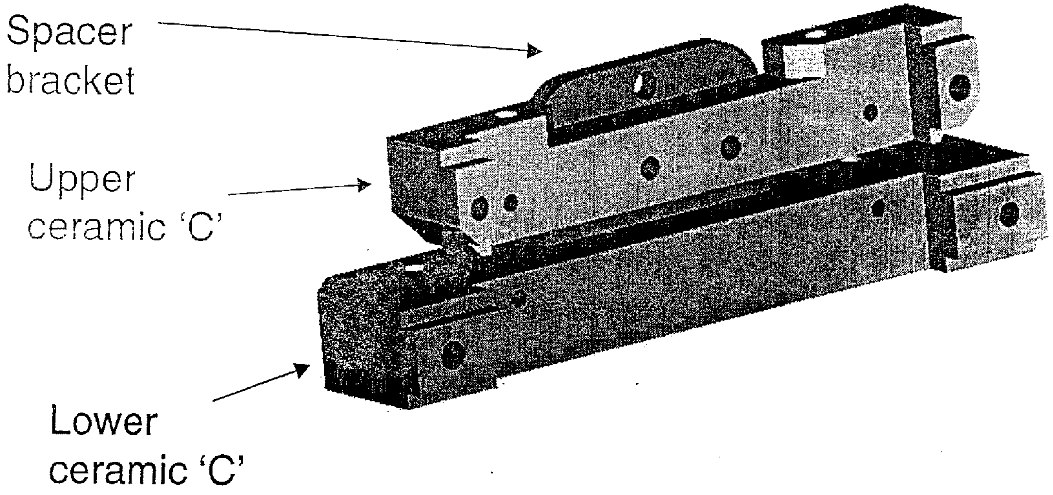
Detectors

- The bridge chips are epoxied to a PUB bar and a fanout board.



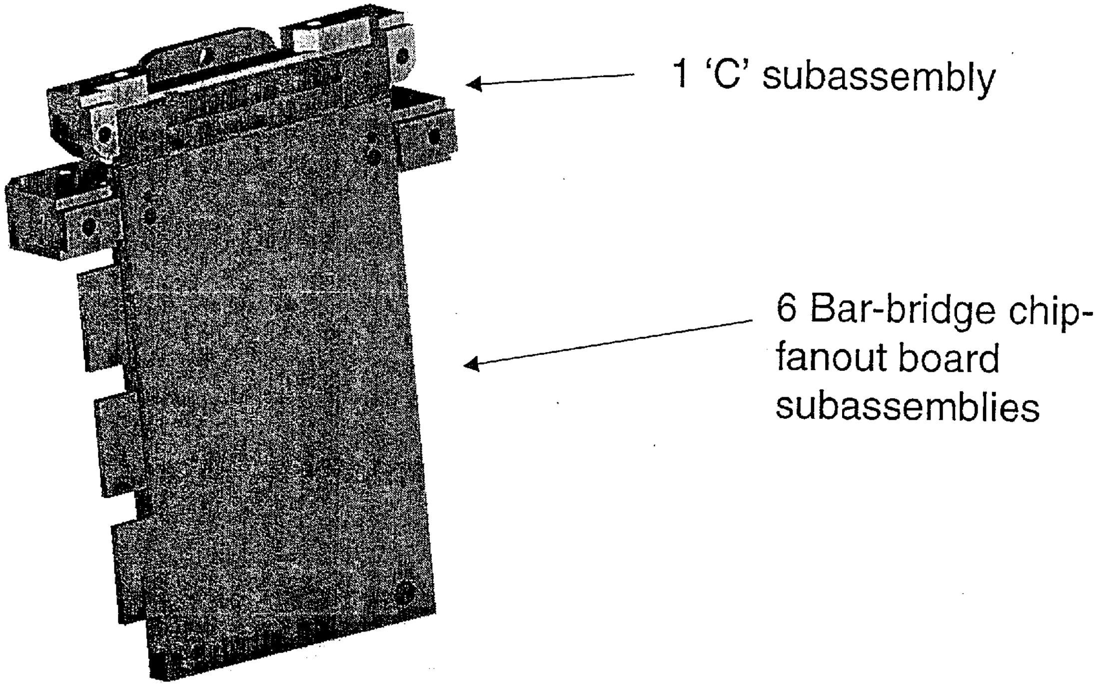
Detectors

- The upper and lower ceramic ‘C’ parts are aligned and assembled into two ‘half C’ subassemblies.



Detectors

- Six PUB bar-bridge chip-fanout board subassemblies are aligned and epoxied to each ceramic ‘C’ subassembly.

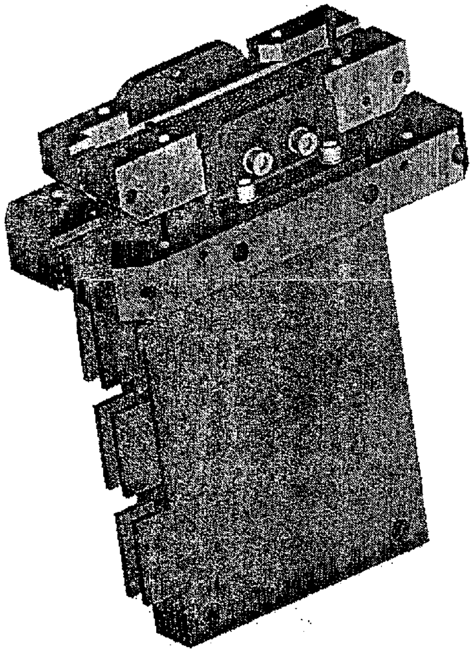


1 ‘C’ subassembly

6 Bar-bridge chip-fanout board subassemblies

Detectors

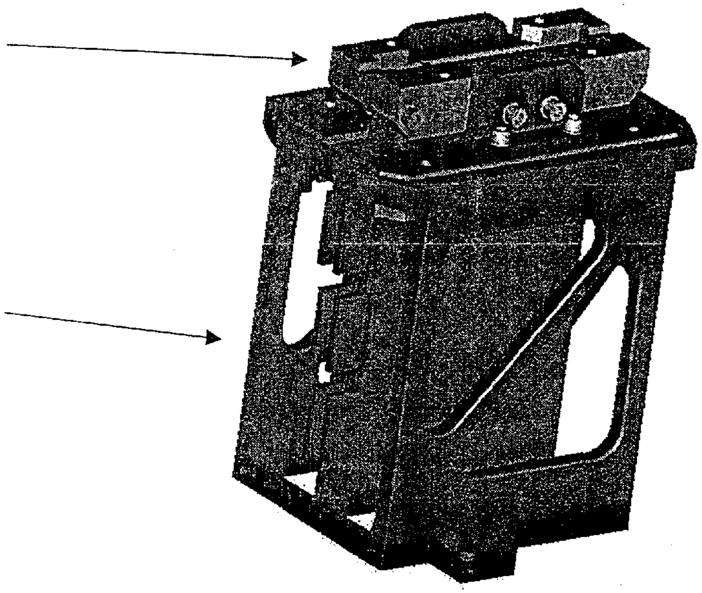
- Two of the resulting subassemblies are aligned and bolted together to form a 12X32 array.



Two half detector subassemblies joined into one full detector array subassembly

Detectors

- The resulting 12X32 detector assembly is lowered into and bolted to the card-cage interface structure.

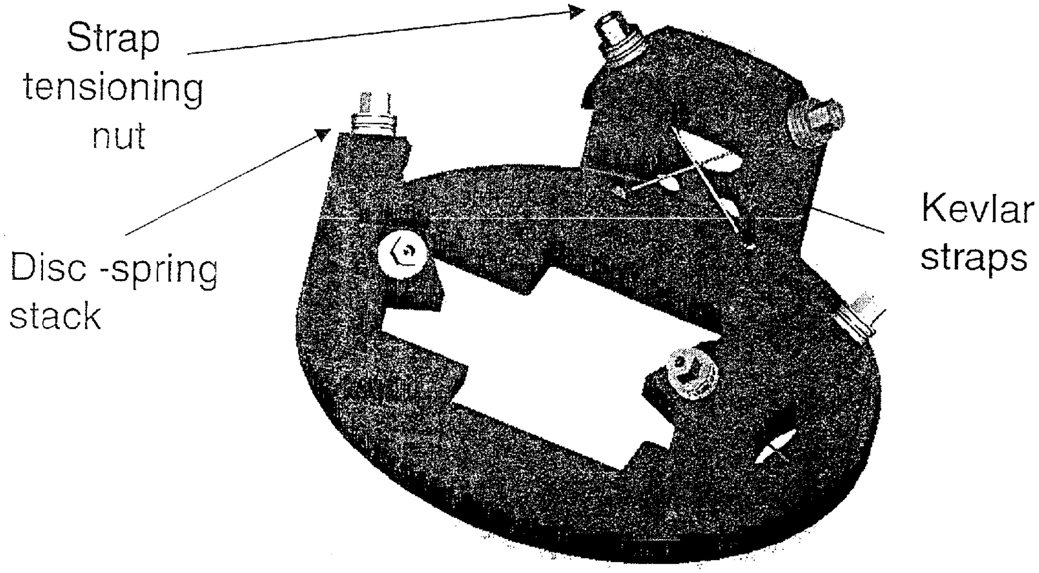


Full detector array subassembly from previous picture

Card cage interface structure

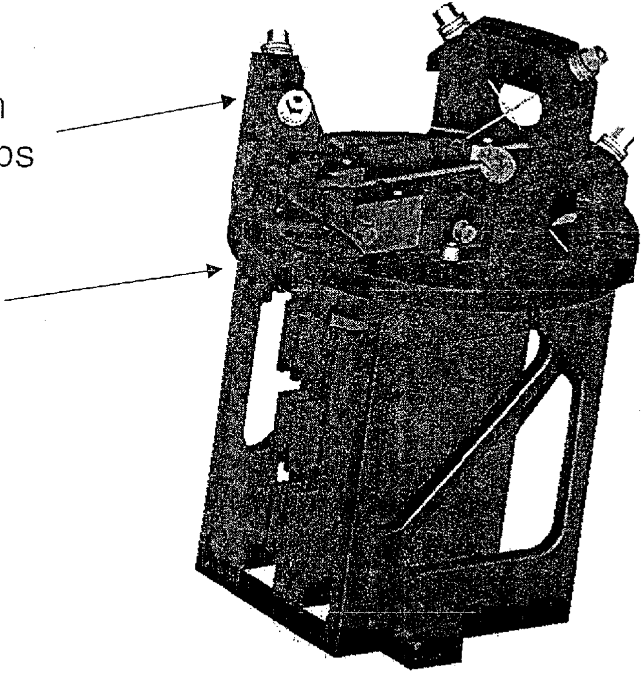
Detectors

- The six kevlar straps are epoxied to end hardware and tensioned into the claw with a Belleville spring stacks on the top ends.



Detectors

- The claw is lowered over the detector array and bolted to the lower 'C's

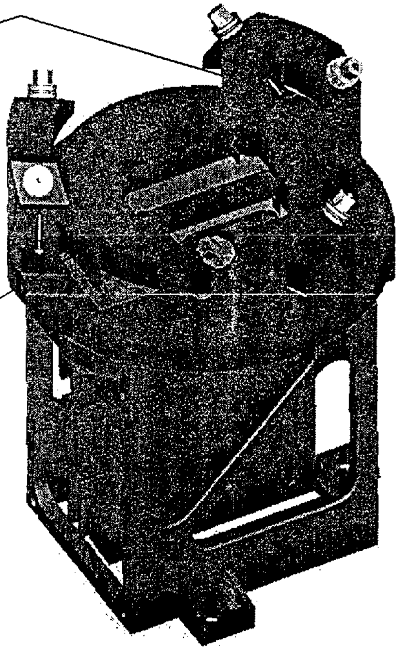


Suspension claw with tensioned kevlar straps

Full detector array in card cage structure

Detectors

- The cold plate is lowered, twisted into position with its ‘hooks’ or ‘grooves’ at the kevlar straps, and bolted or epoxied to the upper ‘C’s.

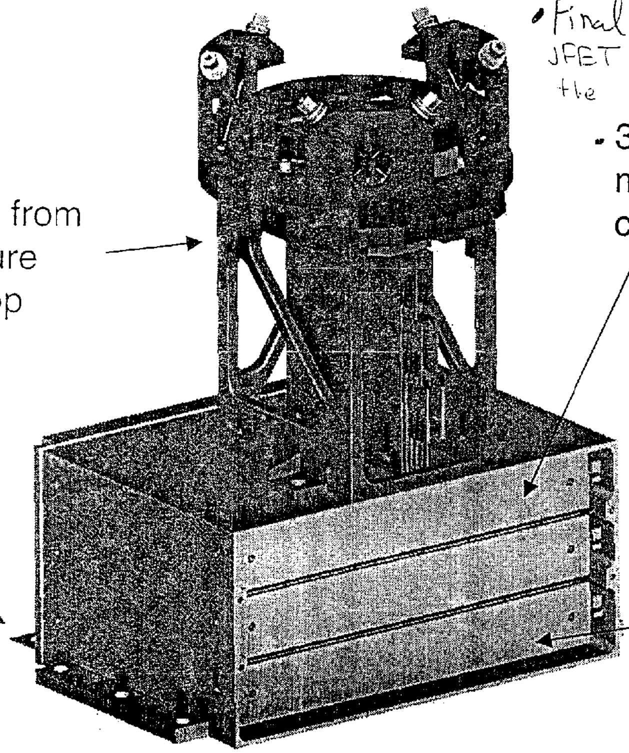


Suspension cold plate epoxied to kevlar straps at each strap set crossing point

Suspension cold plate (ceramic)

Detectors

- The assembly is mounted to the top of the JFET box.
  - Final version will not have a JFET Box, Fan out boards [illegible] hold the electronics.



- Subassembly from previous picture mounted to top of JFET box

JFET heat straps

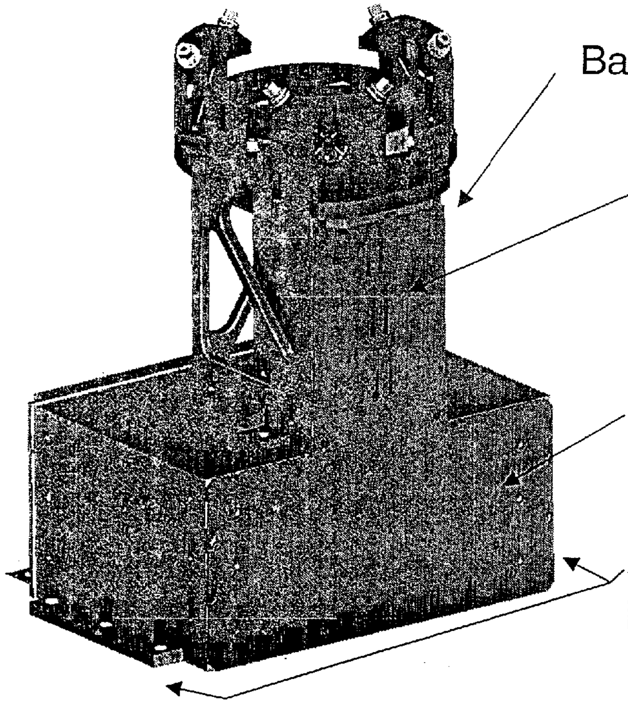
- 3 JFET electronics modules on card guides

- Not shown high density connectors are on both ends of the modules

Michael Amato

Detectors

- The back plane board is aligned to the fan out board tabs and attached to the card cage structure and the JFET box.



Back plane board

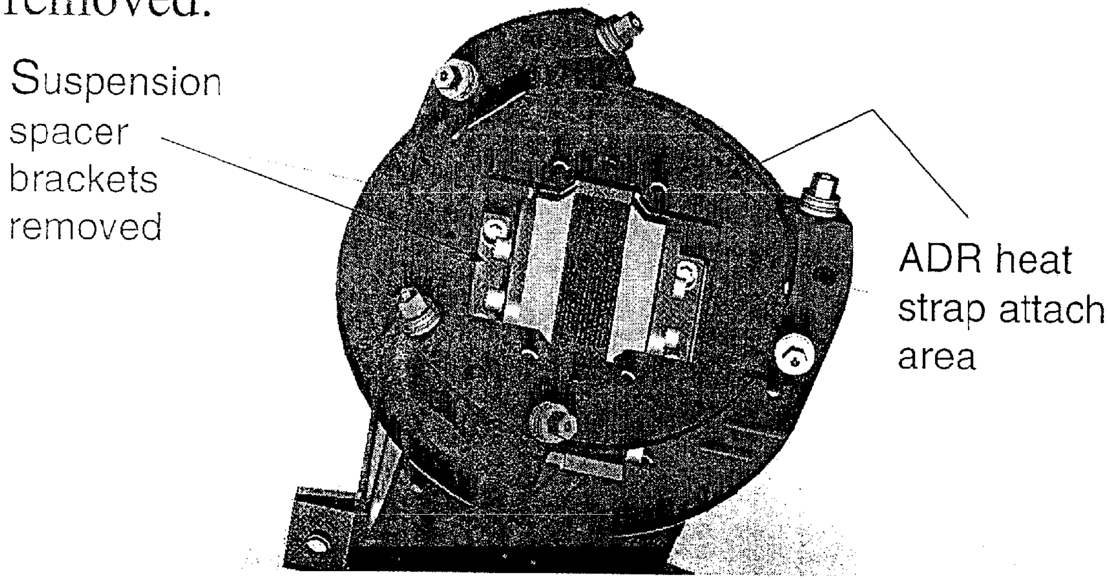
The pads on the tabs
of the fan out boards
are wire bonded
to mother board tabs

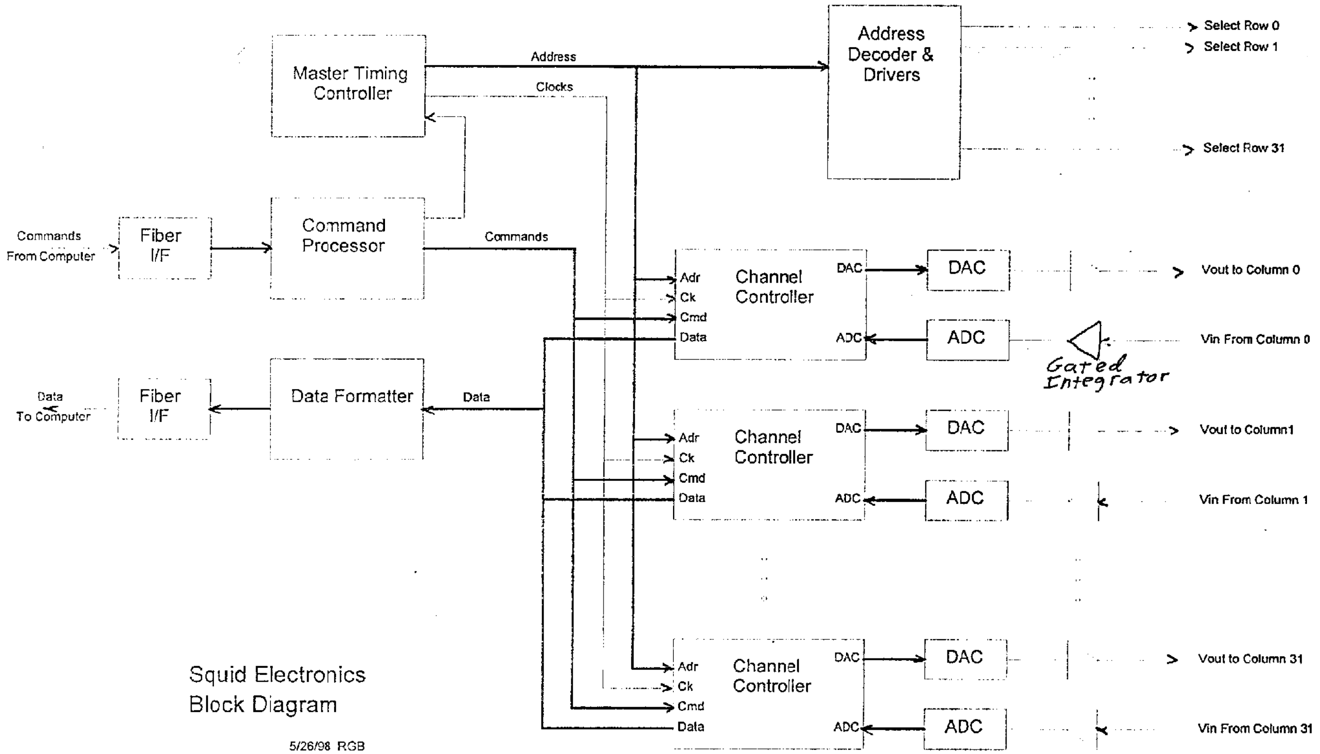
Hign density connector
mates (not shown)

Shim adjustable mechanical
interface to instrument

Detectors

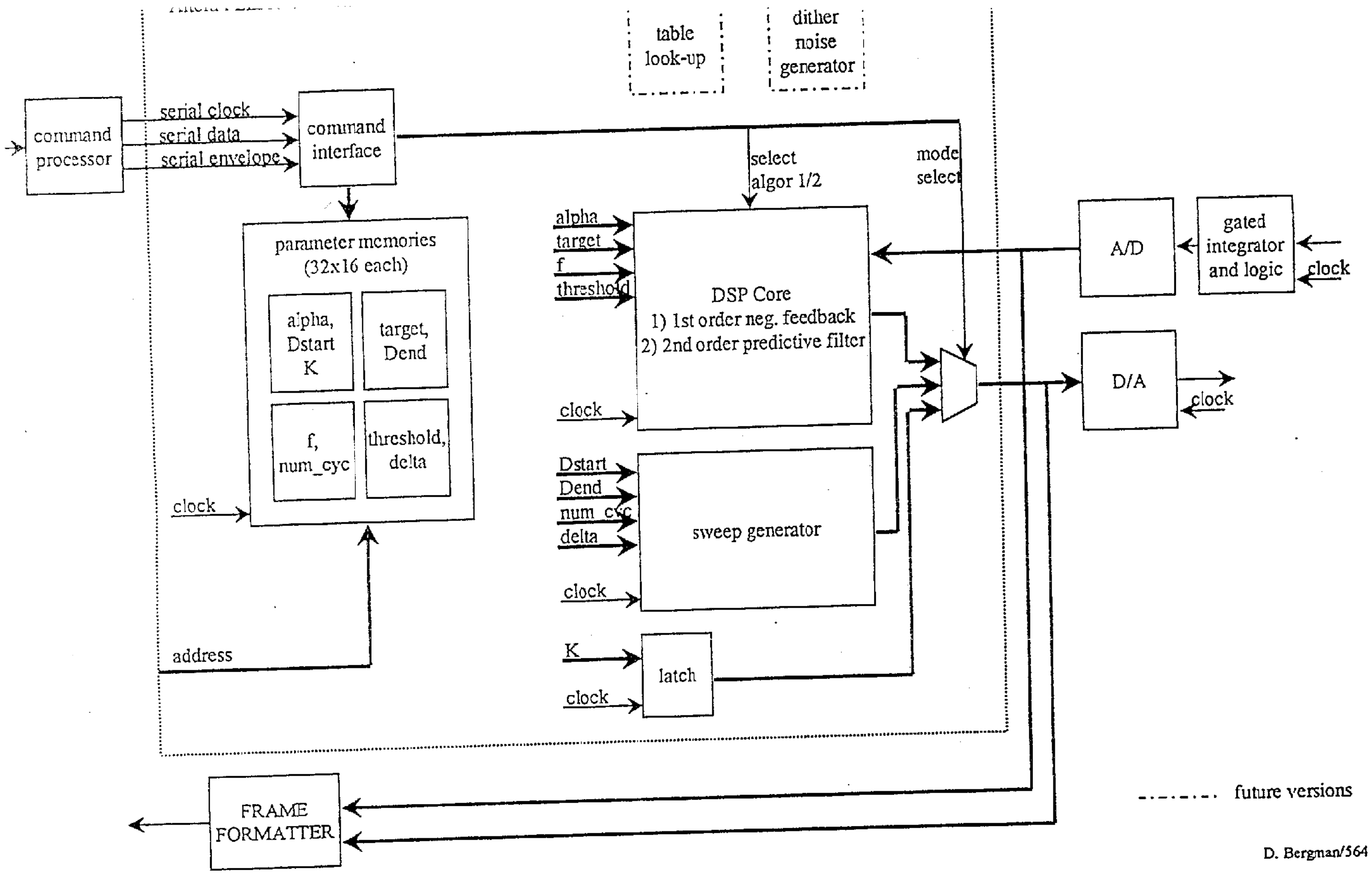
- The ADR heat strap is attached to the suspension cold plate and the suspension brackets which suspended the detectors during the assembly are removed.





Squid Electronics
Block Diagram

5/26/98 RGB



D. Bergman/564

D. Bergman/564

MARK 1.8/2 SALIENT CAPABILITIES

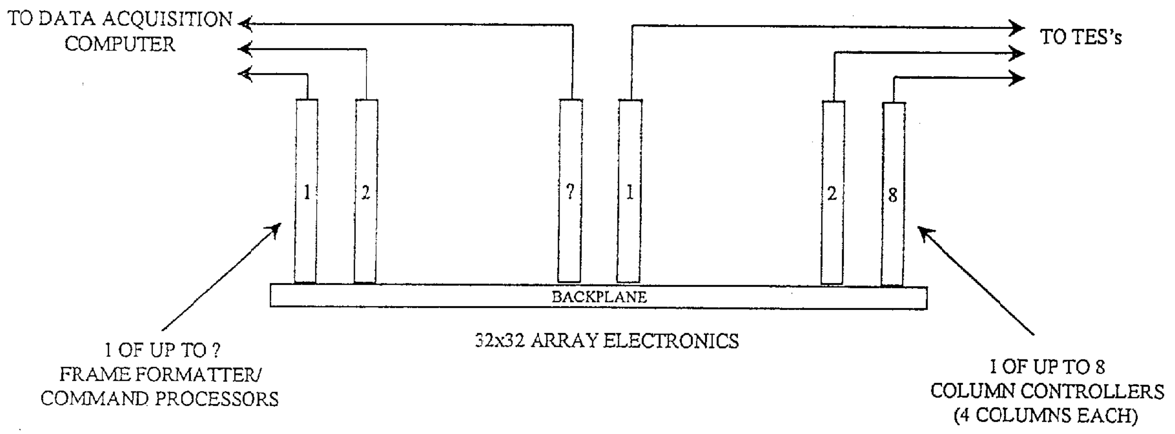
(Reference: Rick Shafer e-mail, 5/18/98)

- 32 ROW x 4 COLUMN PROCESSING (MARK 2)
  - 32 ROW x 1 COLUMN PROCESSING (MARK 1.8)
- 14-BIT A/D, 16-BIT D/A
- 3.2 MHz PIXEL RATE, 100 kHz FRAME RATE (CLOCK RATE ADJUSTABLE)
- RECONFIGURABLE CONTROL ALGORITHMS
  - 1st ORDER NEGATIVE FEEDBACK
  - 2nd ORDER PREDICTIVE FILTER
  - SWEPT D/A OUTPUT
  - FIXED D/A OUTPUT
- DATA COLLECTION VIA FRAME FORMATTER CARD TO DATA ACQUISITION COMPUTER S/W

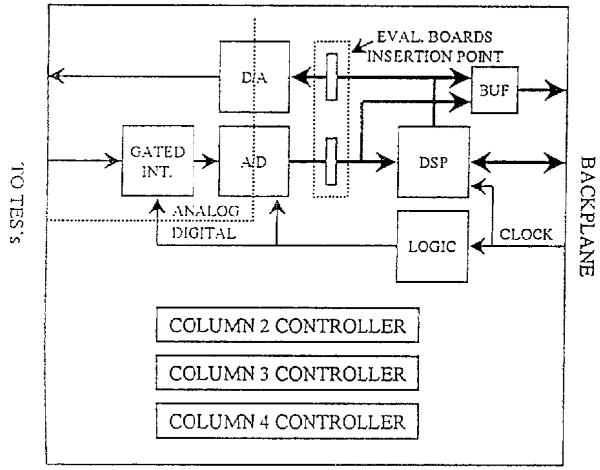
SCHEDULE

- COMPLETE MARK 1.8 FABRICATION BY THANKSGIVING
  - A/D, D/A EVALUATION BOARDS, GATED INTEGRATOR PROTOTYPE BOARD, DSP PROTOTYPE BOARD
- TEST ELECTRONICS WITH SQUIDS AT GSFC LATE NOVEMBER, EARLY DECEMBER
- TEST ELECTRONICS WITH TES's AND SQUIDS AT COLORADO MID-LATE DECEMBER
- COMPLETE MARK 2 FABRICATION (4 COLUMN) BY LATE JANUARY, EARLY FEBRUARY

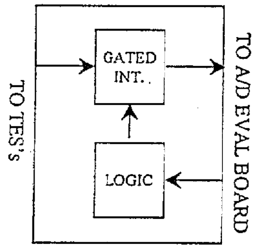
TENTATIVE ARCHITECTURES AND BOARDS REQUIRED FOR DIFFERENT BUILD-UPs



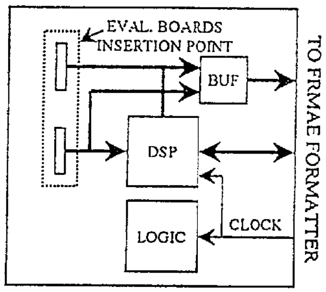
32x32 ARRAY ELECTRONICS



COLUMN CONTROLLER BOARD (MARK 2)



GATED INTEGRATOR
EXPANSION BOARD
FOR A/D EVAL. BOARD
(MARK 1.8)



DSP PROTOTYPE BOARD
(MARK 1.8)

D. Bergman/564

6b

Systems design and array interface specifications

Feedhorn option

Jamie Bock

FEEDHORN - COUPLED ARRAYS

INTERFACES

17 SEPTEMBER 1998

MECHANICAL

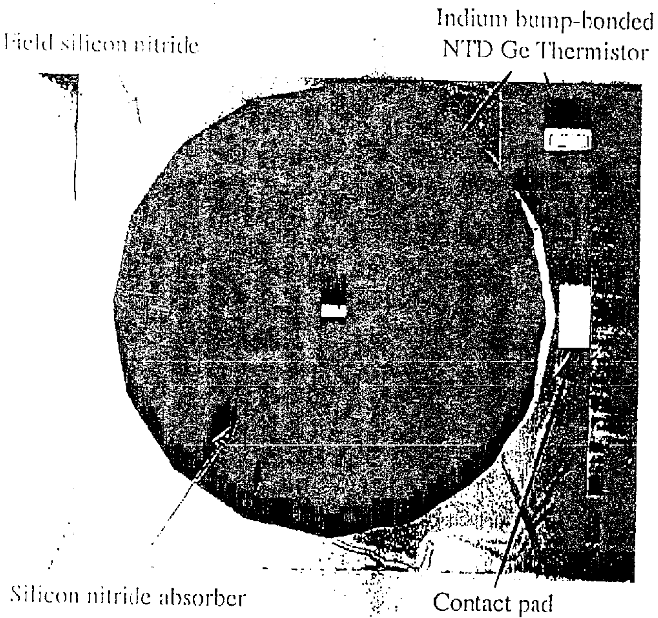
THERMAL ([illegible])

WIRING

READOUT

[redacted]

Silicon Nitride Micromesh Bolometer

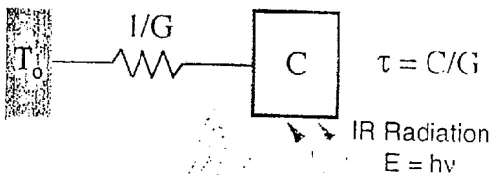


Silicon Nitride Micromesh Bolometer with Indium Bump-Bonded NTD Ge Thermistor

[illegible] dimensions:
[illegible] x 5μm wide x 1μm [illegible]
[illegible]ameter: 5.6 mm
[illegible]ing: 400 μm
[illegible]tor: 1.5%
[illegible]tor: 300 x 100 x 5[illegible]

Principle of Operation:

- Incident infrared **radiation** is absorbed by silicon nitride **micromesh**.
- Absorber **temperature** changes.
- Temperature **change** is detected by neutron transmutation **doped** (NTD) Ge thermistor.



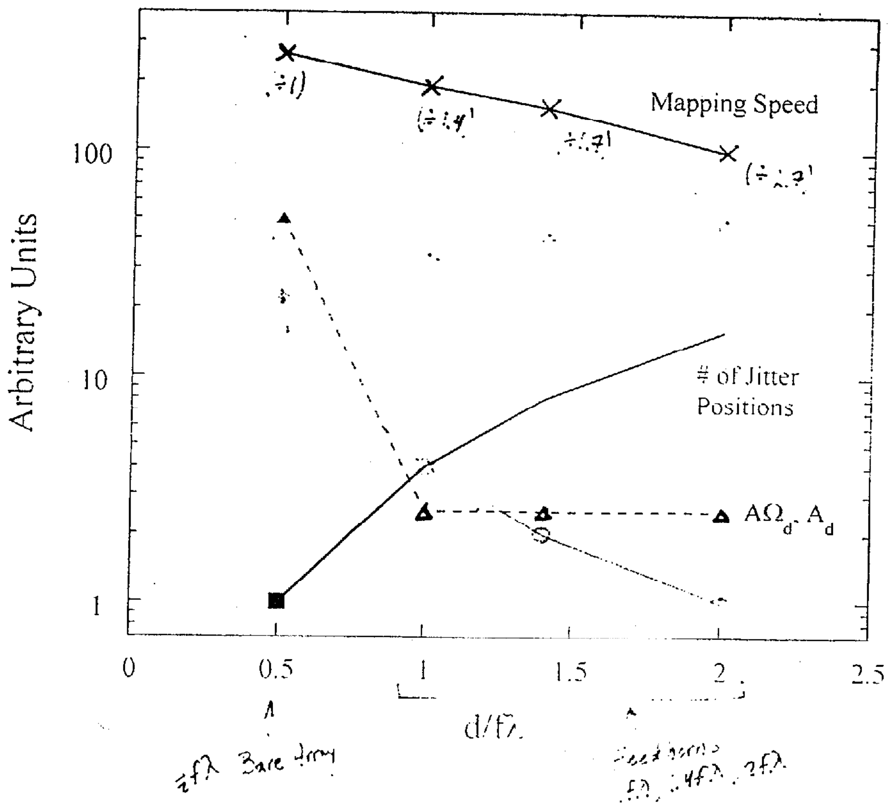
$\tau = C/G$

Advantages:

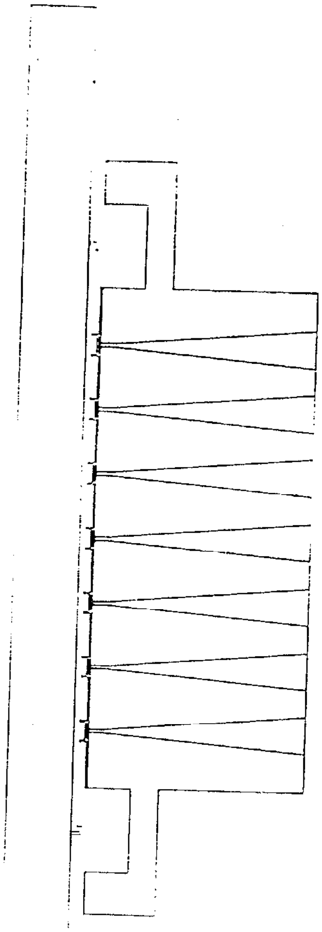
- Low G → high sensitivity
- Low C → fast response
- Small mass → reduced microphonic response
- Mesh absorber → small cosmic ray cross section
  → short λ rejection
- Excellent DC stability
- 2D array compatible

J. J. Bock 9/96

Tradeoffs in a Mapping Observation



- Background-limited case
- f/5



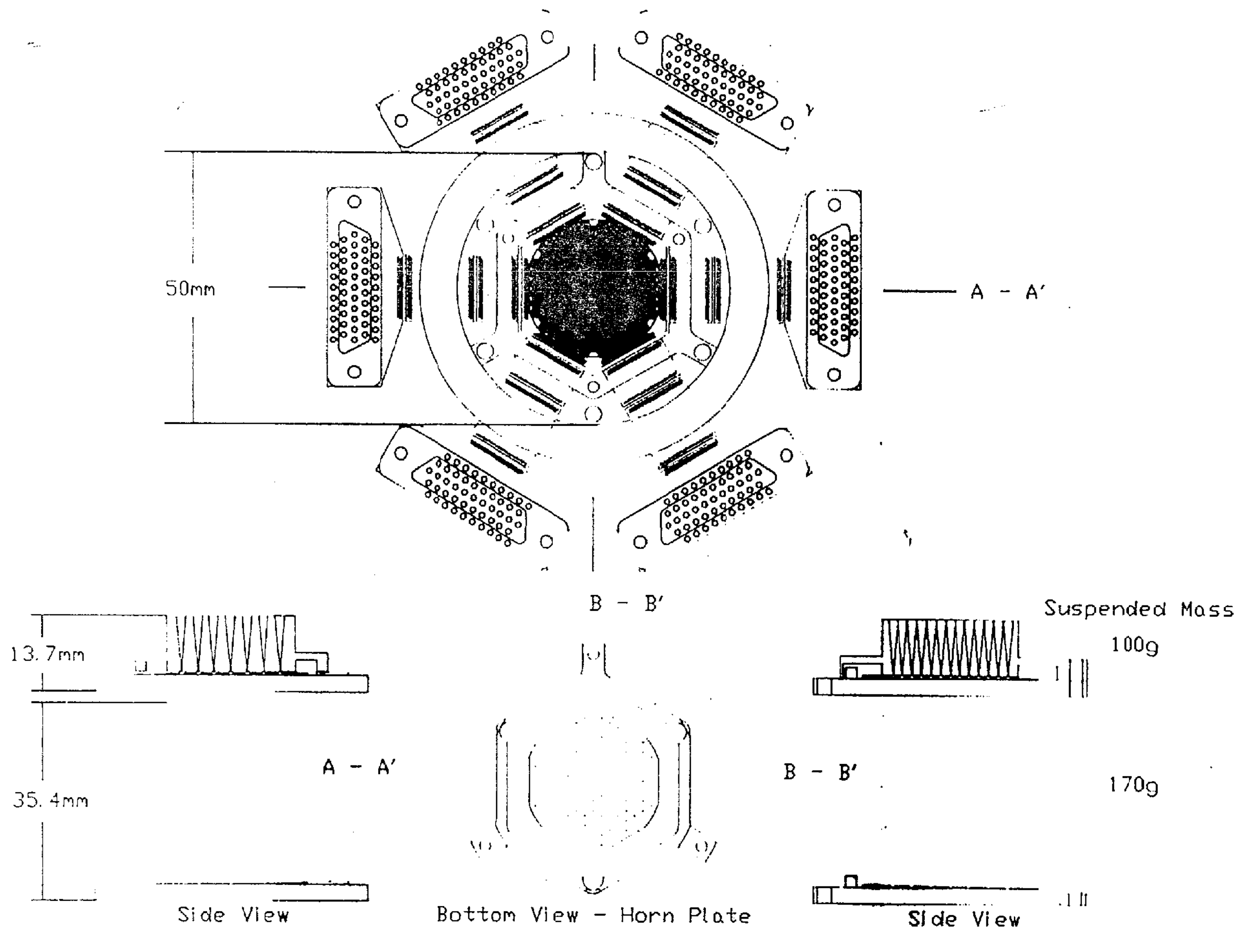
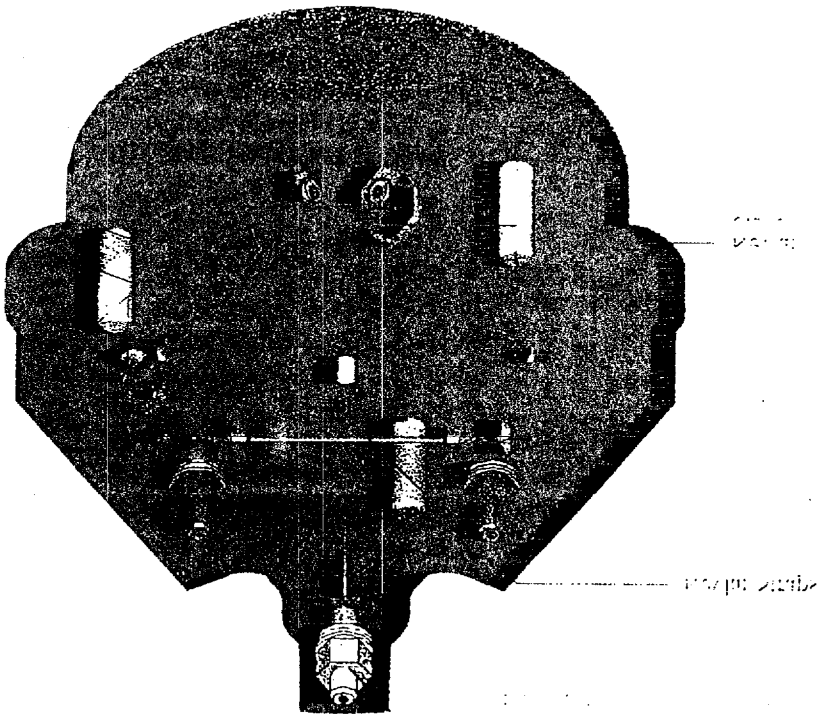

50mm
A - A'
B - B'
13.7mm
35.4mm
A - A'
Side View
Bottom View - Horn Plate
B - B'
Suspended Mass
100g
170g
Side View

Figure 2: Detector Mount Housing with Kevlar Straps

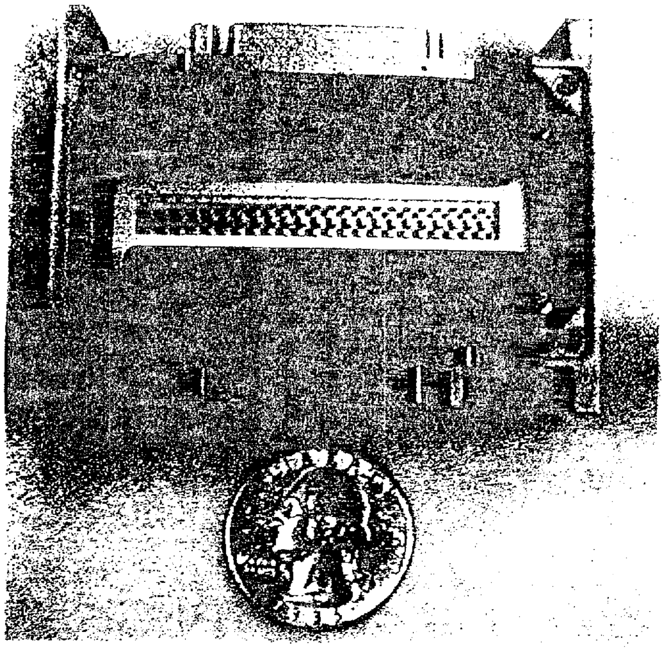


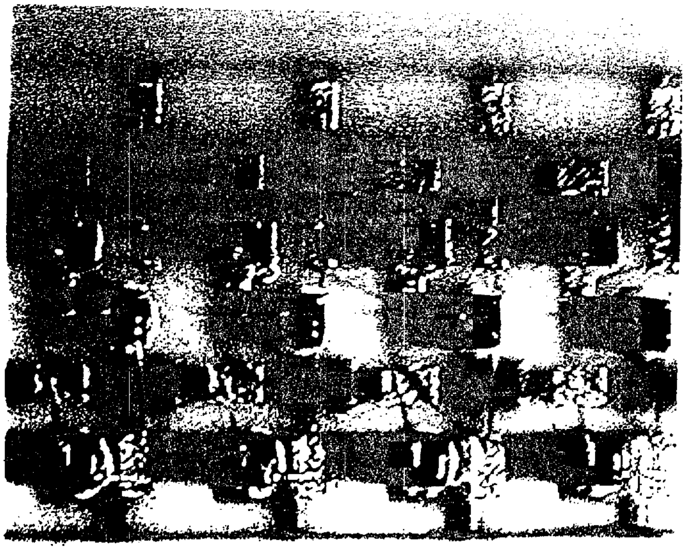
Parameters

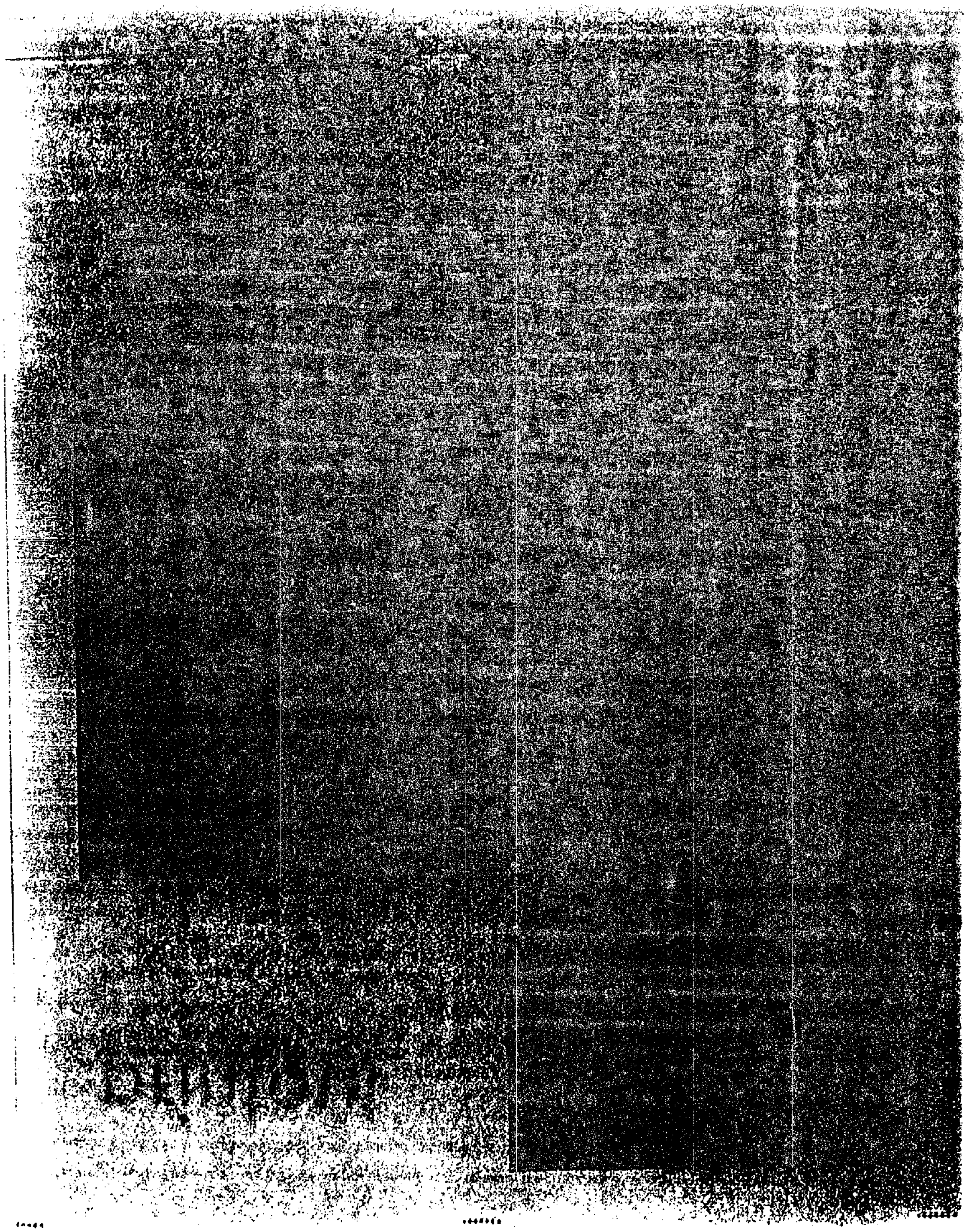
horns =	2	fλ
Rbol =	5	MΩ
C0 =	1	pJ/K
[illegible]	[illegible]	[illegible]

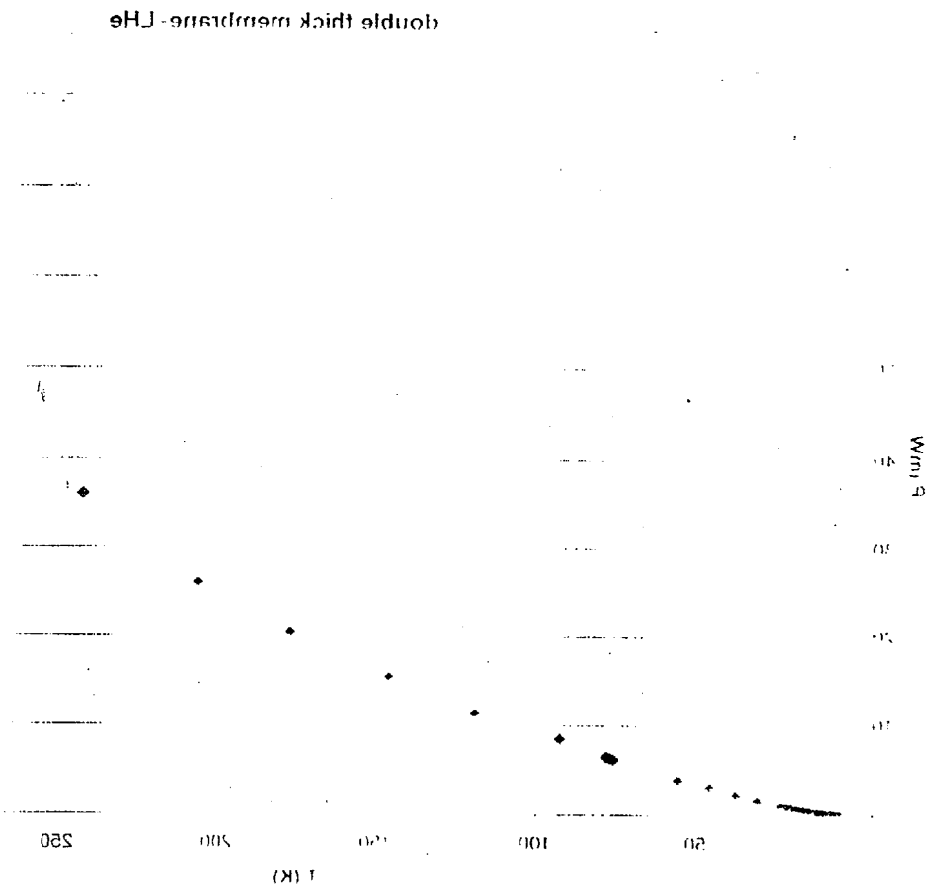
[illegible]	[illegible]	Q (pW)	NEPphoton	G (pW/K)	NEPbolo	Top (K)	Pe (pW)	[illegible]
[illegible]	[illegible]	9	[illegible]	[illegible]	[illegible]	0.40	[illegible]	[illegible]
Phot 350	350	7	8.92	233.33	4.46	0.40	13.25	3.34
[illegible]	500	6	6.91	200.00	4.12	0.40	11.36	[illegible]
[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	0.40	[illegible]	[illegible]
[illegible]	450	2.8	4.97	93.33	2.82	0.40	5.30	8.35

Channel	Vn,bol (nV/rtHz	Vn,tot (nV/rtHz)	Voffset (mV,rms)
Phot 250	11.50	29.56	9.229223772
Phot 350	11.50	25.73	8.139410298
Phot 500	11.50	22.43	7.535629654
FTS 250	11.50	29.56	6.152815848
FTS 450	11.50	23.33	5.14781507

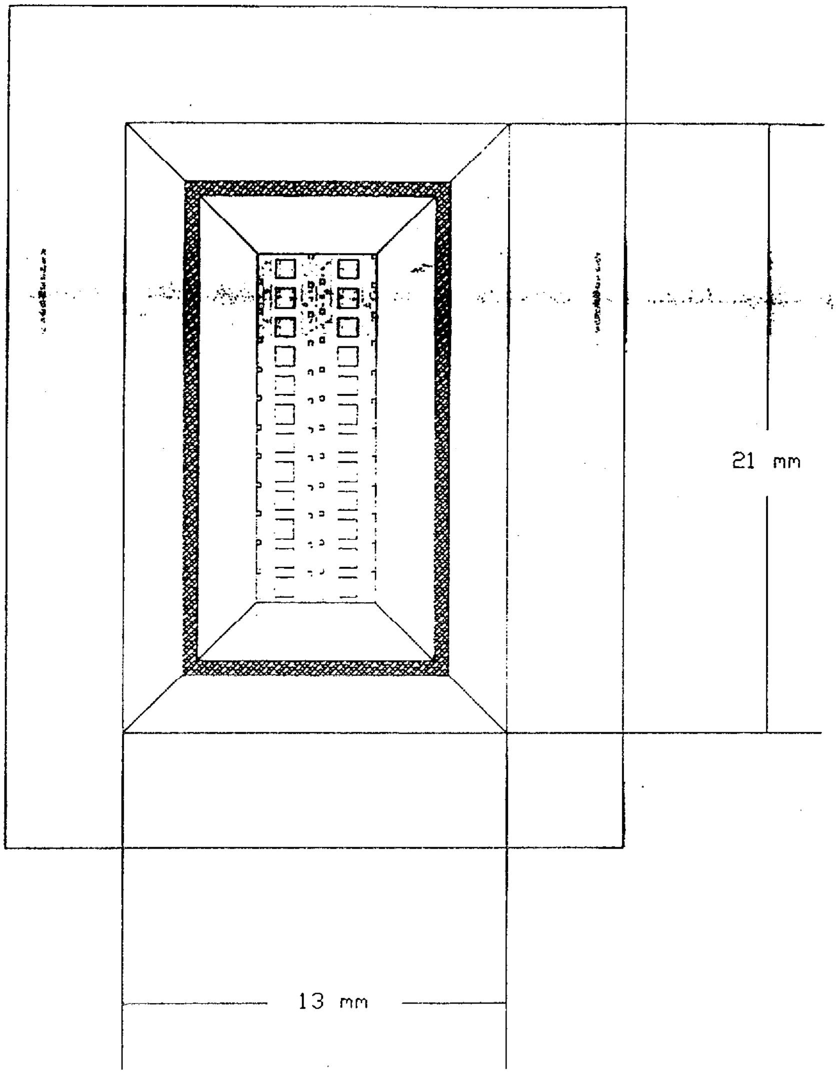


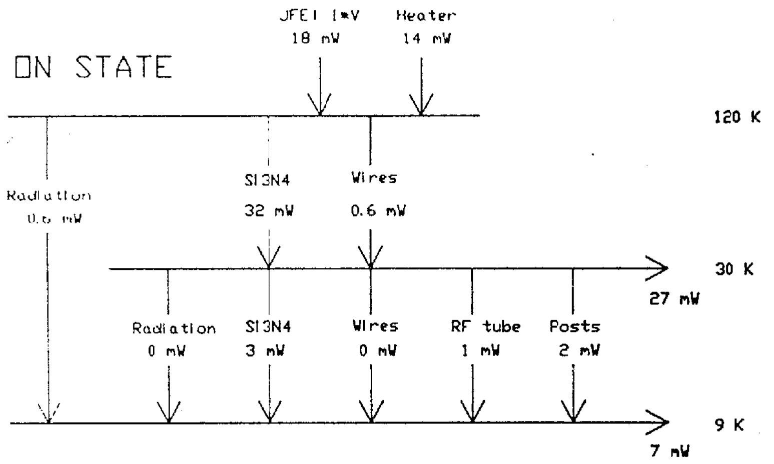


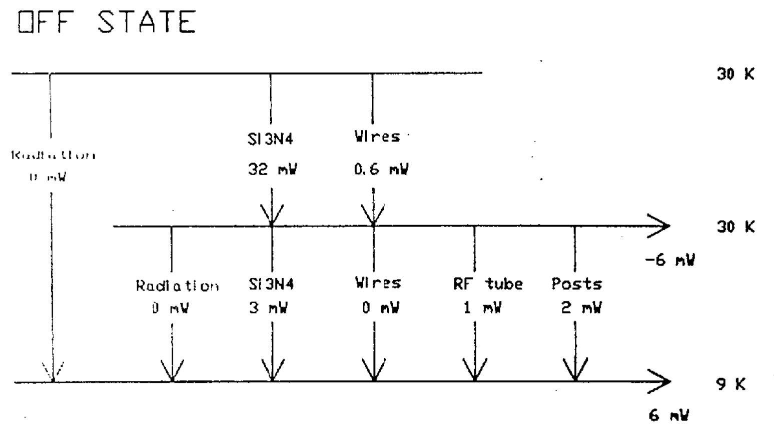




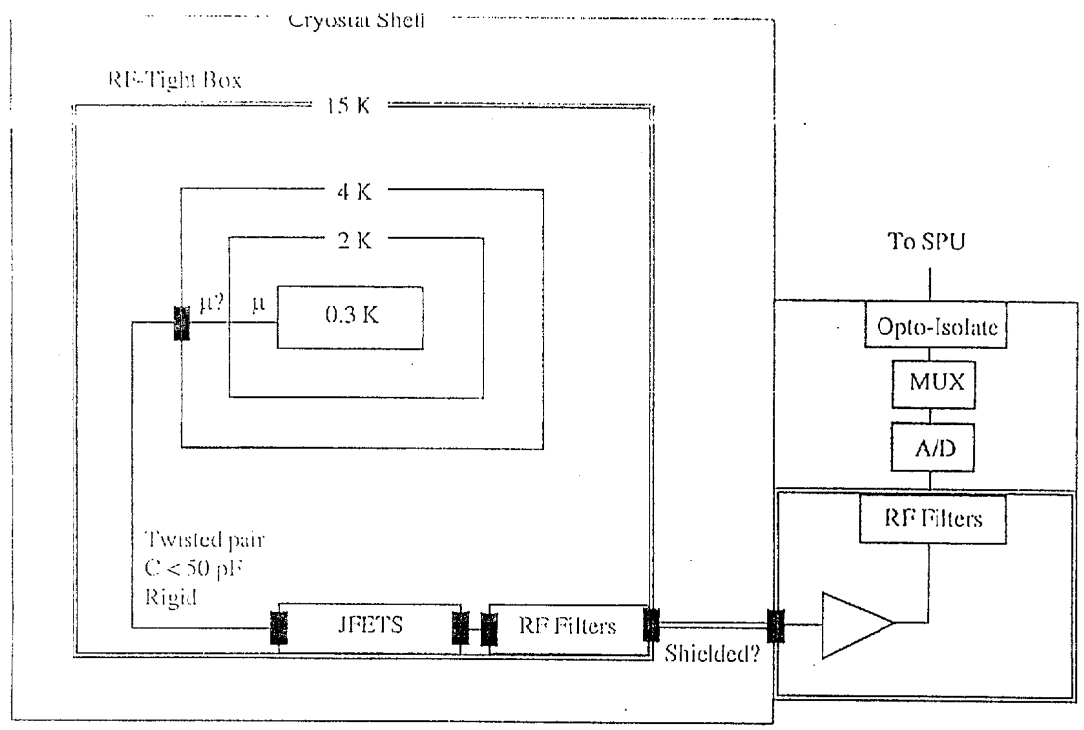
double thick membrane-LHe
P (mW)
10
20
30
40
T (K)
50
100
150
200
250
400


21 mm
13 mm

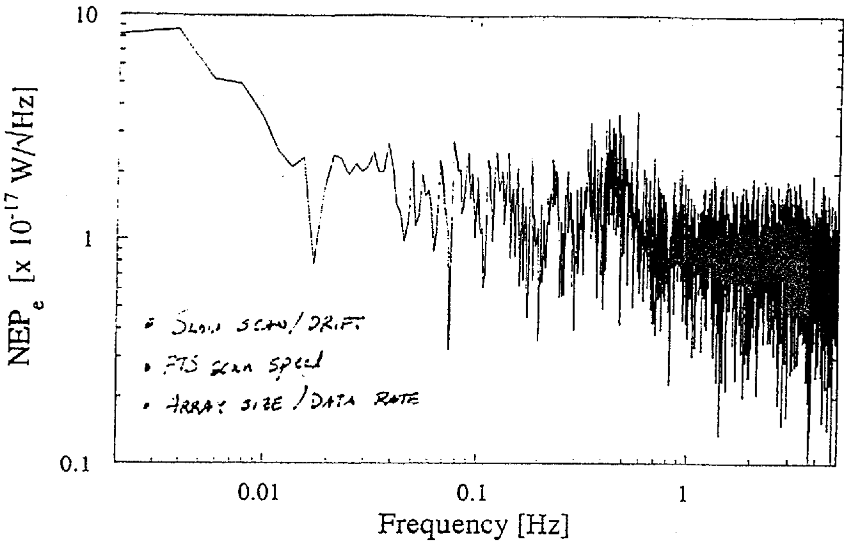

ON STATE
JFET I*V
18 mW
Heater
14 mW
120 K
Radiation
0.6 mW
SI3N4
32 mW
Wires
0.6 mW
30 K
27 mW
Radiation
0 mW
SI3N4
3 mW
Wires
0 mW
RF tube
1 mW
Posts
2 mW
9 K
7 mW


OFF STATE
30 K
Radiation
0 mW
SI3N4
32 mW
Wires
0.6 mW
30 K
-6 mW
Radiation
0 mW
SI3N4
3 mW
Wires
0 mW
RF tube
1 mW
Posts
2 mW
9 K
6 mW

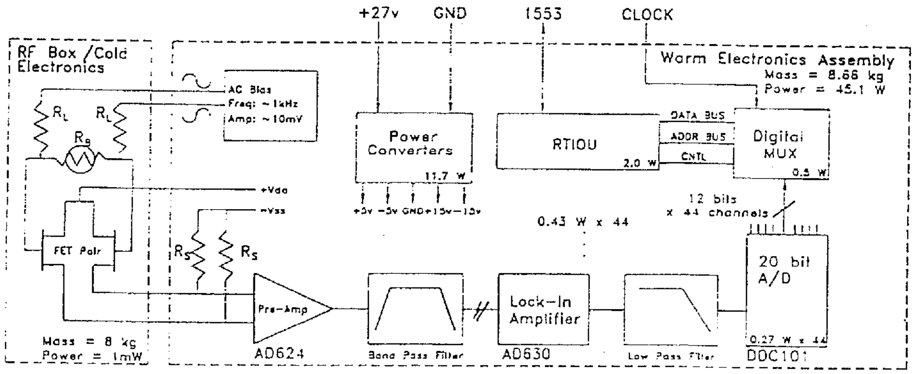
SPIRE Wiring - 2fλ Feedhorns



DC-STABLE READOUT



- SLOW SCAN / DRIFT
- FTS SCAN SPEED
- ARRAY SIZE / DATA RATE



Measured noise spectrum of a micromesh bolometer operating from a 300 mK cold stage using a DC-stable total-power readout circuit. Low frequency noise stability is required to produce accurate maps using the slow-scanning strategy employed in many space-borne observations (e.g. COBRAS/SAMBA). The slow rise in the noise spectrum at low frequencies is caused by drifts in the voltage reference in the 20-bit A/D converter: the feature at 0.5 Hz is due to the response time of the thermally regulated cold stage.

[illegible] SINGLE

READOUT

$\dot{\theta} \approx \frac{1}{2\pi}\frac{\theta_{FWHM}}{\tau}$

$\dot{\theta} \approx 21.3\,\theta_{FWHM} \approx 6'/s$ for $\tau = 10ms$

scan time < 100s ⇒ scan length < 10°

Max data rate ~ 50Hz · 18bits · 150 = 135kbps

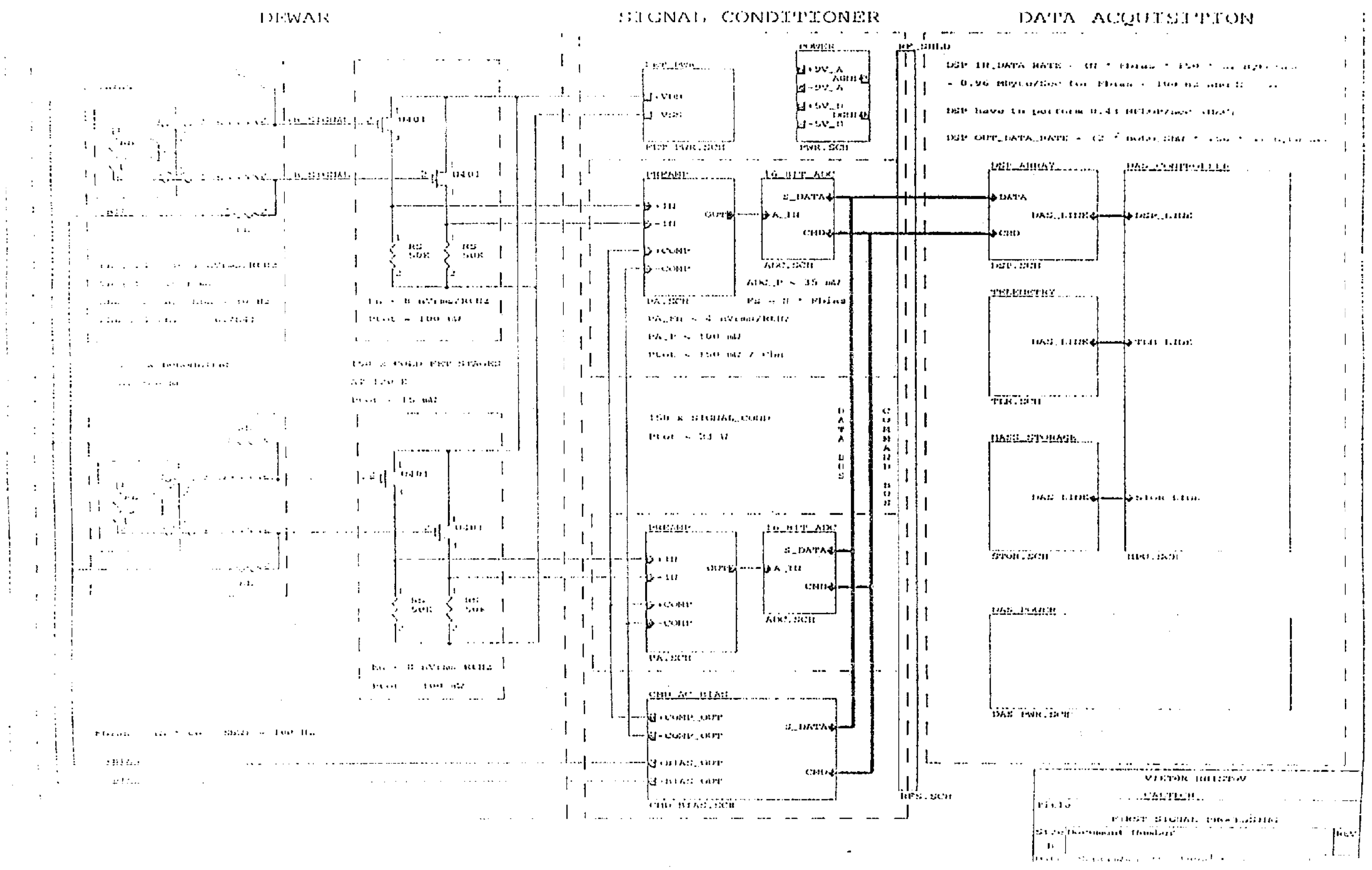
[illegible] SAMPLED MAP IN $\underline{1}$ SCAN

[illegible] ROTATED, OFFSET, ABERATIONS

[illegible] RECONSTRUCTED

[illegible] TO [illegible]

[illegible]


DEWAR
SIGNAL CONDITIONER
DATA ACQUISITION
N_SIGNAL
S_SIGNAL
Q401
RS 50K
RF_SHLD
POWER
+9V_A
AGND
-9V_A
+5V_D
DGND
-5V_D
PWR.SCH
FET_PWR
+VDD
VSS
FET_PWR.SCH
PREAMP
+IN
-IN
+COMP
-COMP
OUTP
PA.SCH
16_BIT_ADC
S_DATA
A_IN
CMD
ADC.SCH
ADC_P < 35 mW
PA_P < 100 mW
DATA BUS
COMMAND BUS
CMD_AC_BIAS
+COMP_OUT
-COMP_OUT
+BIAS_OUT
-BIAS_OUT
CMD_BIAS.SCH
RFS.SCH
DSP_ARRAY
DATA
CMD
DAS_LINK
DSP.SCH
DAS_CONTROLLER
DSP_LINK
TELEMETRY
TLM_LINK
TLM.SCH
DASS_STORAGE
STOR_LINK
STOR.SCH
MPU.SCH
DAS_POWER
DAS_PWR.SCH
VICTOR
CALTECH
FIRST SIGNAL PROCESSING
Size
Document Number
B
REV

6c

Systems design and array interface specifications

CEA option

Louis Rodriguez

CEA
BOLOMETER ARRAYS
PROGRESS STATUS

TO BUILD BOLOMETER ARRAYS

TO HAVE ACCESS TO A TECHNOLOGY :HERE AT CEA/LETI
Manufacture of integrated electronic circuits,
and microsensors for industry.

TO HAVE KNOWLEDGE OF CRYOGENIC DETECTORS FOR SCIENTIFIC SPACE PLATFORMS: ISO and CASSINI.

TO HAVE ACCESS TO PHYSICAL PROPERTIES:

OPTICAL ABSORPTION DATA.

THERMAL CONDUCTANCES OF MATERIALS:
Si, metal wires, others.

SPECIFIC HEAT DATA to compute heat capacity of the bolometer.

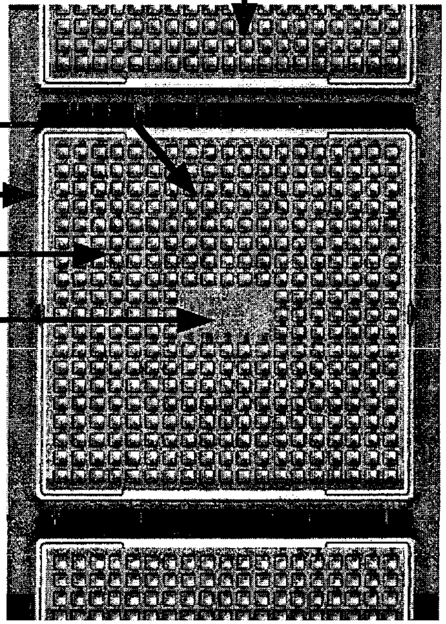
A THERMOMETER with known response and noise density
to compute SENSITIVITY.

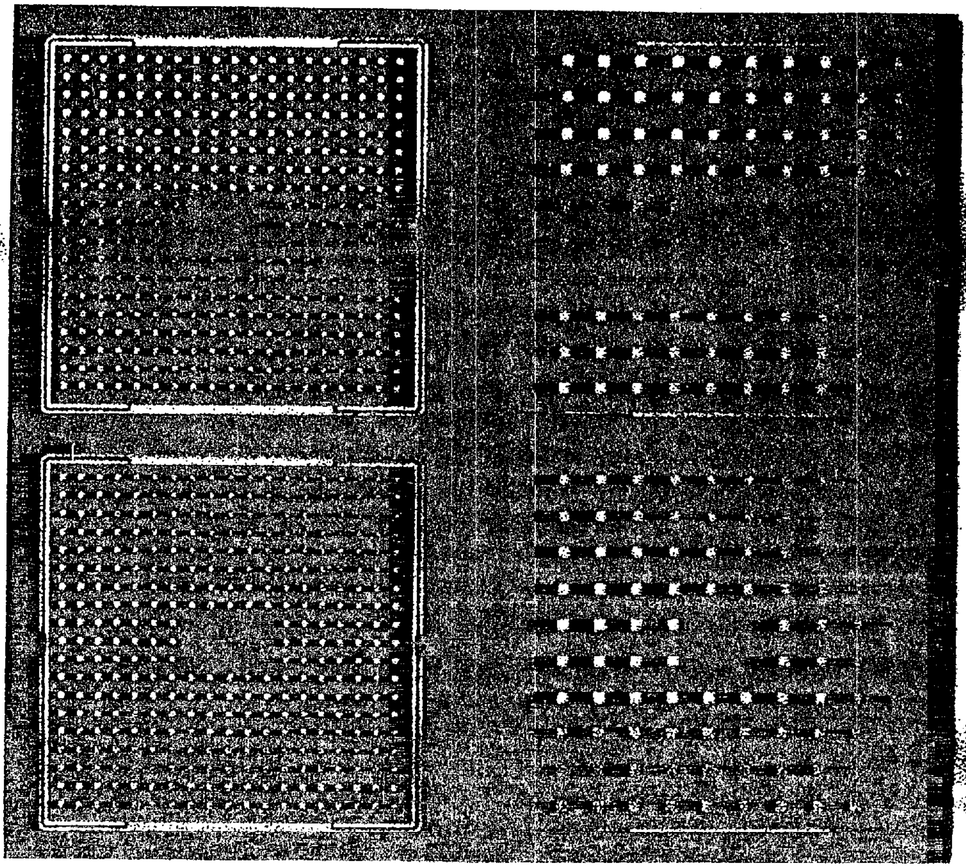
TO DEVELOP MODELS :

For observations

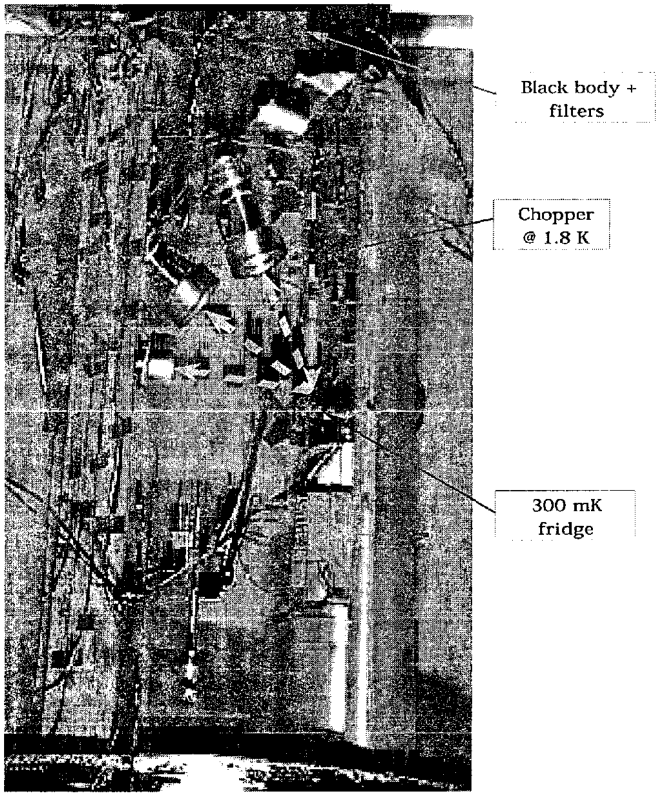
For optical absorption.
For thermal behaviour of the bolometers: bandpass and expected sensitivity
For electrical read out and signal processing.
For thermal requirements of the focal planes.

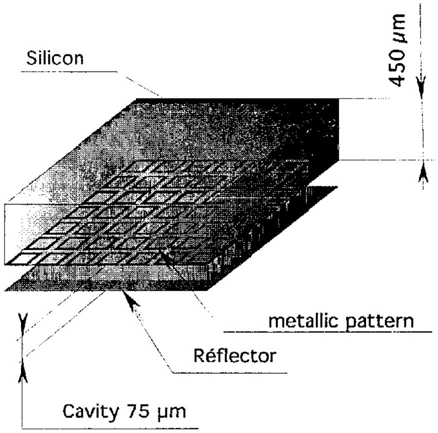
TO ENSURE THAT SOLUTIONS ARE CONSISTANT WITH AVIABLE THECHNOLOGIES FOR SCIENTIFIC SPACE BASED OBSERVATORY.

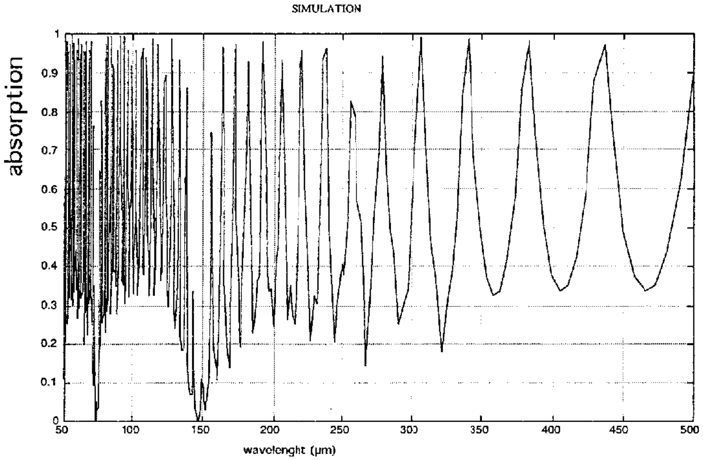




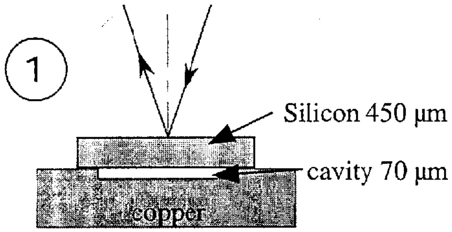
OPTICAL ABSORPTION MODEL (I)

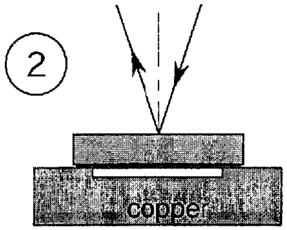




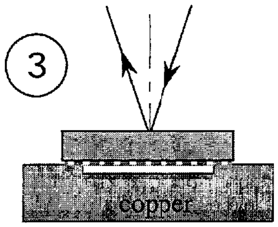


OPTICAL ABSORPTION MODEL (II)

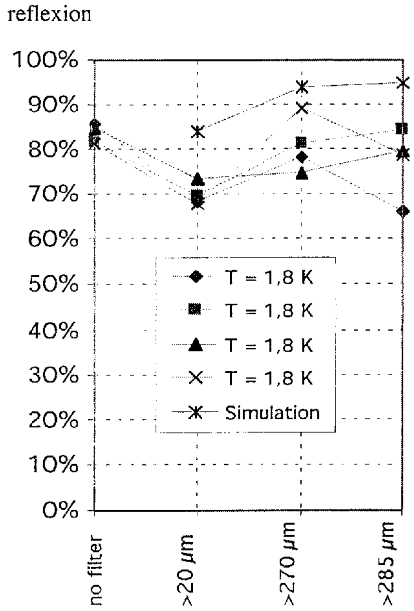


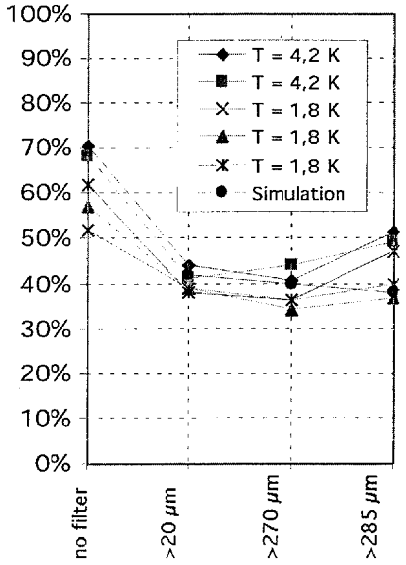


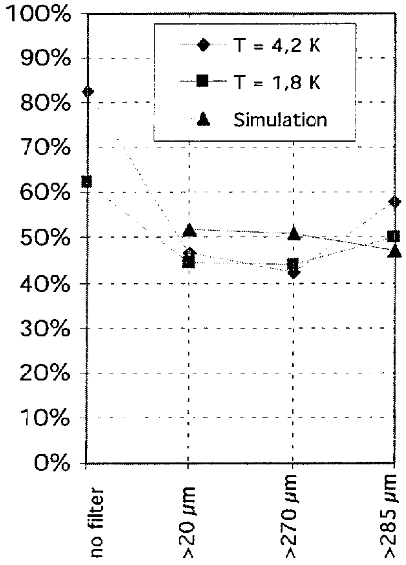
plain metallic absorber
54 Ω/sq

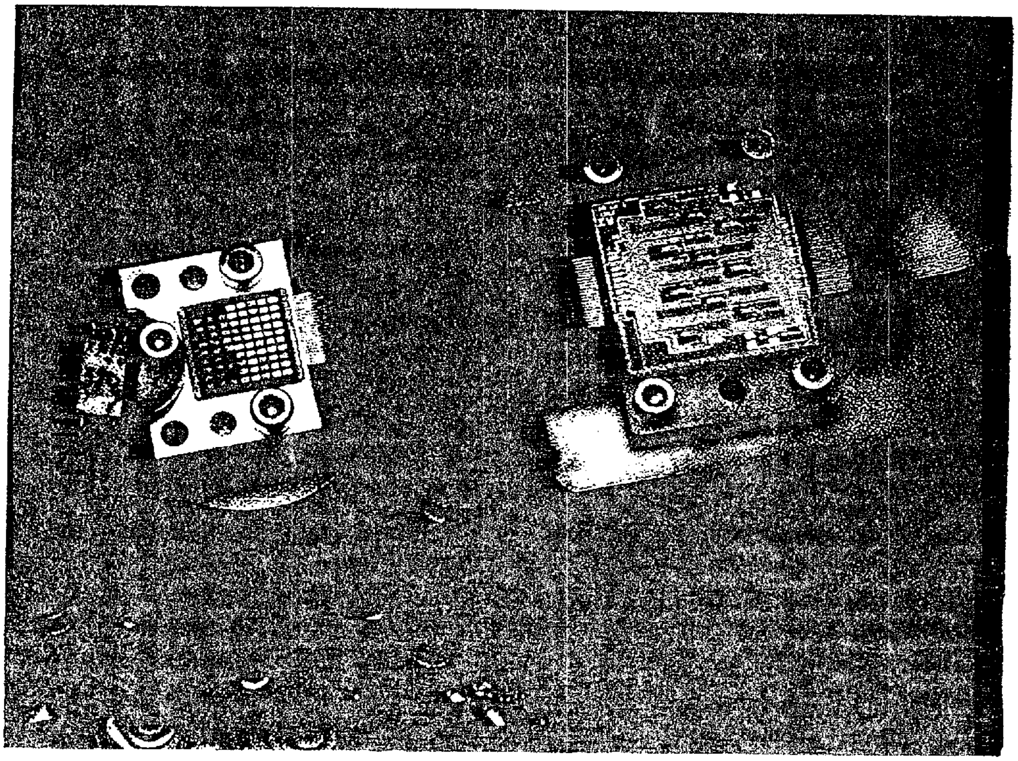


idem + metallic pattern
377 Ω/sq









THERMAL PROPERTIES OF THE BOLOMETERS (I)

THERMAL CONDUCTIVITY (SAp & LETI+SBT)

TWO STEPS

1) CARACTERIZATION OF THERMOMETERS

Calibration of reference thermometers in the temperature range 300 à 900 mK, and for bias range10->1000 mV :

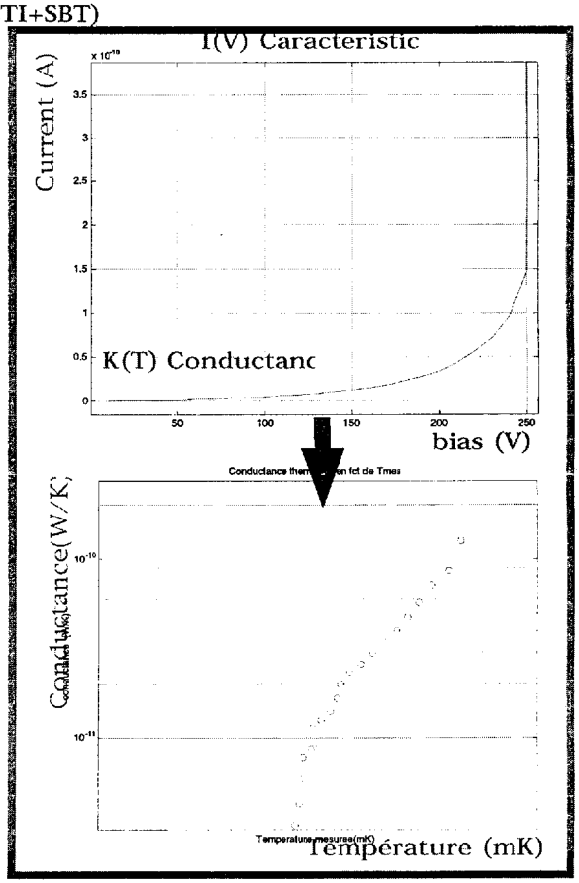
$$R(T) = Ro.\exp[(\frac{T}{To})^{1/2}].\exp(-\frac{q(aT^2+bT+c)E}{kT}) \; .$$

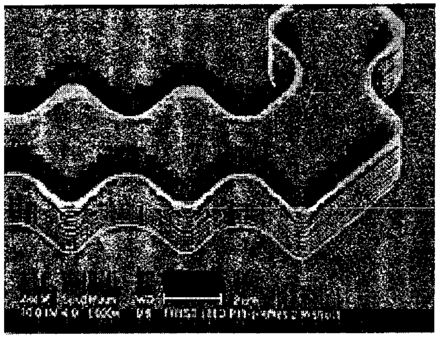
2) APPLICATION TO BOLOMETERS

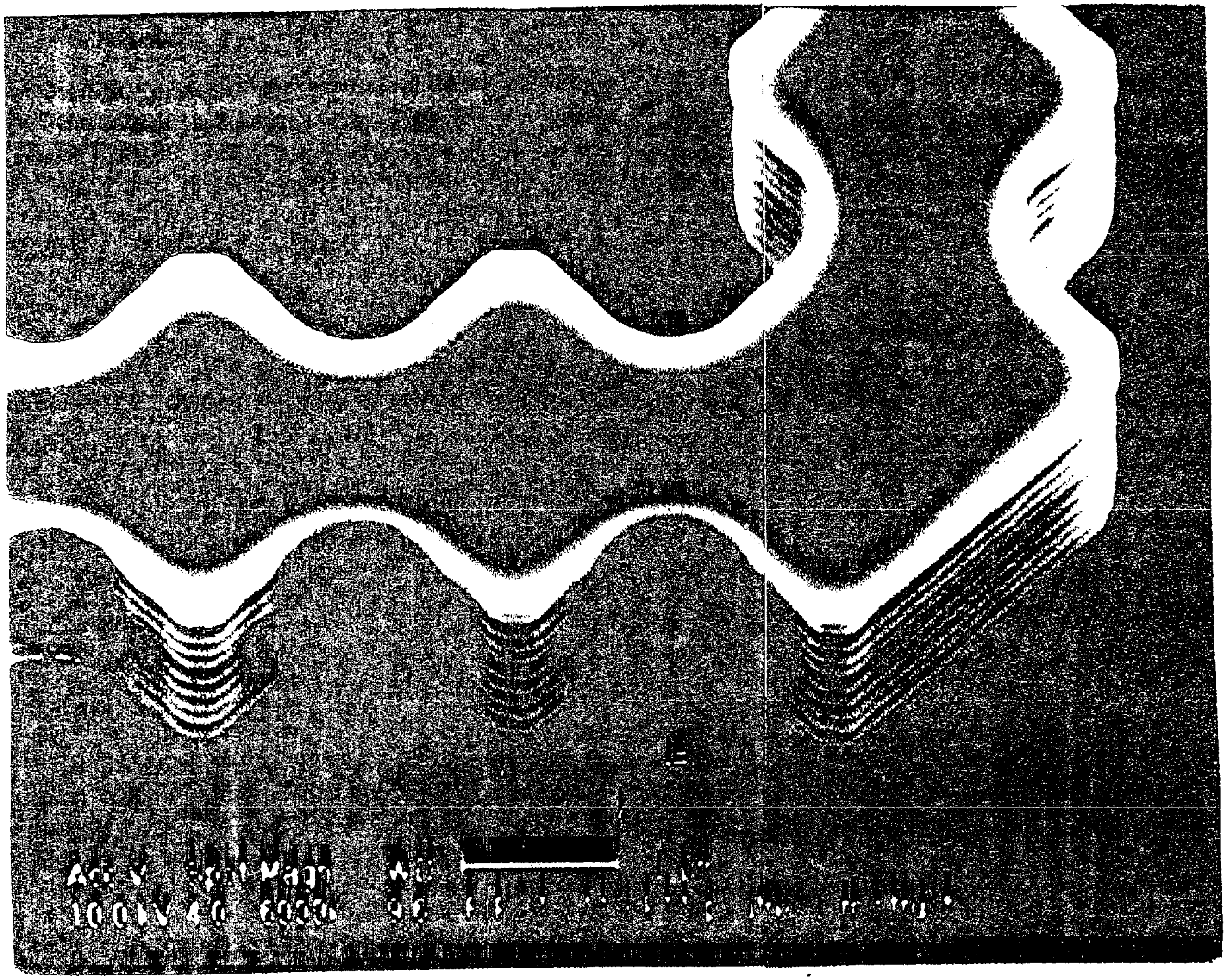
Result: for straight "beams", the resuslt is close to Casimir law, with a contribution of the metal passivation layer. For wiggly beams, silicon contribution remains identical with a strong decrease of conduction of the passivation layer.

Measured conductivity for these beams

$$G6(T) = (0.2497 \pm 0.06).10^{-9}\,T^3 + (0.009 \pm 0.002).10^{-9}\,T$$

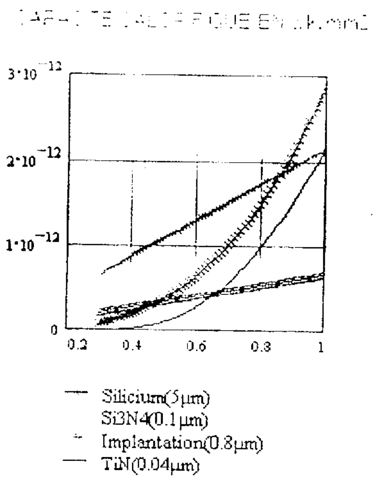


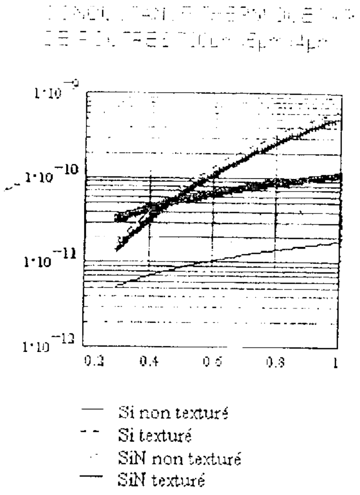


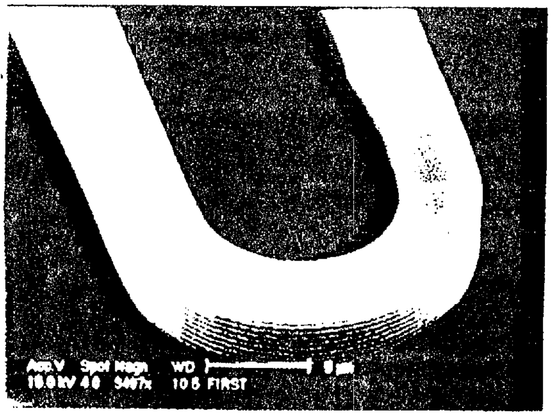

Acc.V Spot Magn WD
10.0 kV 4.0 6000x 9.6

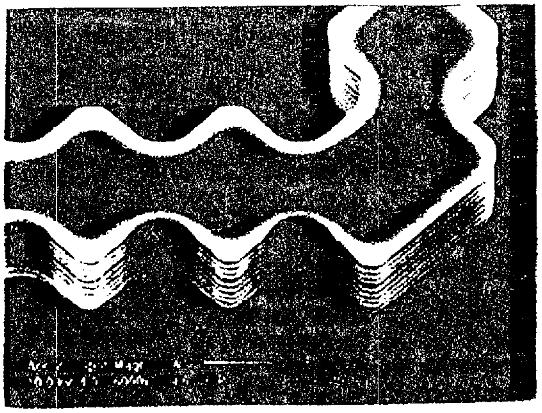
CEA/LETI/LIR, le 11/09/98

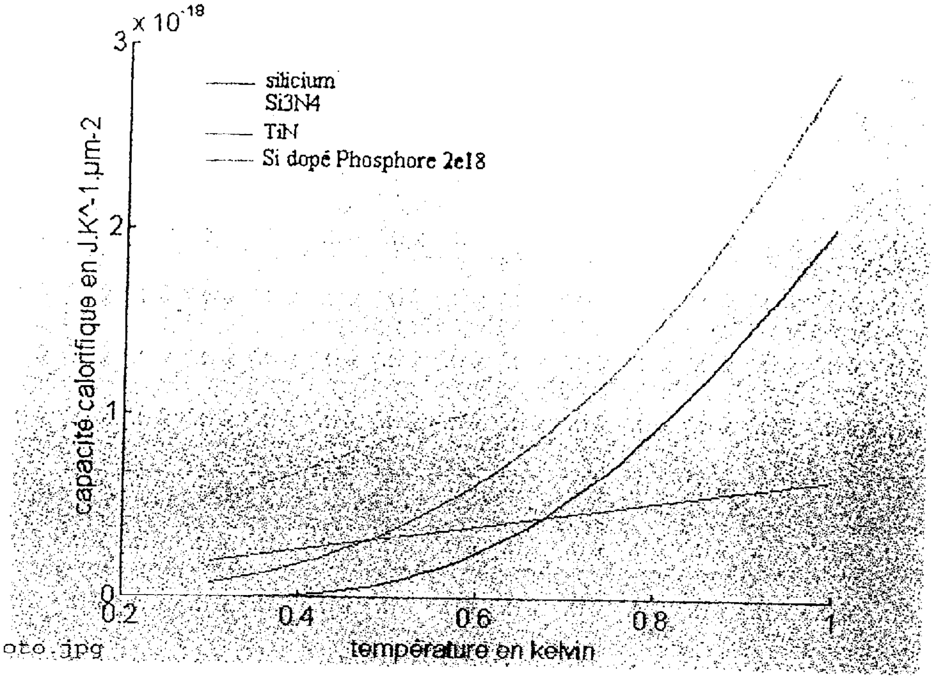
MODELES THERMIQUES SUB-KELVIN DU BOLOMETRE FIRST



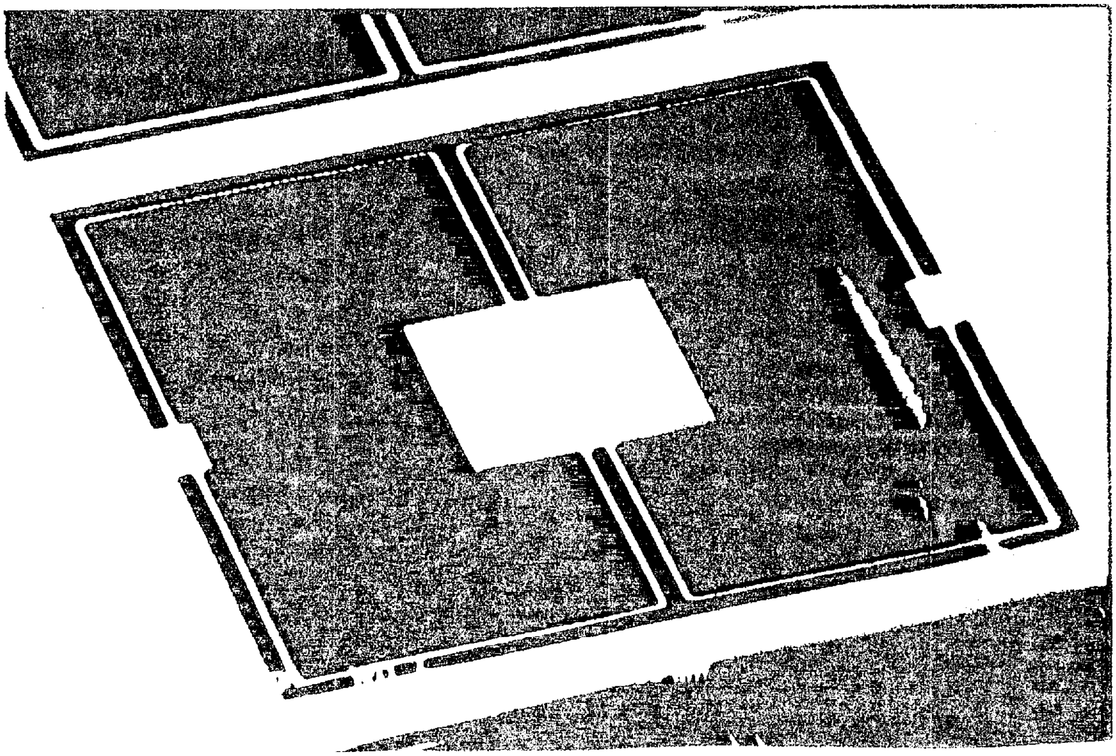






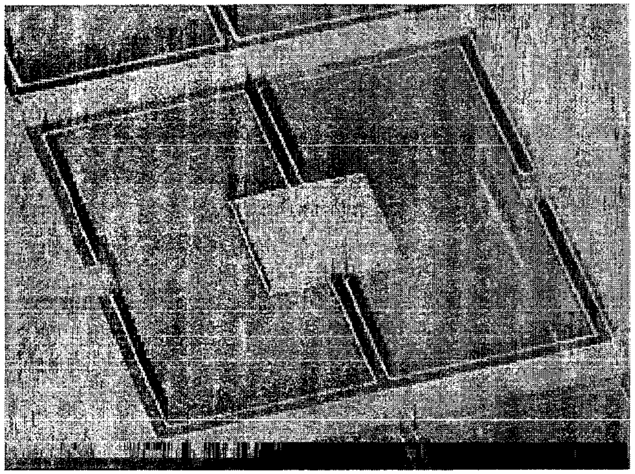


bolo-photo.jpg



THERMAL PROPERTIES OF THE BOLOMETERS (II)

SPECIFIC HEAT & HEAT CAPACITY (LETI+SBT)



ON DEDICATED PIXELS (Fig.)

A power step is injected in one of the thermometers and we measure the temperature decrease :

-2 thermometers 40*40*0.8μm³
-2 thermometers 100*100*0,8μm³
+absorbing metal layer
+passivation TEOS
+passivation Si3N4 (metal protection).

Knowing the thermal conductance we deduce by differnce the heat capacity of bolometer components with T .

Résults: Heat capacity of Si $C(T)=5,8(\pm1,3)10^{-7}\ T^3$ J/K/cm³. Close to predicted values (Casimir 1938)

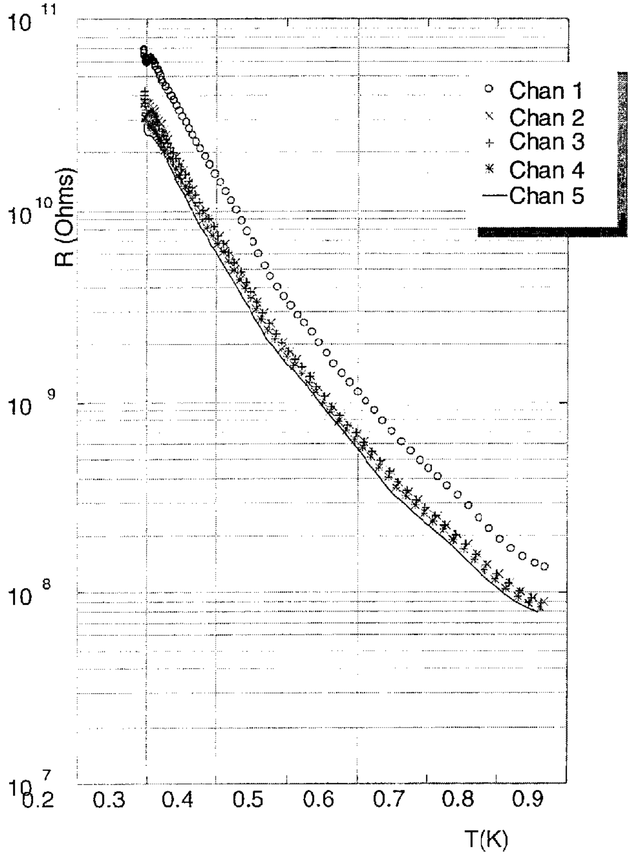
- TEOS and implanted Boron at 4E12 at/cm² not measurable.
- Passivation Si3N4 : $C(T)=2,15(\pm0,32)10^{5}\ T^3$ J/K/cm³.
- Implantation P+,B+ $C(T)=8,25(\pm1,23)10^{7}\ T^3$ J/K/cm³
- Metal TiN $C(T)=5.81\ 10\ Tc\ \exp(-1,44Tc/T)$ J/K/cm³

GOOD NEWS: The most important contribution is passivation Si3N4 used to protect the metallic absorbing layers. Other contributions will be negligible compared to silicon. Silicon contribution is consistant to the Casimir model used for predictions.

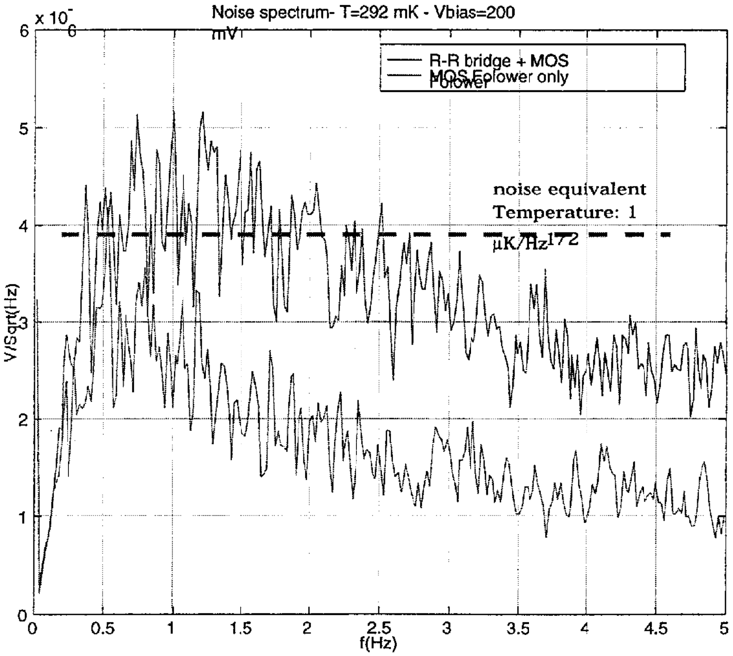
CONSEQUENCES: The thermal response will be faster than forseen: $\tau<10$ ms

THERMAL RESPONSE OF BOLOMETERS

These results have already been presented



These characteristics are checked with every new array tested.



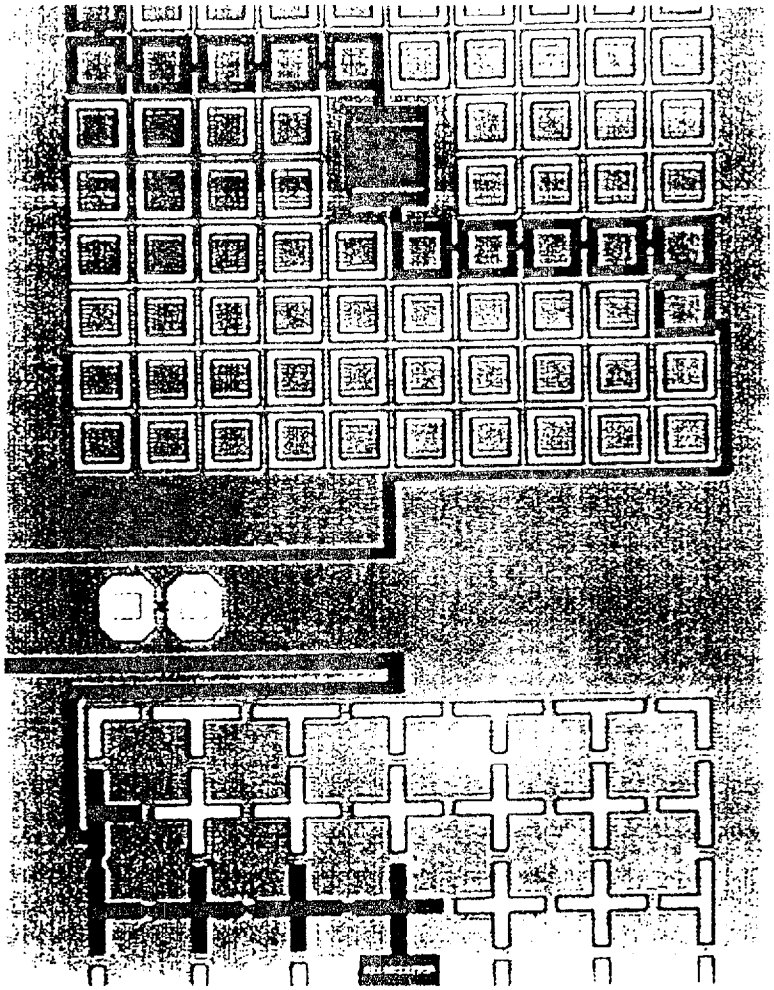


Photo d'ensemble d'un bolomètre montrant que les pistes WN connectées aux plots TiNiAu d'hybridation se sont oxydées (bleuissement) alors que les motifs WN (carrés ou croix) utilisés comme absorbeur n'ont visiblement pas évolué

MAIN UNEXPECTED PROBLEMS SOLVED SINCE 1996

MANUFACTURE OF SELF-STANDING STRUCTURES IN COLLECTIVE PROCESS:

BOLOMETER ARRAYS proceed from superposition of 3 thechnologies:
-Standing sensors at DMITEC
-Indium hybridization by bumbs
- Deep implantation of P & B and metallization with exotic alloys (TiN,WN).

Ensure compatibility of these technologies was less straightforwad than foreseen.

-Manufacture yield was low: often broken pixels were found at grid liberation step .
-Residues were found between beams and grids.
-Chemical reaction of WN with solutions used for grid liberation converted metallic contacts in "isolating contacts".

THERMOMETERS MANUFACTURE:

-Deep implantation was poorly controled some wafers were lost .

-The implantation profiles are inhomogeneous a small part of the implanted layers contribute to the thermometric properties, but all contribute to the heat capacity.

THERMAL INSULATION OF READ OUT CIRCUITS

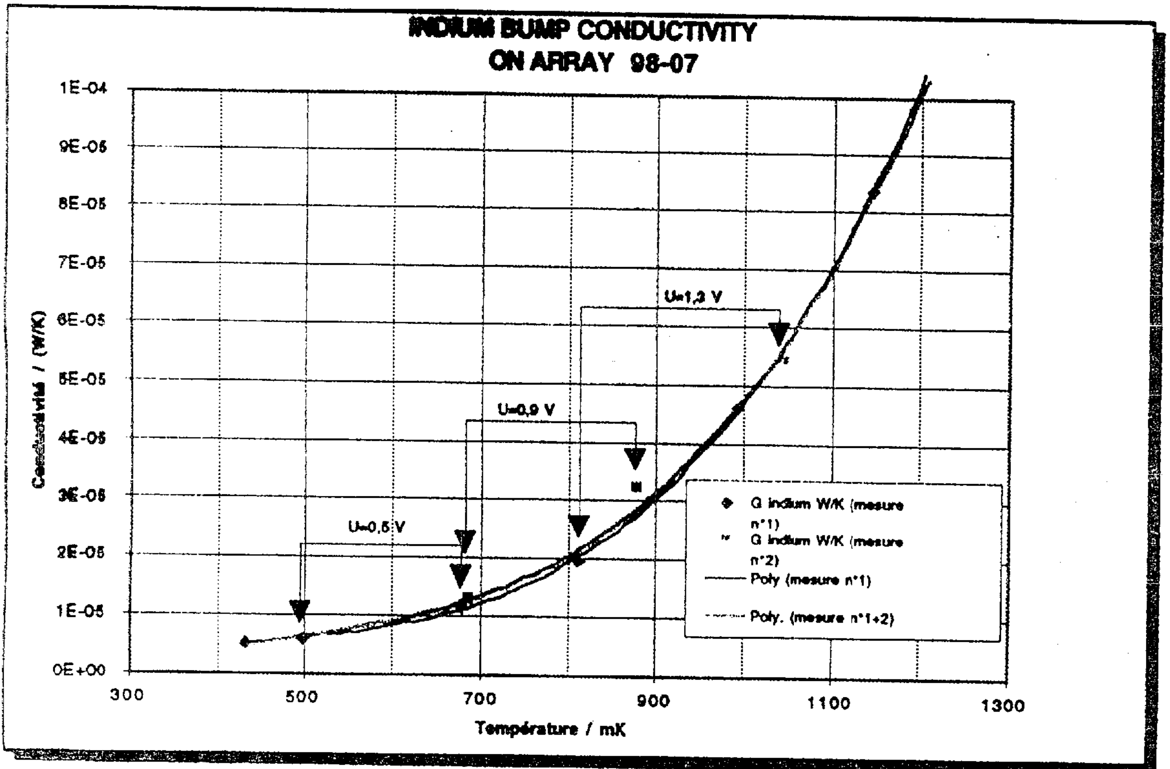
The thermal insulation of read out circuit (2K) from 300 mK interconnection circuit was devoted to the superconducting indium bumps (90)Measurements done at SAp showed a larger thermal conductance than expected:15 μW/array. Incompatible with the thermal budget at 300mK.

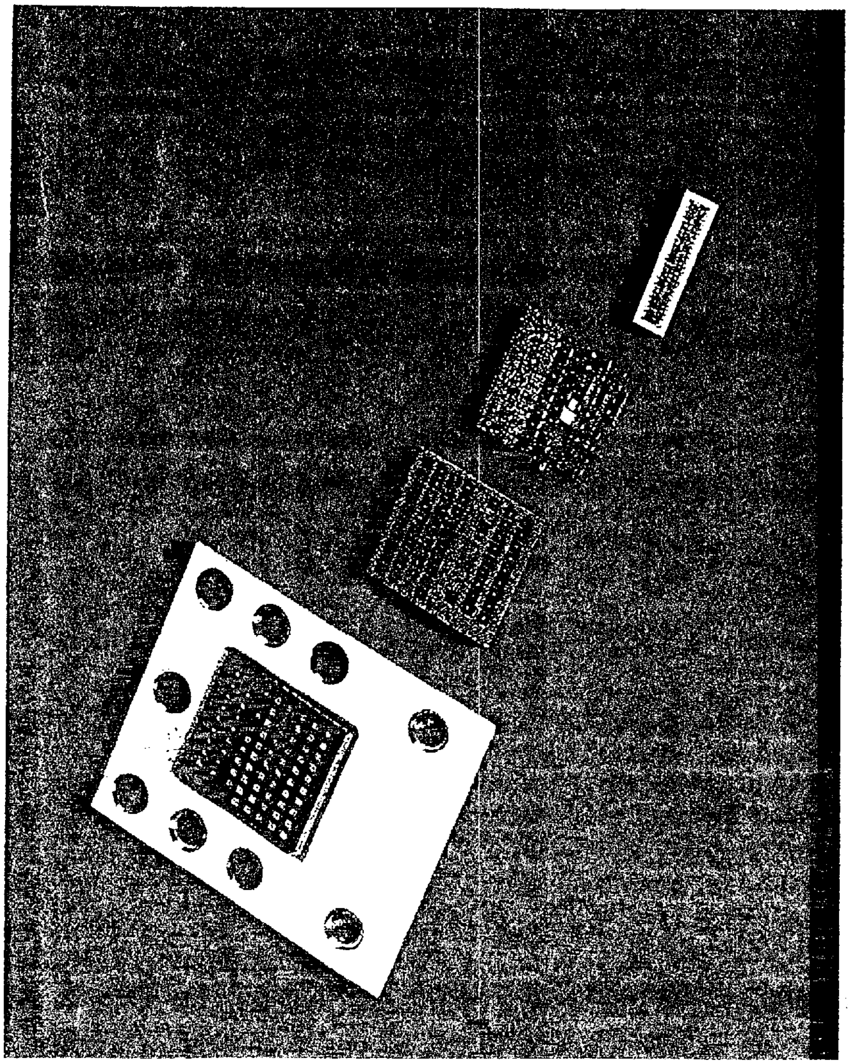
This problem is not yet solved, we will test new solution by early 99. We need a waiver on this parameter for th selection process: the new arrays under manufacture will use the same decoupling scheme

INDIUM BUMPS THERMAL CONDUCTIVITY

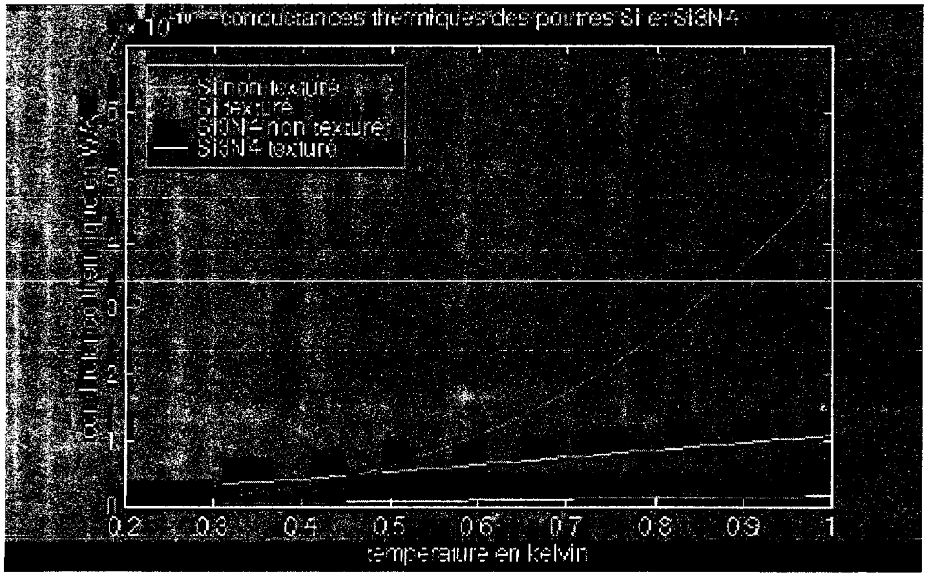
Using high power dissipation on bolometers and measuring substrate (reference) temperature, we deduced the thermal conductivity of the indium bumps. They were supposed to isolate the cold read out circuit at 1,8 K from the 300 mK stage .

We measured a conductivity variation with T^3 in place of T, incompatible with admitted thermal load on the ^{3}He fridge.





THERMAL CONDUCTANCE (II)



CURRENT SITUATION

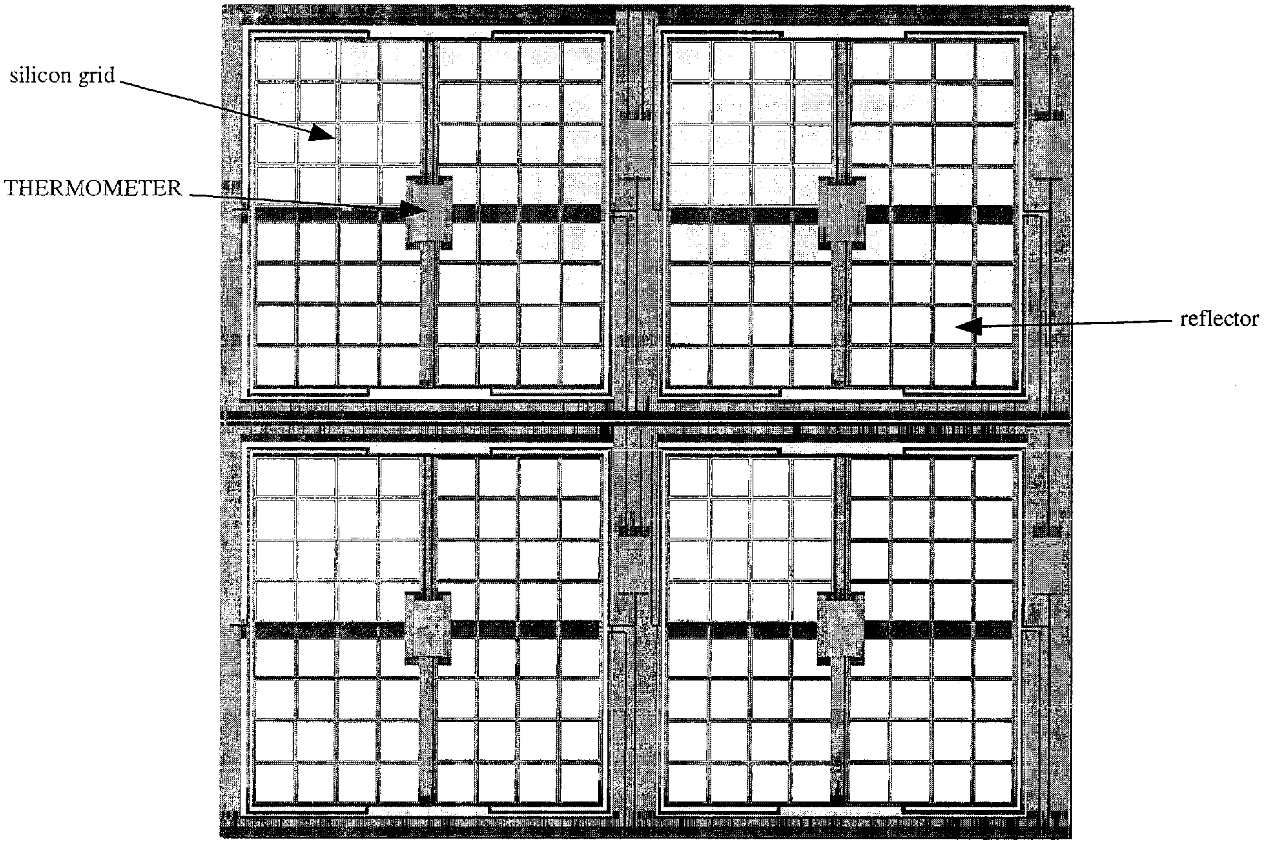
DETECTOR ARRAYS
THE MANUFACTURE OF ARRAYS FOR THE SELECTION PHASE STARTED IN JUNE.
GEOMETRICAL AND THERMAL PARAMETERS FIXED IN THE DESIGN PHASE(FEB 98):
HOMOGENEOUS ARRAYS16 x 16 pixels. STEP 750µm.
MUX 8->1 SUBSTRATE TEMPERATURE 300 mK under a 1pW background.
MUX and read out circuits will be integrated to the arrays.

32 array types will be manufactured. They differ from:
- -the absorbing pattern (crosses, capacitives loops, grids).
- -Thermometer: implanted or mesa (double SOI wafer and thermal diffusion).
- -absorbing metal(TiN or WN)
- -Independent bias of the thermometers grids or not,
- -Reflector type.

OUR MAIN CONCERN IS THE NUMBER OF TESTS TO BE DONE IN A SMALL AMOUNT OF TIME:
FEB99->SEPT 99 .

OTHER CONCERN : HOW TO CONNECT THE FIVE FOCAL PLANES TO THE DISTANT ELECTRONICS. 500 WIRES REP A SUM OF MECHANICAL AND THERMAL DIFFICULTIES. WE WORK TO INCREASE THE MUX SCHEME

1999 BOLOMETER DESIGN



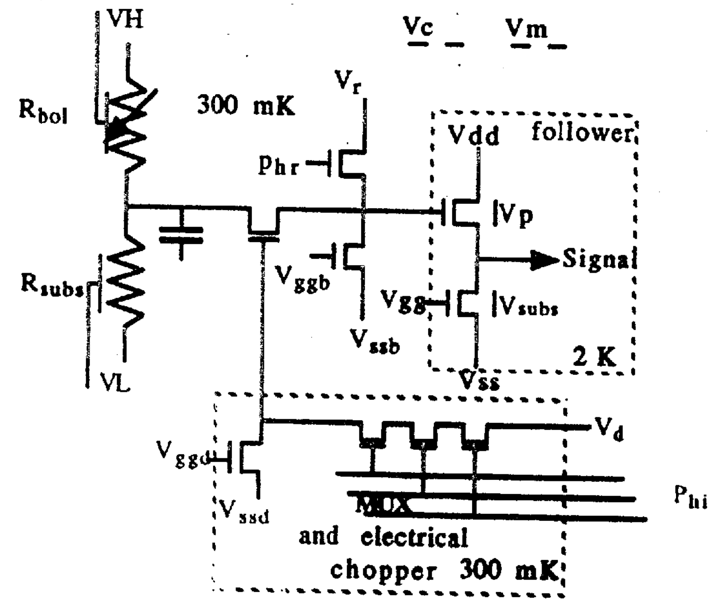
SITUATION PRÉSENTE

ELECTRONIQUE:

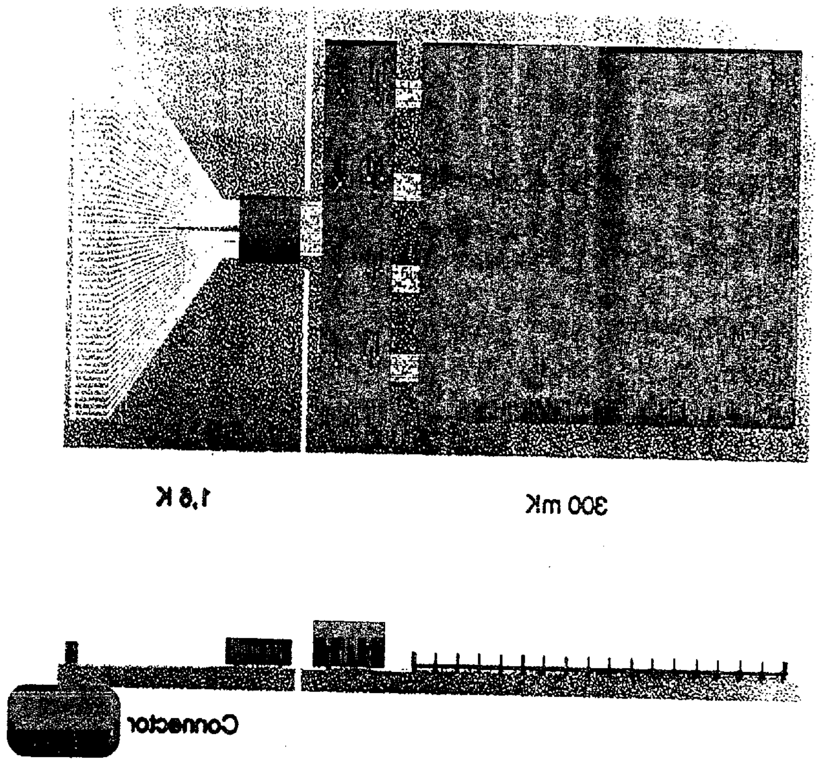
Le schéma de l'électronique froide (0,3-2K) est maintenant bien avancé. Il comporte un multiplexeur/hacheur à 300 mK qui sera testé prochainement au SAp (8->1/1 kHz). Un suiveur à 2K en cours de tests a Saclay.

Le principal effort sur l'électronique de proximité est déployé pour augmenter la bande passante électrique dans les mêmes proportions que la bande passante thermique.

La prochaine génération de détecteurs permettra l'accès à la grille de résistance des thermomètres.



Un schéma de l'électronique chaude de traitement du signal est en cours de maquettage. Il comprend un ensemble de détection synchrone analogique.


1.8 K
300 mK
Connector

6d

Summary of systems design and interface status

Bruce Swinyard

PROGRESS ON INTERFACES (?)

* MECHANICAL:

PLAUSIBLE SUSPENSION SCHEME PROPOSED FOR 2K/300mK SUSPENSION

⇒ IT LOOKS TOO BIG !

WILL WORK FOR SQUID/~~TES~~ + FEEDHORN

[CEA ?]

JFET BOX STILL LOOKS BIG (160 x 320 mm)

* ELECTRICAL:

TES: COMPLEX ELECTRONICS BASED ON ADVANCED FPGA's AND ADC's
SYSTEM DESIGN WILL NEED TO BE BASED ON MORE CONSERVATIVE COMPONENTS
WILL ESA ALLOW QUALIFICATION OF NEW 'EXOTIC' COMPONENTS

JFET: RELATIVELY STRAIGHTFORWARD ELECTRONICS
⇒ 18 BIT A/D NOT APPROVED PART
~~BUFFER~~ OF ~~AMPLIFIED~~ FILTER. IS REQUIRED ON EVV

CEA: NO CHANGE — BAU DETAILS.

* THERMAL:

TES ⇒ NO ISSUE? WARM ELECTRONICS ??
(AT FPU)

CEA ⇒ 'UNPROVEN' THERMAL SEPARATION OF 300mK/2K

JFET ⇒ NEW DESIGN ALLIEVIATES MANY OF THE PROBLEMS
~~⇒ IS TH~~ IS THIS ACCEPTABLE TO ESA?

* WIRE COUNT

TES - NOT YET
JFET - NOT YET
CEA - NO CHANGE (REDUCED?)

* SPU REQUIREMENTS

TES - INTERNAL TO READOUT?
WHAT ARE REQS ON 'EXTERNAL'
SPU - PROCESSING SPEED?
MEMORY REQS?
JFET - 1MFLOP/S O.K.
MEMORY REQS?

CEA - ?

* OPTICAL - NOT ADDRESSED

* EMI - ~~NOT ADDRESSED~~

JFET - RF SHIELD FROM CUU ⇒ 300mK
DETAILED IMPLEMENTATION?
CEA/TES ?

7

Evaluation criteria and plan and future meeting schedule

Matt Griffin

Array evaluation and selection criteria

Draft note has been circulated – will be updated in response to written/e-mailed comments

Some important points:

- We must have absolute confidence at time of selection that chosen option will work
- A full system design document shall be produced by each array group, compliant with SPIRE design, spacecraft resources and IID-A requirements.
- A detailed array fabrication, test and delivery schedule shall be provided (at least up to CQM)
  - Including relevant warm electronics
  - Consistent with the SPIRE schedule
  - Realistic
- Credible space qualification programme and schedule shall be provided

Draft performance requirements for evaluation tests

Nominal operating conditions

Bath temperature	300 mK
Incident background power (pW)	Filled array: 1.3 2Fλfeedhorn: 5.3
Photon noise NEP (W $Hz^{-1/2}$)	Filled array: 3.8 2Fλfeedhorn: 7.7
Central wavelength (μm)	350
$\lambda/\Delta\lambda$	3

Requirements on measured performance

Detector optical NEP (W $Hz^{-1/2}$) (a) (excluding photon noise)	Filled array: 2.0×10^{-17} 2Fλ array: 4.0×10^{-17}
3-dB freq. of responsivity roll-off (b)	≥ 20 Hz
Maximum pixel-pixel variation	Noise: 20% Responsivity: 20%
Yield (good pixels) (c)	> 50% (for demonstration arrays only)
Crosstalk	TBD
Ionising radiation response	Shall be characterised with γ-rays and avg. projected area (cosmic ray cross section) shall be quoted for all proposed array types
Pixel angular response	Shall be characterised or modelled
EMI susceptibility	Shall be characterised or modelled
Thermal and vacuum cycling	TBD

Schedule of detector array meetings

Detector array group meetings:

January 1999	QMW
May 1999	Saclay
September 1999	Caltech.

TBC

Array Test Prog.

Simulations / Selection Criteria

Review of well-defined systems designs

Formal selection meeting:

January 2000	RAL

Full documentation to be provided by mid-December 199~~8~~9 (last minute updates in January if necessary).

8a

Array development progress reports

Goddard/NIST

Harvey Moseley

TES/Pop-Up Array Progress

SPIRE Quarterly Meeting
GSFC
Sept 17-18, 1998

Progress Since Last Meeting

- Procurement of test Cryostat initiated
- Mark II (1.8) SQUID readout requirements established, design developed,parts procured
- Mechanical design for Pop-Up array structure developed.
- Pop-Up detector tested with TES

Detector Electronics

- "Mark 1.8" electronics completed by Nov. 20
- Software for control and operation by Nov.20
- Test with SQUID mux by Dec. 10
- Test with pop-up arrays Dec. 20

Test Cryostat

- Cryostat of QMWC design ordered from Precision Cryogenics
- ^{3}He system ordered from Simon Chase

Mechanical Design

- Mechanical design for detector mounting nearly complete
  - Structural support
  - Thermal isolation
  - Electrical interconnections
  - Fab of model to begin in Oct.

SQUID Multiplexer

- Multiplexer improvements planned
  - Input circuit includes coupling inductor plus filter inductor. Filter being developed.
- Test anticipated for Fall, test with Mark 1.8 electronics by Dec.

Detector Tests

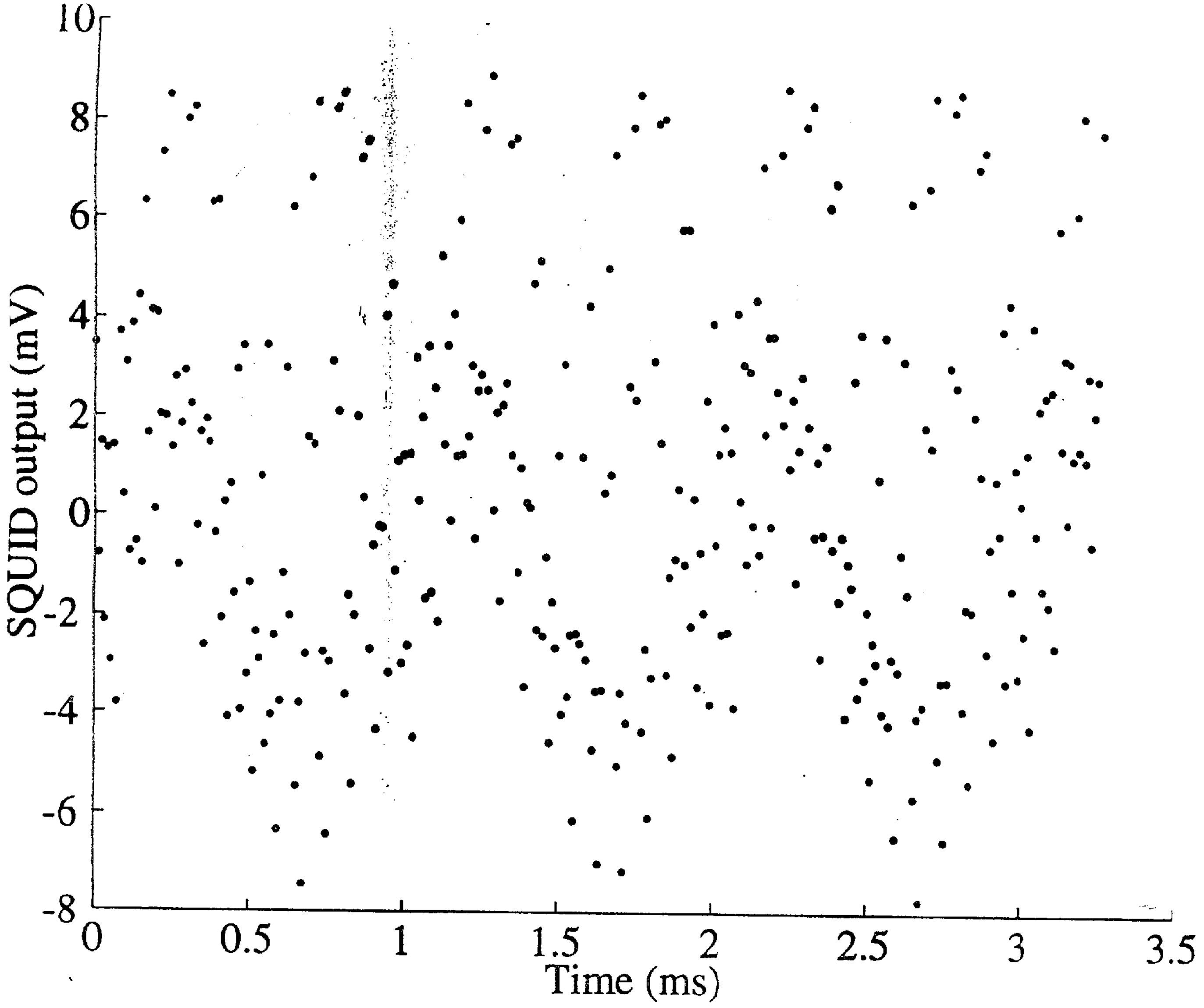
- TES (Tc=440 mK) applied to pop-up detector.
  - Conductance ~ 30 pW/K , just about right
  - NEP ~1.2 x 10^{-17} W/√Hz
  - τ_{eff} ~ 2 ms

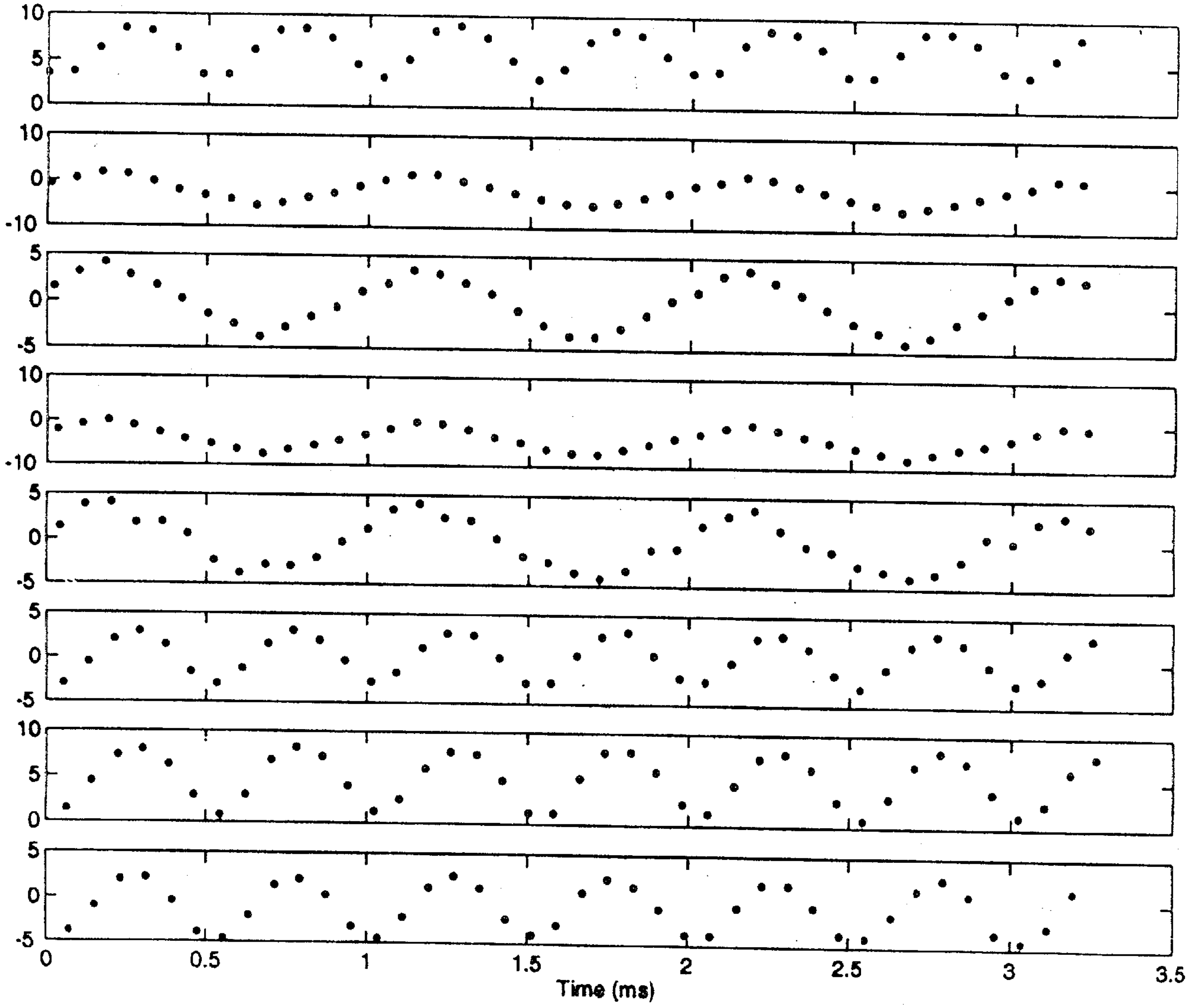
Schedule for Oct. - Dec.

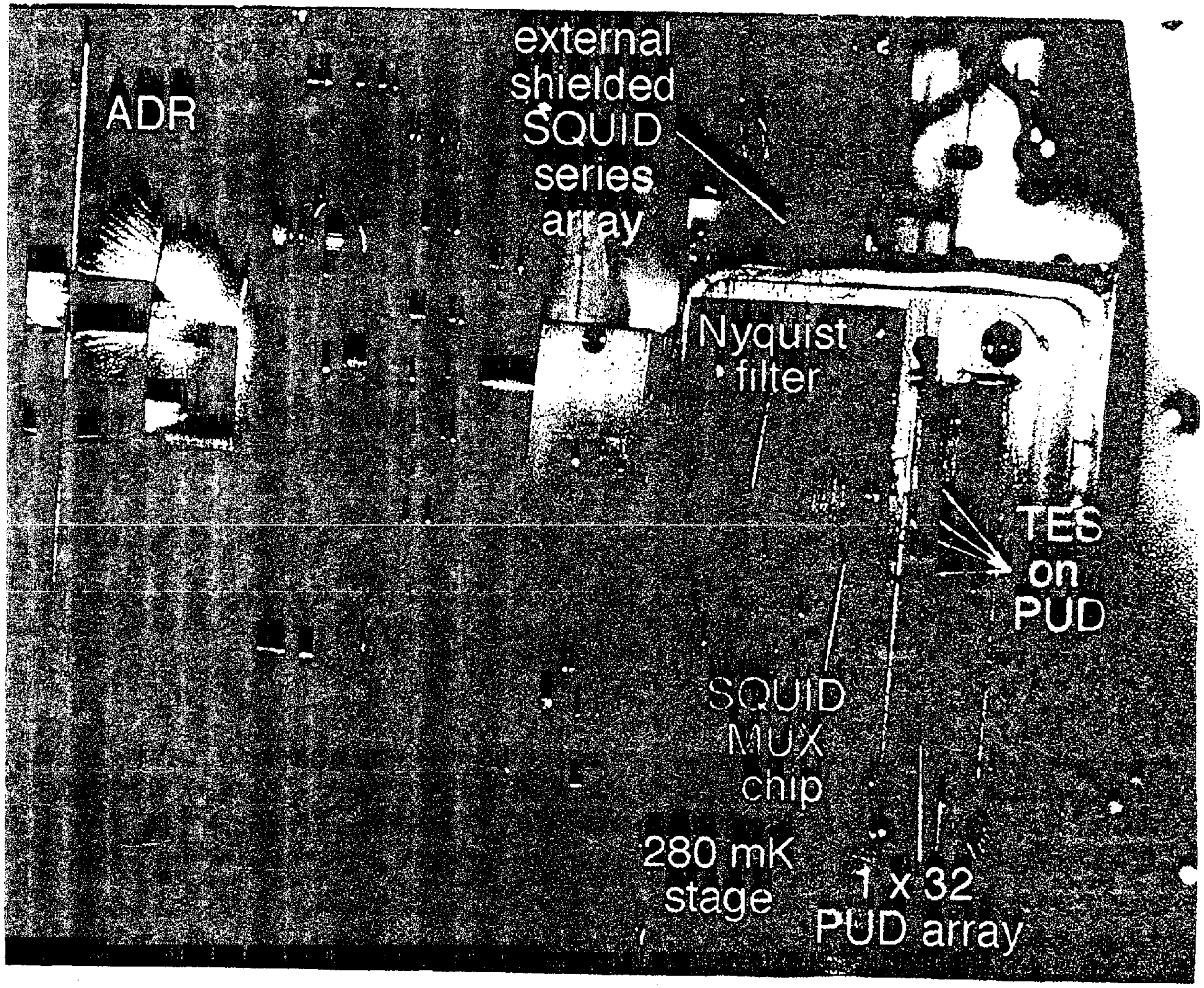
- Detector Work
  - Fold previously tested pop-up, retest
  - Microwave design of pixel
  - Definition of pixel design for downselect array
  - Test of absorber concepts in FTS
  - Complete process design for TES/PUD integration
- Complete and Test Mark 1.8 electronics
- Receive and test cryostat

Oct. - Dec. Continued

- SQUID Mux work
  - Test with pop-up array
  - Evaluate performance with filter inductor
  - Operate with Mark 1.8 electronics
  - Finalize design for downselect array (if changes are required)

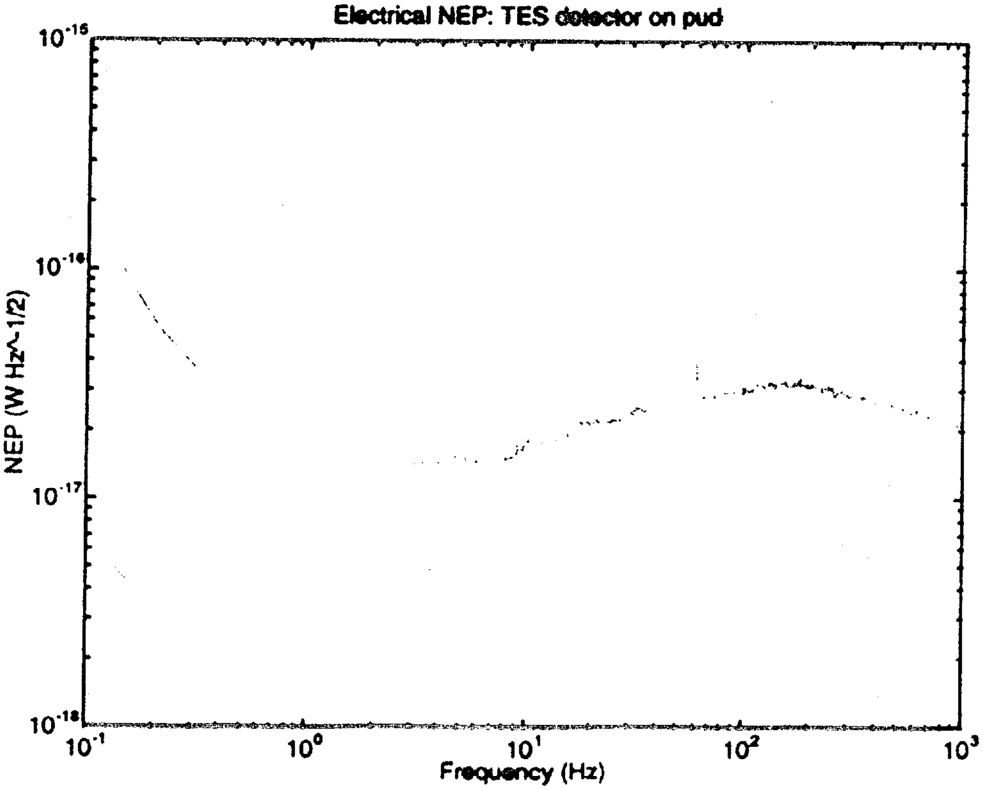

SQUID output (mV)
10
8
6
4
2
0
-2
-4
-6
-8
0
0.5
1
1.5
2
2.5
3
3.5
Time (ms)


10
5
0
10
0
-10
5
0
-5
10
0
-10
5
0
-5
5
0
-5
10
5
0
5
0
-5
0
0.5
1
1.5
2
2.5
3
3.5
Time (ms)

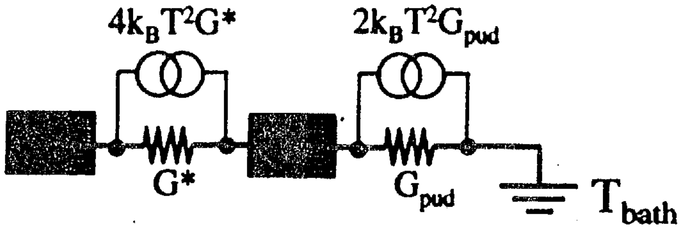

ADR
external shielded SQUID series array
Nyquist filter
TES on PUD
SQUID MUX chip
280 mK stage
1 x 32 PUD array

TES Bolometer on Popup Structure

- Bath temperature 280 mK
- Transition temperature 450 mK
- Thermal conductance 30 pW/K
- Signal bandwidth about 100 Hz
- Maximum power 3 pW
- 1/f knee < 1 Hz
- Electrical NEP
  - 1-10 Hz: 1.5e-17 WHz^-1/2
  - 10-100 Hz: < 3e-17 WHz^-1/2

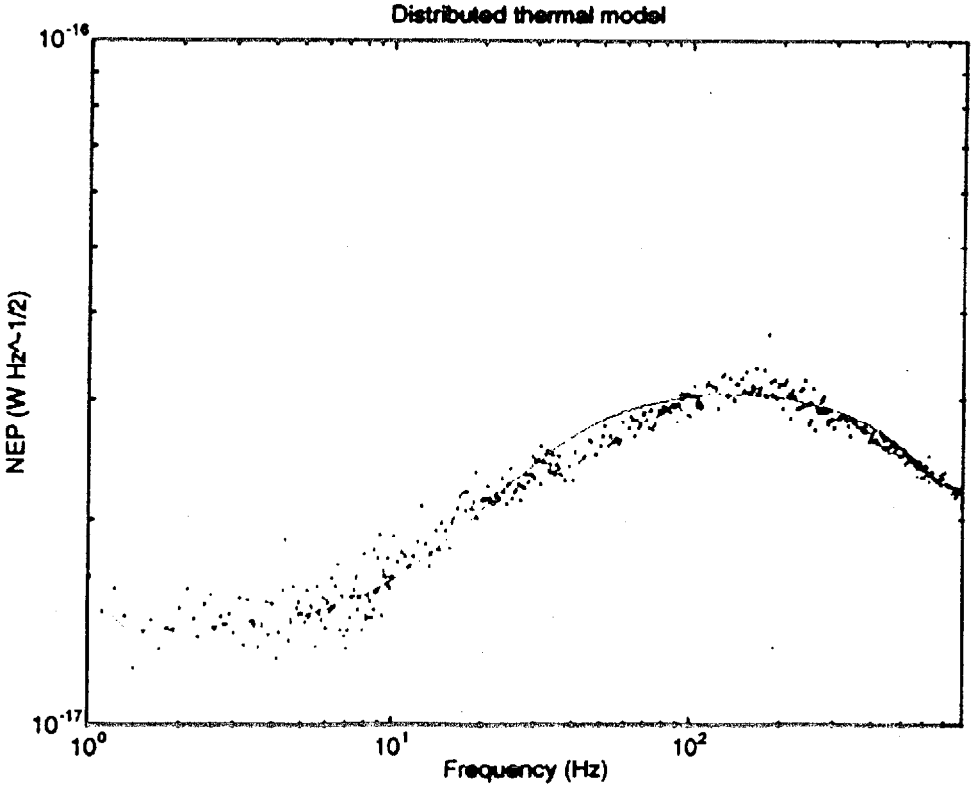


Thermal Circuit Model

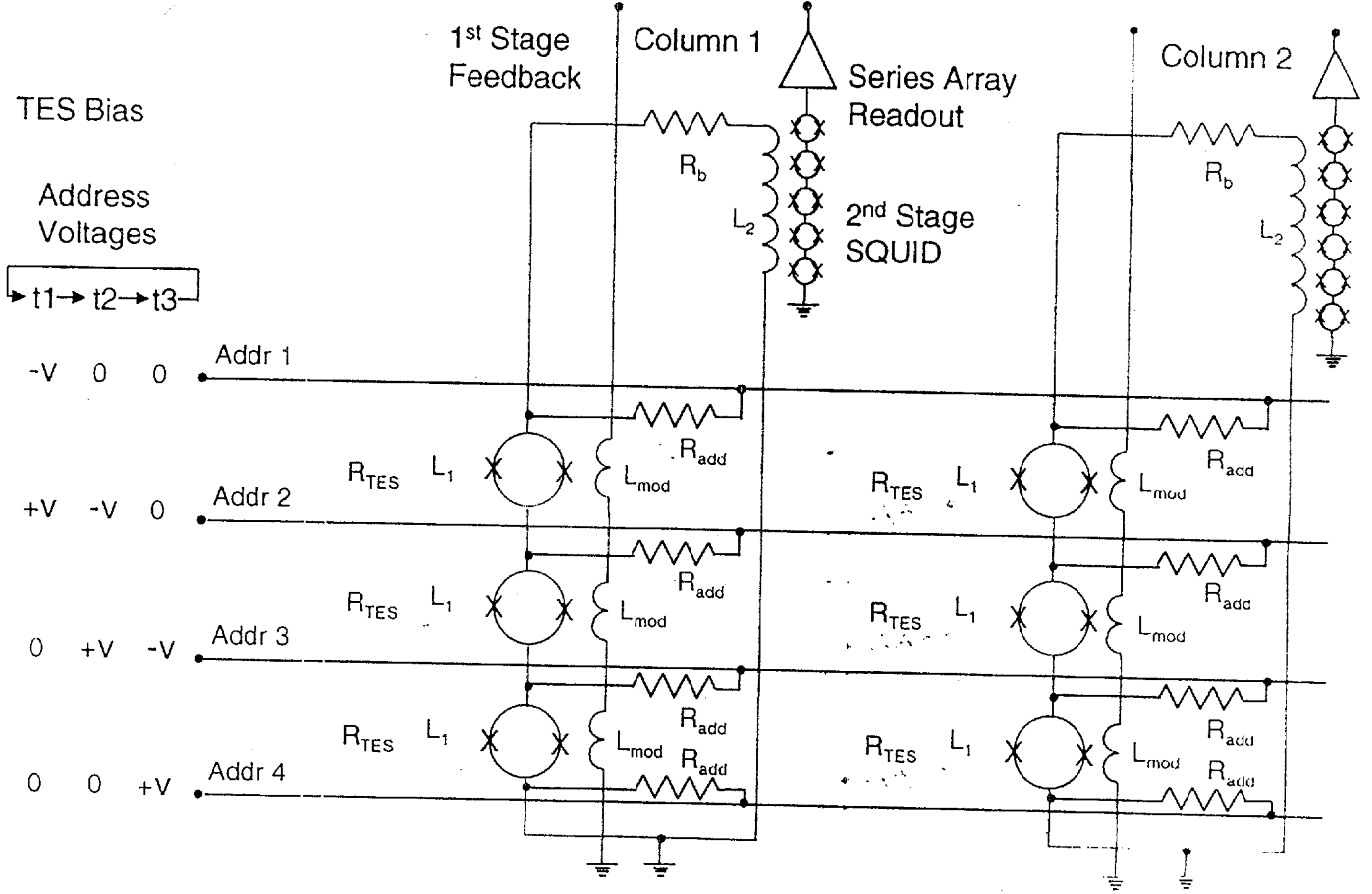


Fit to two free parameters:

$G^* = 300\ G_{pud}$	Thermal conductance within pud
$C^* = C_{TES}$	Extra heat capacity (from granular Al or Al diffused into silicon?)



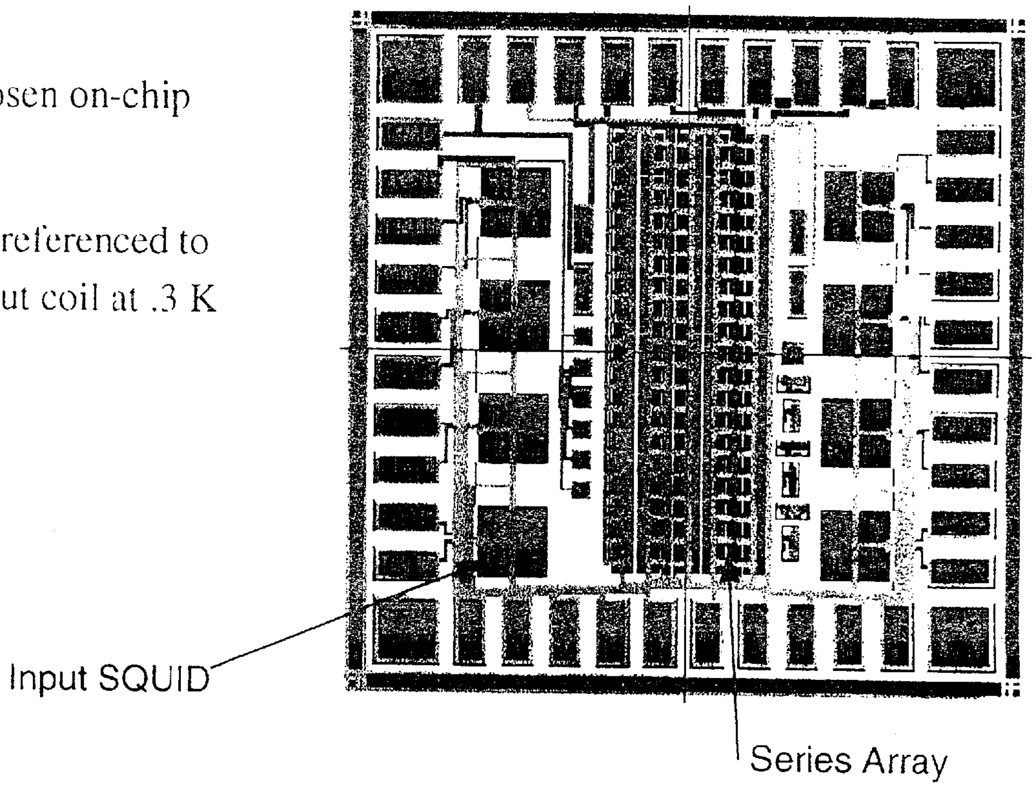
Analog 2x3 SQUID Multiplexer

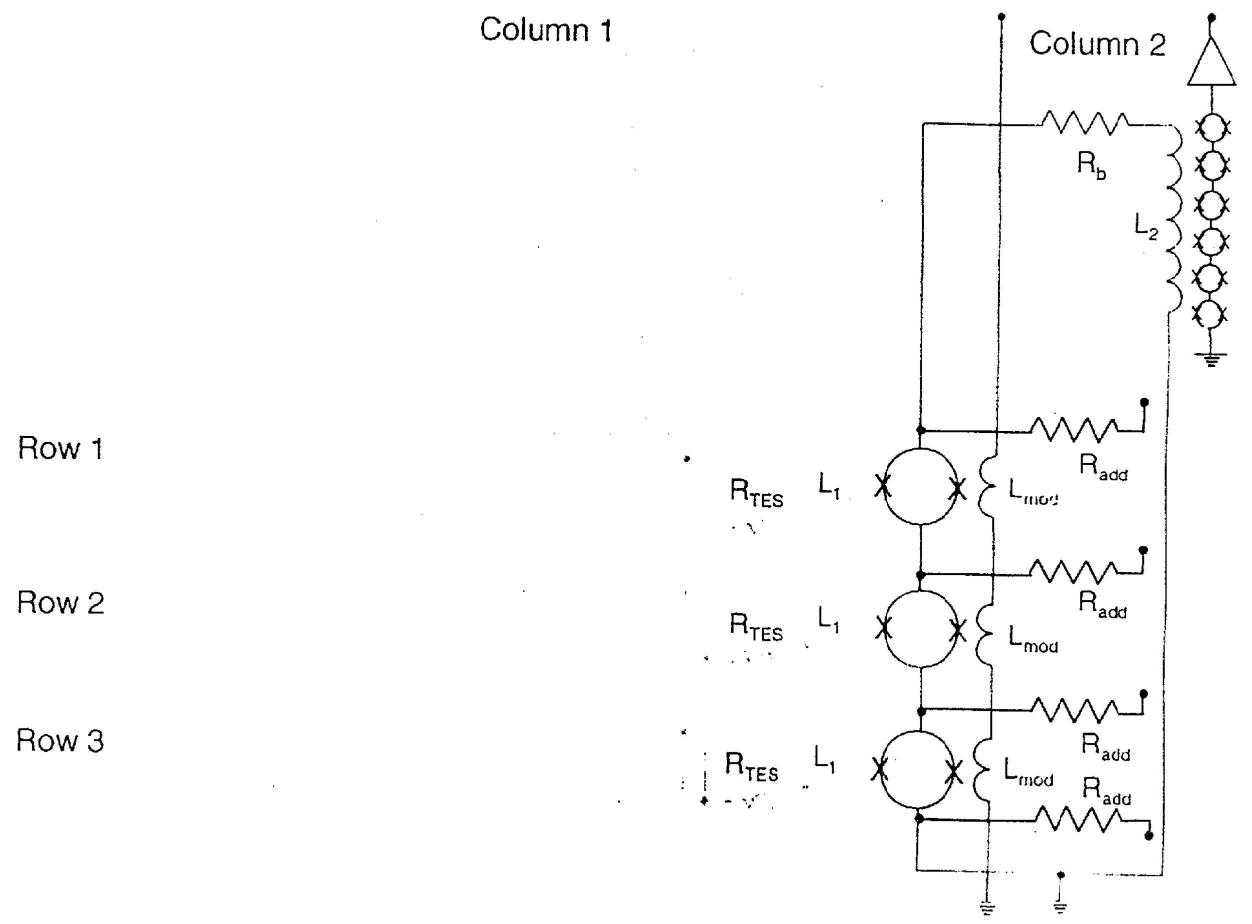


1x8 SQUID Multiplexing Chip

L_2 and R_b chosen on-chip

1.3 $\mu\phi_0/Hz^{1/2}$ referenced to first stage input coil at .3 K




Column 1
Column 2
R_b
L_2
Row 1
Row 2
Row 3
R_{TES}
L_1
L_{mod}
R_{add}

8b

Array development progress reports

Caltech/JPL

Jamie Bock

PROGRESS TO DATE

FEEDHORN - COUPLED ARRAYS

17 SEPTEMBER 1998

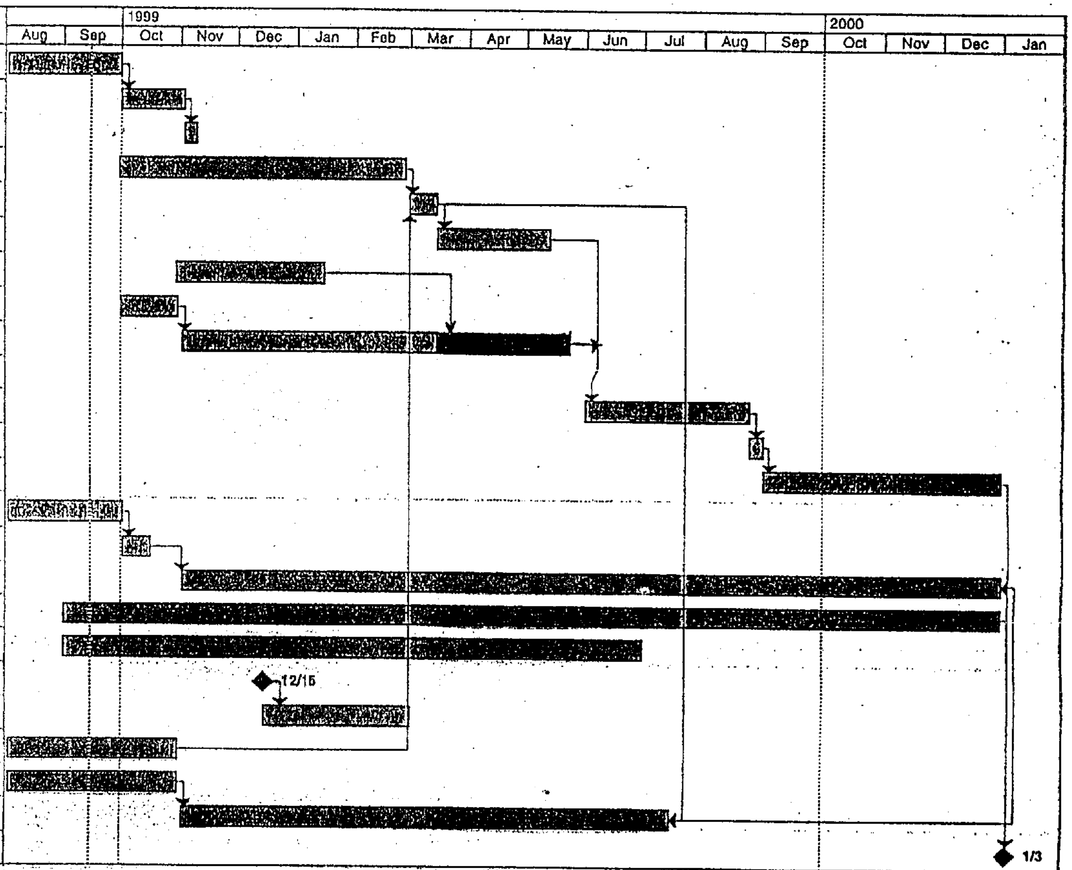
LITHOGRAPHED TES BOLOMETERS
- Al/Ag FILMS HEAT SENSITIVE
- Ti FILMS + Nb LEADS → CONTACTS
- Nb/Ti BOLOMETERS NOW IN PROCESS

FEED HORN + NTD ARRAYS
- BOOMERANG DETECTORS (~10^2 x area) WITHIN SPIRE SPECS
- ARRAY PROCESS DEVELOPED
  - INDIVIDUAL BOLOMETERS THROUGH ENTIRE PROCESS
  - BOLOCAM SCIENCE ARRAYS COMPLETENESS ~75%
  - SPIRE 350μm TEST ARRAY MASKS COMPLETE
- BOLOCAM TEST DEWAR ASSEMBLED
  - DUMMY ARRAY THERMALLY CYCLED
  - PROTOTYPE WAFER DARK RUN NEXT

TEST DEWAR PLANS

SCHEDULE

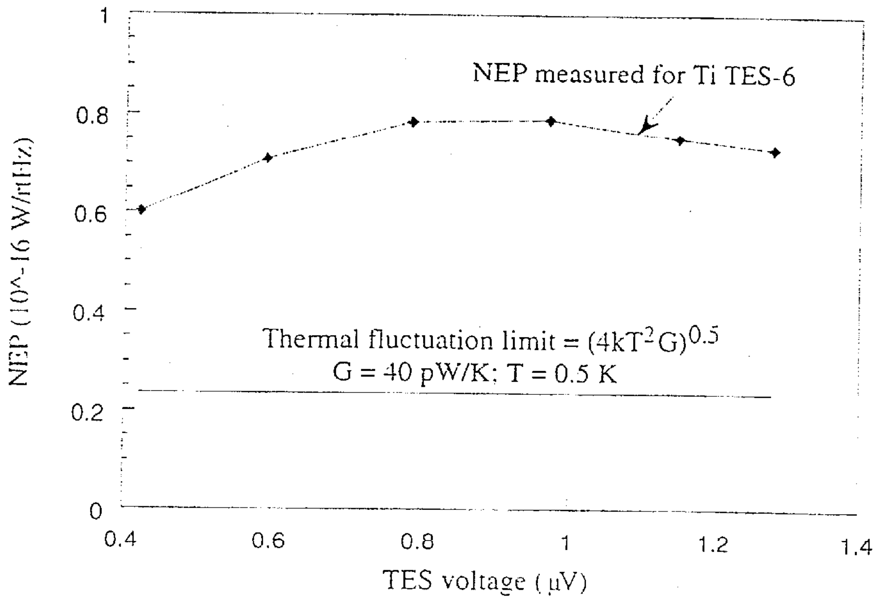
ID	Task Name	Duration
1	Fabricate Ti/Nb TES Bolometers	43 days
2	Test Ti/Nb TES Bolometers a: C	23 days
3	Ship Ti/Nb TES Bolometers to C	5 days
4	Order JFET, Load Resistor Moc	108 days
5	Fabricate Readout Electronics	11 days
6	Test Readout Electronics	43 days
7	Order Feedhorn Array Plates	56 days
8	Fabricate NTD Ge for SPIRE	22 days
9	Fabricate SPIRE 61-Element Ar	151 days
10		
11	Test SPIRE 61-Element Detectc	61 days
12	Deliver SPIRE 61-Element Dete	5 days
13	Test SPIRE 61-Element Detectc	88 days
14	Fabricate NTD Ge for Bolocam	44 days
15	Fabricate Bolocam 144-element	11 days
16	Test Bolocam Array	305 days
17	Study of low-power JFETS and	349 days
18	Design Mechanical & Electrical	217 days
19	Receive Test Dewar & Refriger	0 days
20	Characterize cryogenics	55 days
21	Design Readout Electronics	65 days
22	Design DAS	65 days
23	Fabricate DAS	184 days
24	Focal Plane Downselect	0 days



Project: Spider
Date: Tue 9/15/98

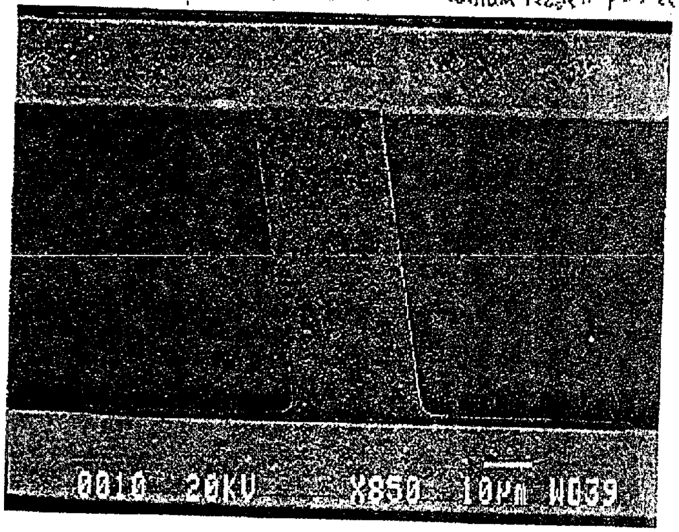
Task	▨	Milestone	◆	Rolled Up Split	…………	External Tasks	▨
Split	…………	Summary	▬	Rolled Up Milestone	◇	Project Summary	▬
Progress	▬	Rolled Up Task	▨	Rolled Up Progress	▬		

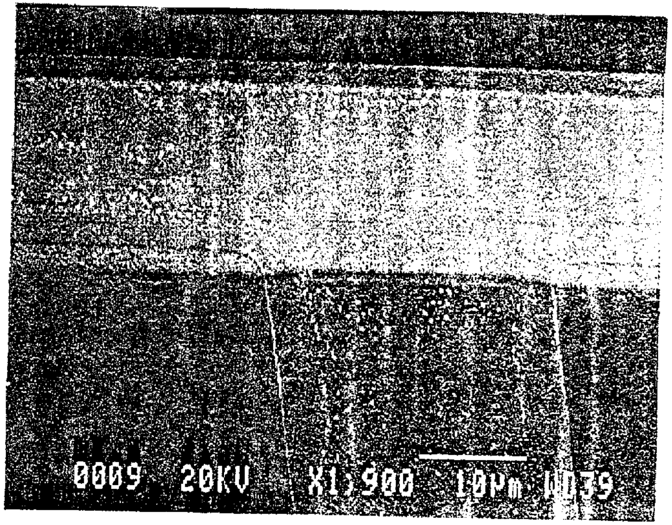
Titanium Transition Edge Sensor: NEP vs. voltage
(measured value is ~3 times larger than thermal fluctuation limit)



Tapered Ti TES with Niobium (3500Å) leads (length), eC 2

2.





Required Detector Performance for SPIRE

	Wavelength [μm]	NEP_{Phot} [$x10^{-17}$ W/√Hz]	τ [ms]	$NEP_{Bolo}\sqrt{\tau}$ [x 10^{-17} J]	NEP^{a}_{Tot} / NEP_{Phot}
Photometer (1 fλ feeds)	250	8	30	0.7	1.04
	350	6	30	0.5	1.08
	500	5	30	0.4	1.12
Spectrometer (2 fλ feeds)	200 - 300	8	10^{b}	0.4	1.12
	300 - 670	5	10	0.3	1.25
Measured Bolometer (NTD Ge at 300 mK)	$1000 - 1800^{c}$	1.2	100	0.4	

[a] $NEP^2_{Tot} = NEP^2_{Johnson} + NEP^2_{Phonon} + NEP^2_{Amp} + NEP^2_{Photon.}$

[b] Optical time constant of absorber measured ≤ 4 ms.

[c] 2.5 mm absorber diameter with 200 μm grid spacing.

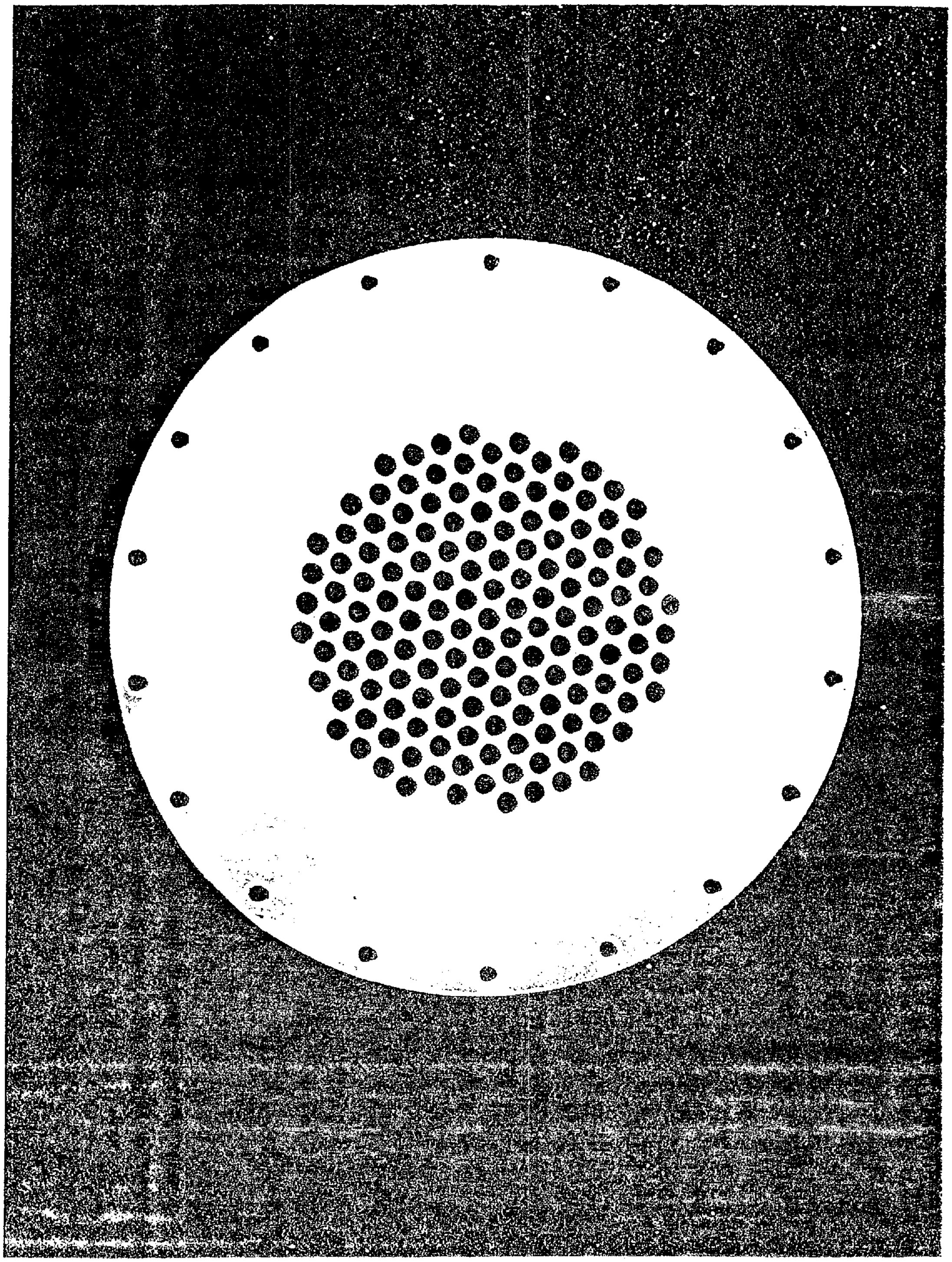
Current detector technology meets performance specifications

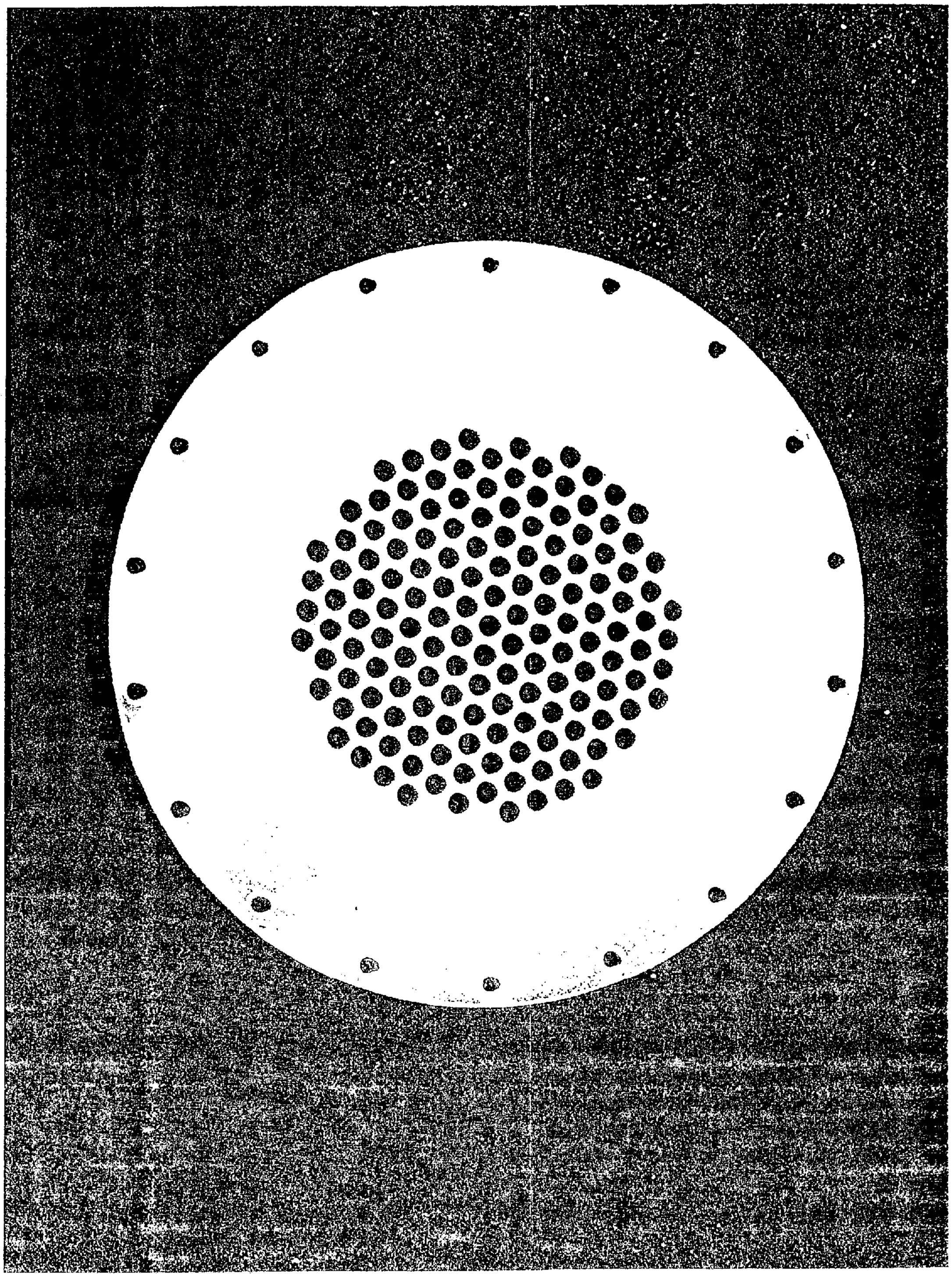
BOOMERANG SOUTH POLE BOLOMETERS (5/98)

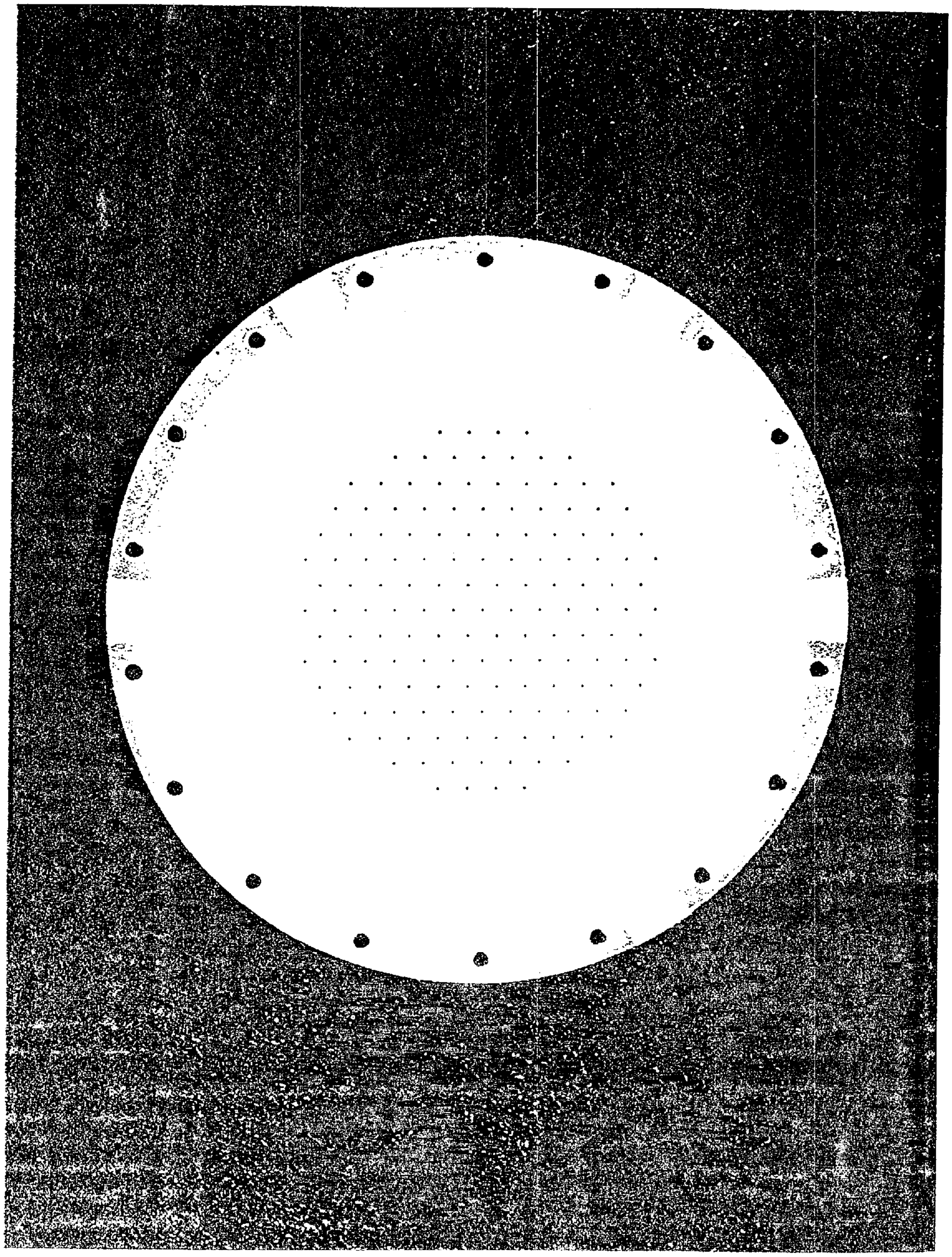
λ = 750μm - 3.3 mm

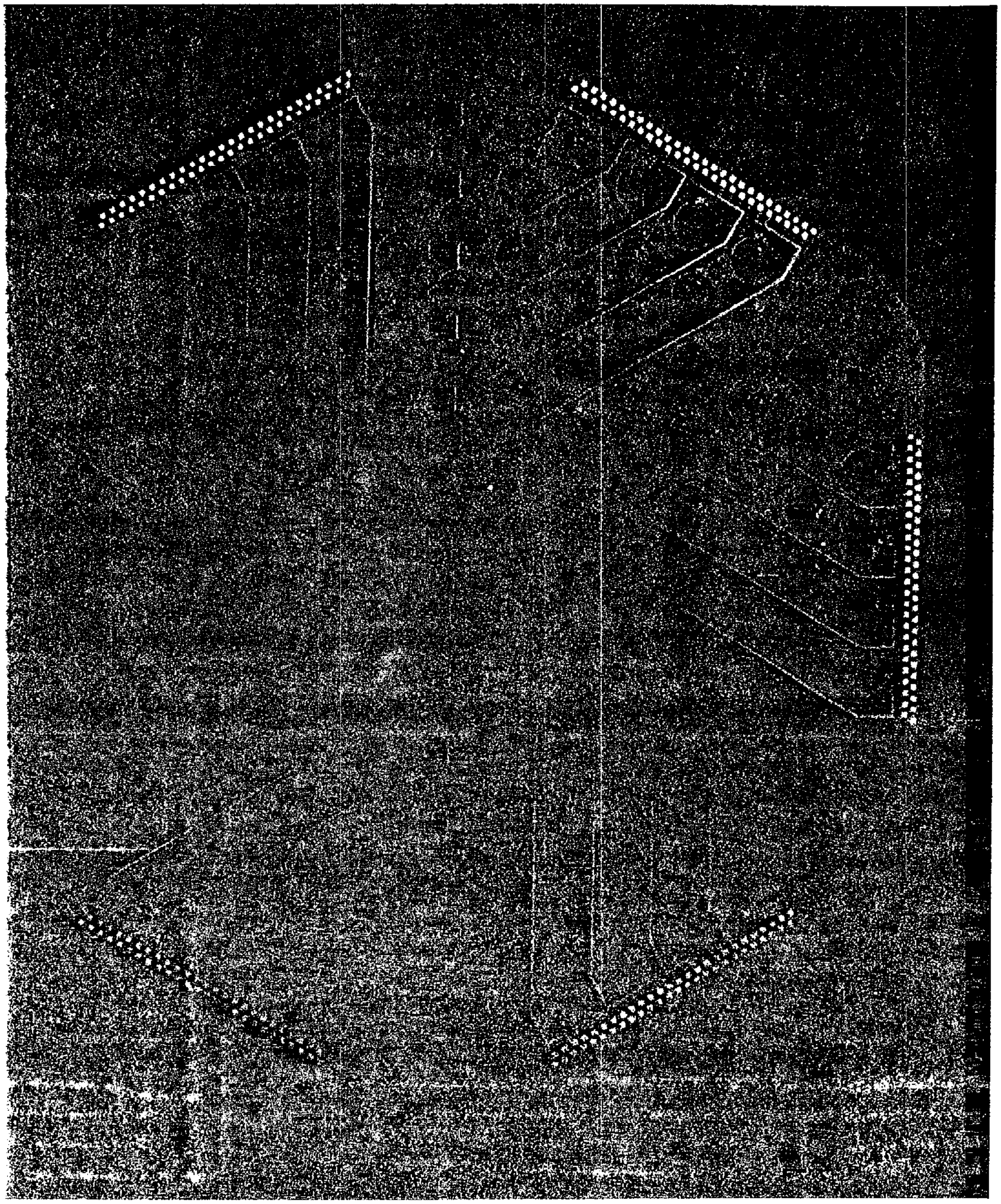
$NEP\sqrt{\tau} \leq 0.4 \times 10^{-17}$ J

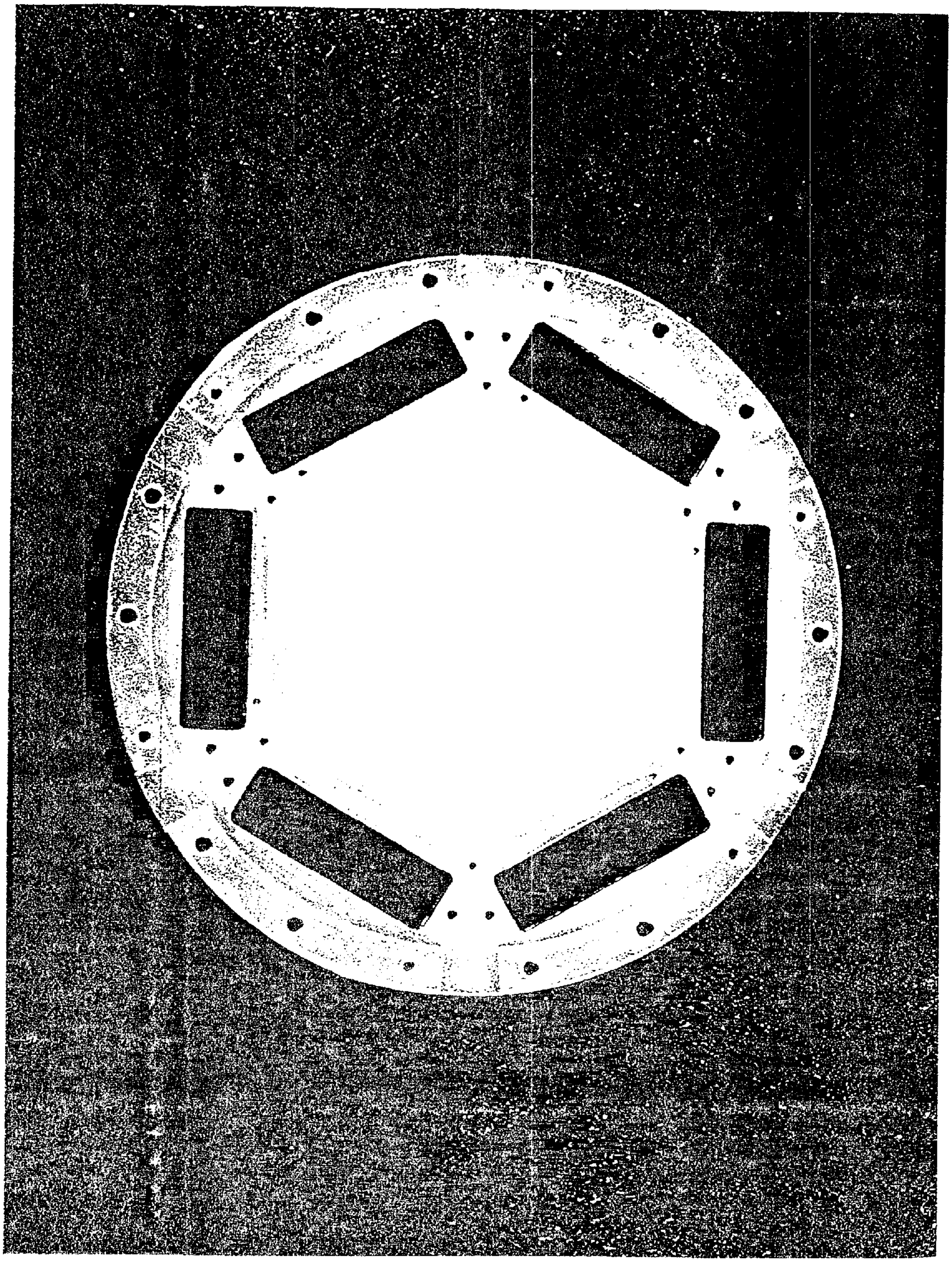
τ = (2 - 20) ms [optical]

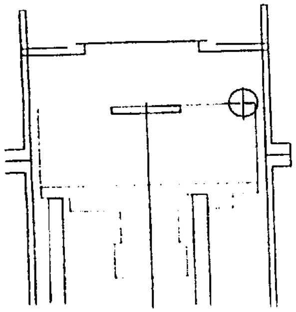


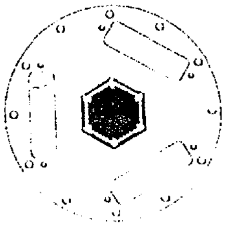


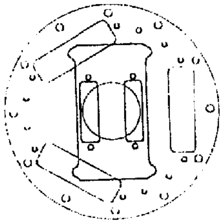


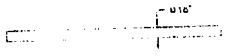




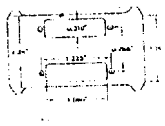




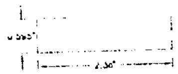




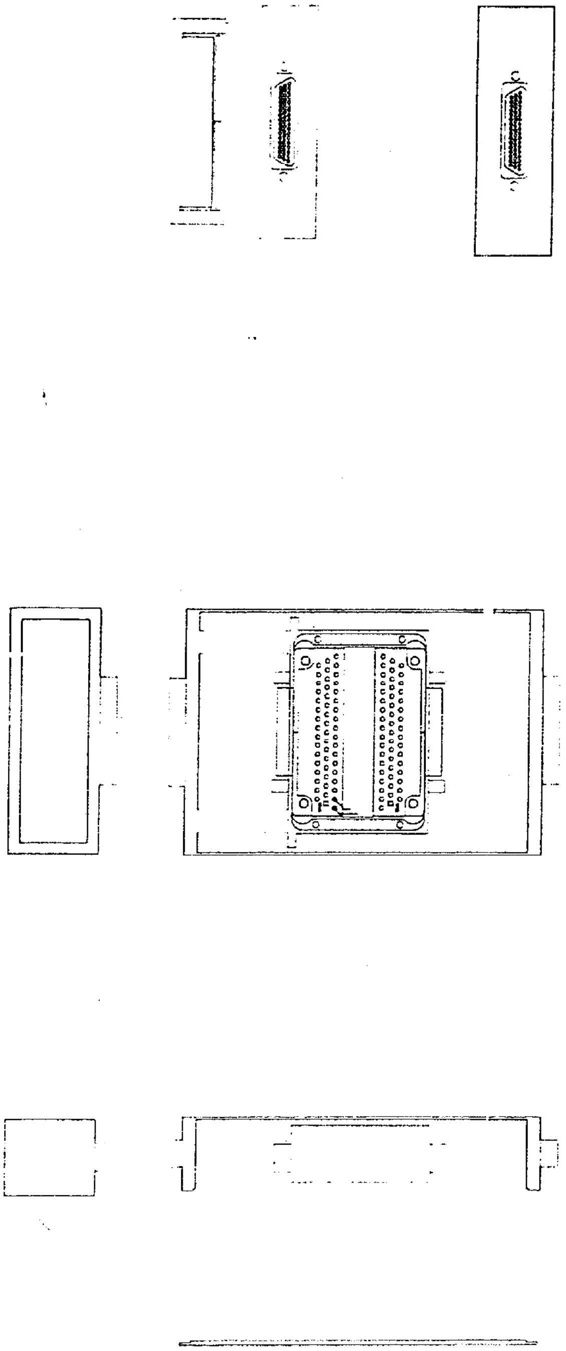
0.18"

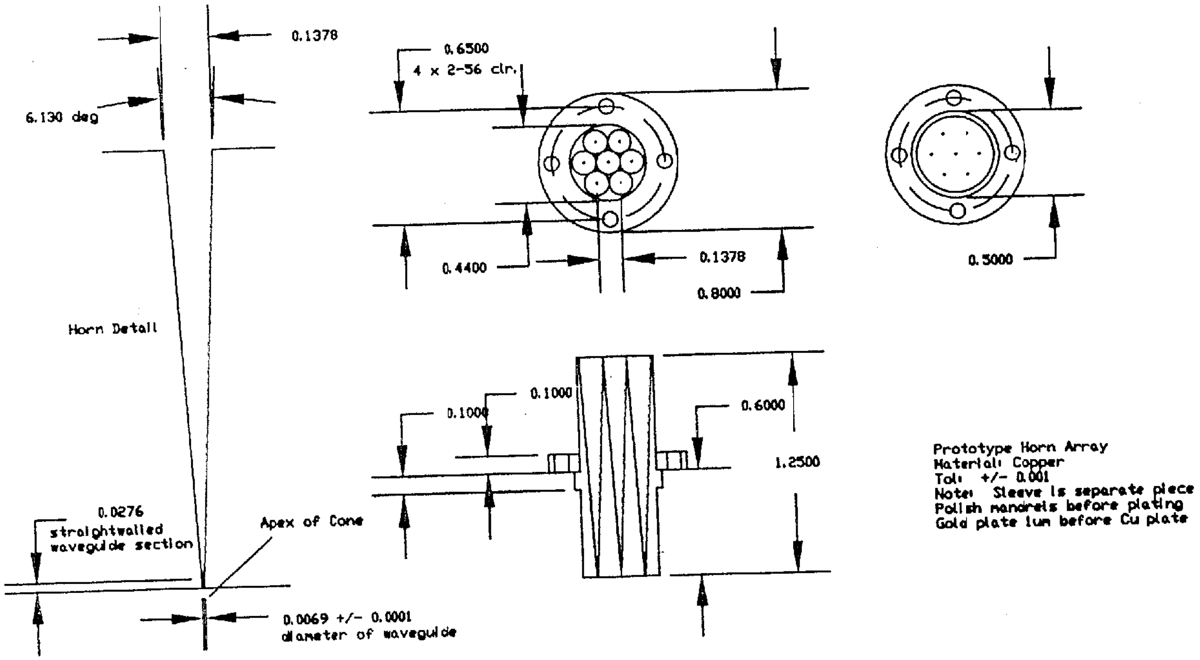


0.310"
1.225"

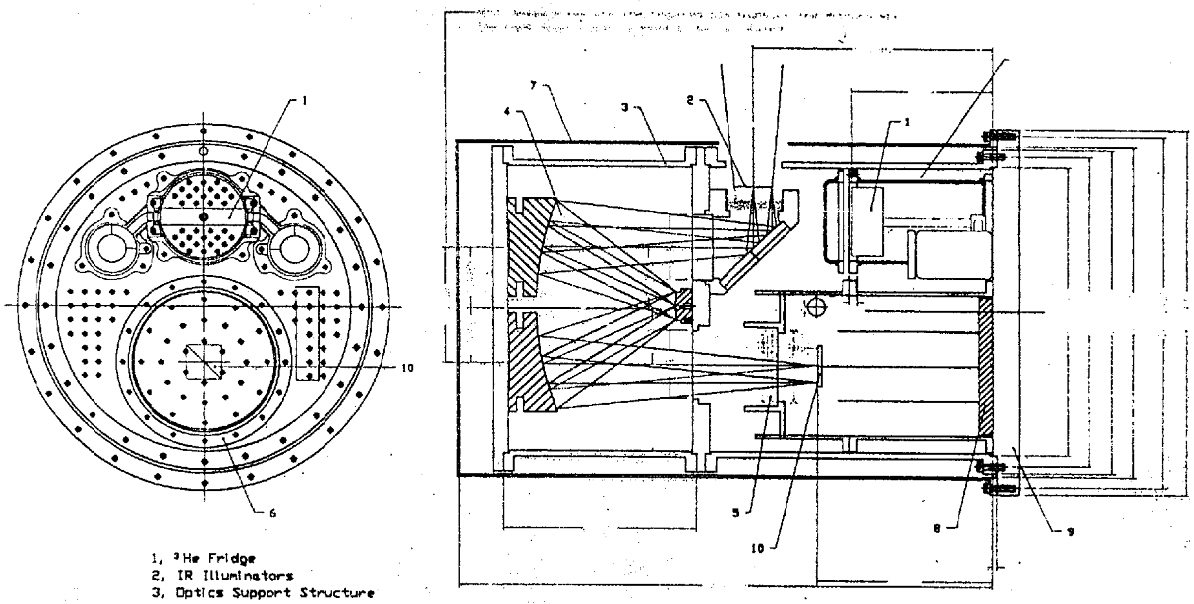


2.50"





Prototype Horn Array
Material: Copper
Tol: +/- 0.001
Note: Sleeve is separate piece
Polish mandrels before plating
Gold plate 1um before Cu plate



1, ³He Fridge
2, IR Illuminators
3, Optics Support Structure
4, Offner Optical Relay
5, Filters
6, Detector Array Shield
7, 4K Shield
8, Detector Interface Plate
9, Cold Plate
10, Detector Array

$2f\lambda$ feedhorn option

Testing Program

- Optical tests - modular elements ✓
- Support structure ⇒ GSFC ⇔ JPL
- JFETs

Systems Issues

- ESA resources
  - RF-tight seal to dewar
  - power dissipation
  - components
  - harness
- RF shielding
- Mapping modes
- Horn tests → QMW

9

BACUS status and array test plans

Peter Hargrave

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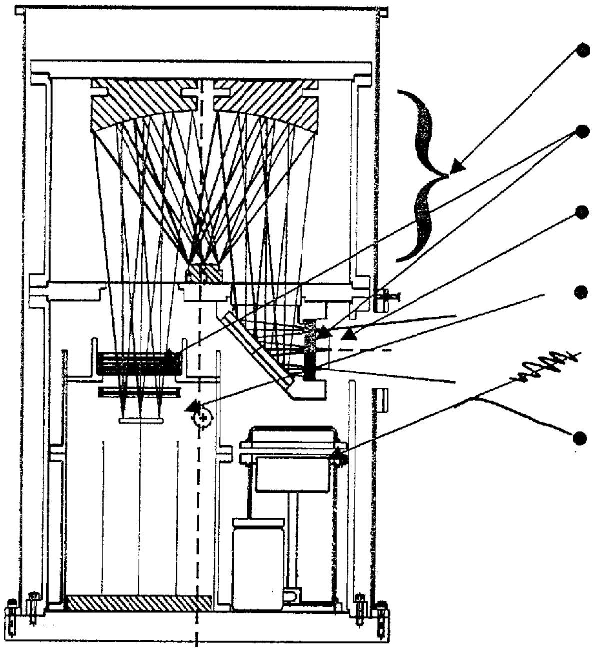
BACUS Status & Array Test Plan

P.Hargrave, B.Maffei, F.Gannaway,
M.Griffin & P.Ade

Design of BACUS Module



- F5 Offner Relay
- Filters
- Illuminators
- Detector Module & Shields
- He-3 Fridge & Shields

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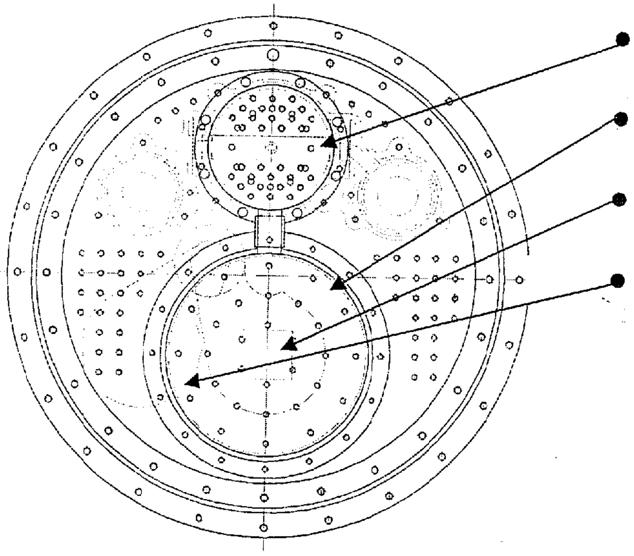
BACUS Design

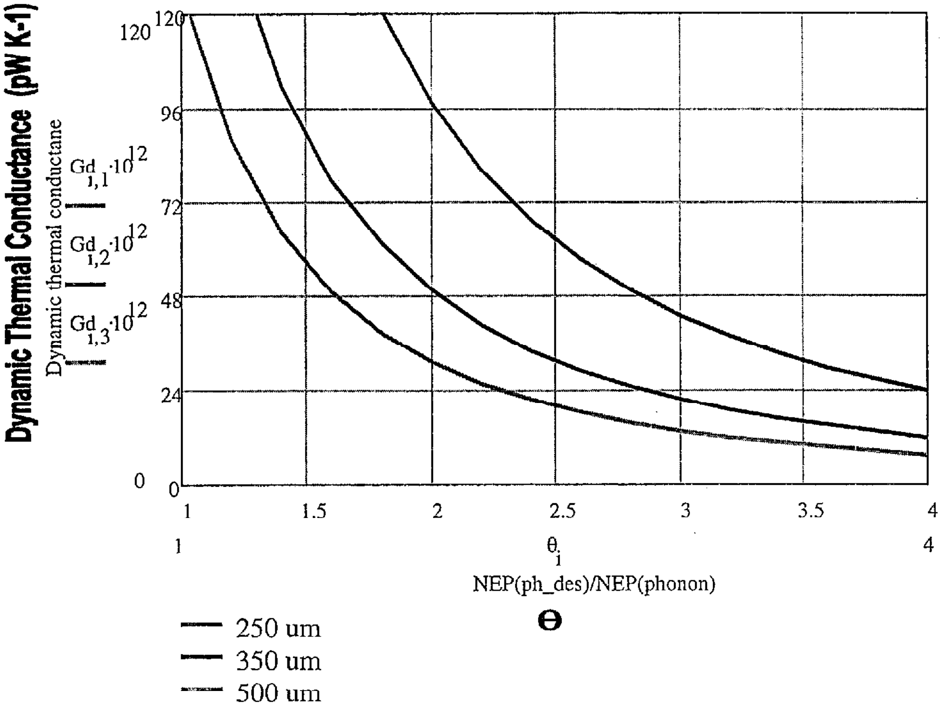


- He-3 Fridge & Shields
- Detector Module
- Detector Array
- Blanking/Flat-Fielding Plate

Cryogenics

- Cryostat from Precision Cryogenics (Indiana)
- Optics at 1.5K (Pumped L^{4}He Bath)
- Detector stage at 300mK - Kevlar isolated stage linked to ^{3}He fridge (Chase Research)

TES thermal conductance for SPIRE bands vs. insurance factor θ



Conclusions

- For TES sensors, we need an "insurance factor" θ to make sure the arrays work in the instrument. I suggest ~~mi~~nimum of ~ 2.
  Max
- Required TES dynamic thermal conductances for SPIRE (with $\theta = 2$ are):

λ (μm)	G_d (pW K^{-1})
250	100
500	50
350	30

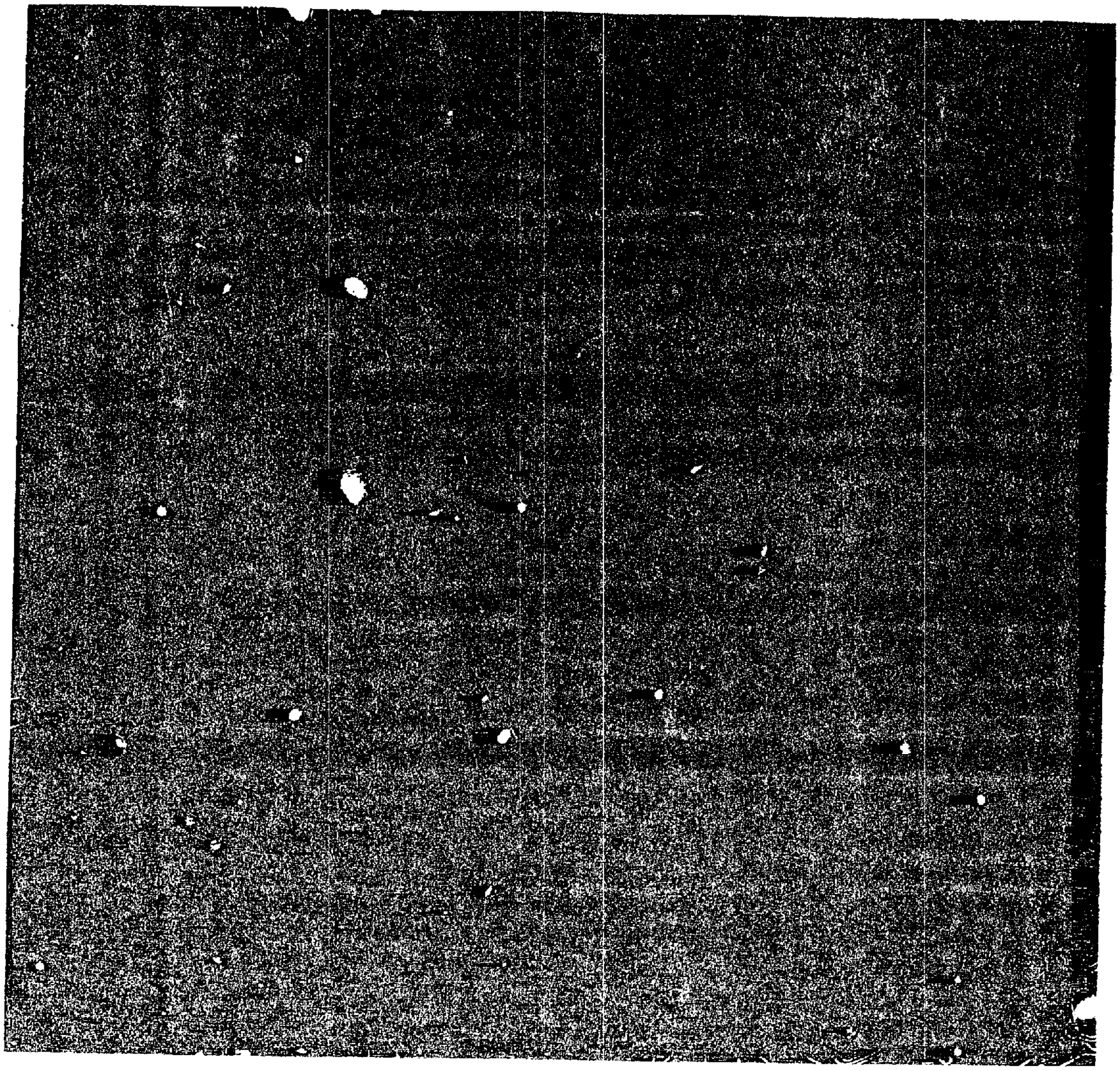
- Semiconductor bolometers are not susceptible to complete saturation at higher than expected background levels
- Background during satellite ground tests may be too high to operate TES bolometers unless we incorporate a cold shutter
- This analysis should be checked and refined and may be corrected. But the issue must be addressed by TES groups for array selection.

10b

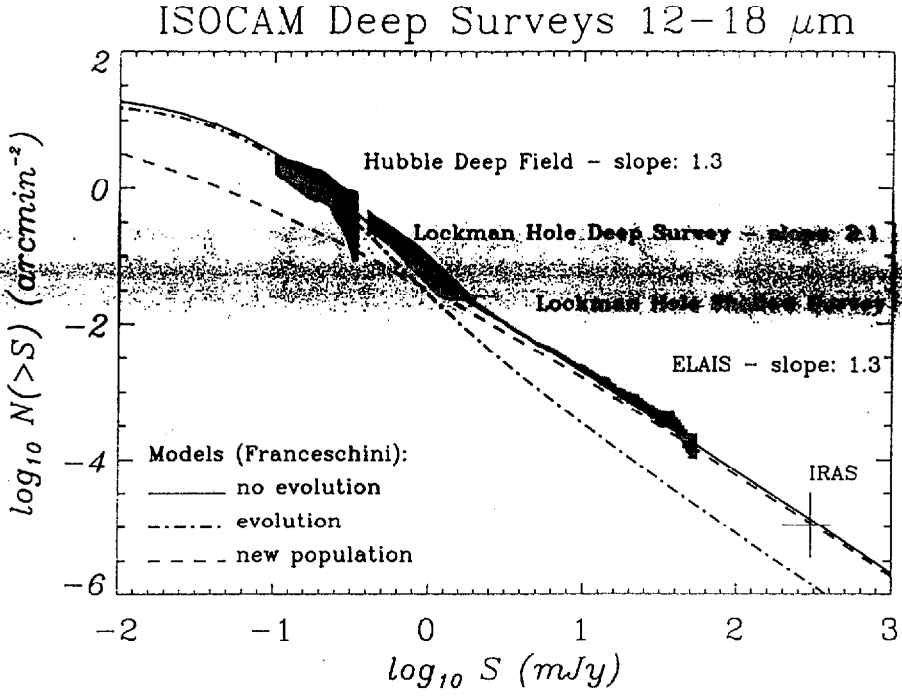
Simulations of SPIRE observations

Laurent Vigroux

ISOCAM 7 μm ( ) and 15 μm ( )
superimposed with Hubble Space Telescope image



Visible light : NASA/ESA/HST and R. Williams and the HDF Team (STScI)
Infrared : ESA/ISO/ISOCAM, CEA-Saclay and H. Aussel et al.


ISOCAM Deep Surveys 12−18 μm
Hubble Deep Field − slope: 1.3
Lockman Hole Deep Survey − slope: 2.1
Lockman Hole Shallow Survey
ELAIS − slope: 1.3
IRAS
Models (Franceschini):
no evolution
evolution
new population
$\log_{10} N(>S)\ (arcmin^{-2})$
$\log_{10} S\ (mJy)$
2
0
−2
−4
−6
−2
−1
0
1
2
3

[illegible]

Optics

- F5 Offner Relay
- Mirrors from Symons Mirror Technology (diamond turned Al-6061)
- All optics at 1.5K
- Baffling scheme needs finalising

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Optics

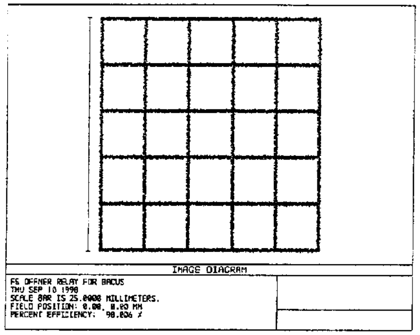
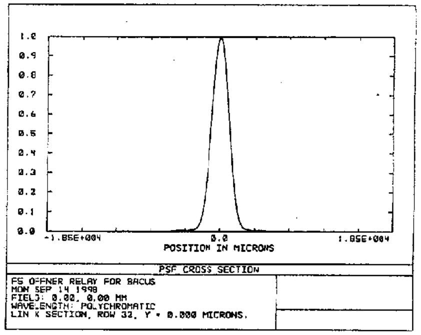


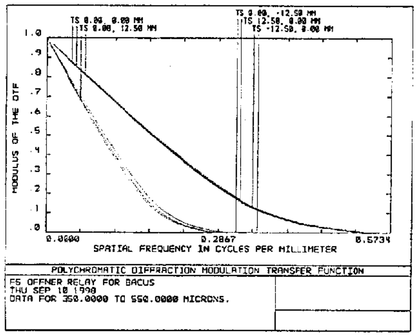
IMAGE DIAGRAM

FS OFFNER RELAY FOR BACUS
THU SEP 10 1998
SCALE BAR IS 25.0000 MILLIMETERS.
FIELD POSITION: 0.00, 0.00 MM
PERCENT EFFICIENCY: 98.806 %



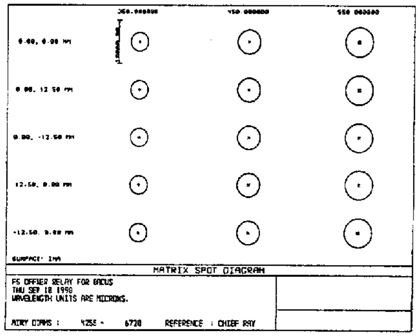
PSF CROSS SECTION

FS OFFNER RELAY FOR BACUS
MON SEP 14 1998
FIELD: 0.00, 0.00 MM
WAVELENGTH: POLYCHROMATIC
LIN K SECTION, ROW 32, Y = 0.000 MICRONS.



POLYCHROMATIC DIFFRACTION MODULATION TRANSFER FUNCTION

FS OFFNER RELAY FOR BACUS
THU SEP 10 1998
DATA FOR 350.0000 TO 550.0000 MICRONS.



MATRIX SPOT DIAGRAM

FS OFFNER RELAY FOR BACUS
THU SEP 10 1998
WAVELENGTH UNITS ARE MICRONS.

AIRY DIAMS : 4255 - 6720 REFERENCE : CHIEF RAY

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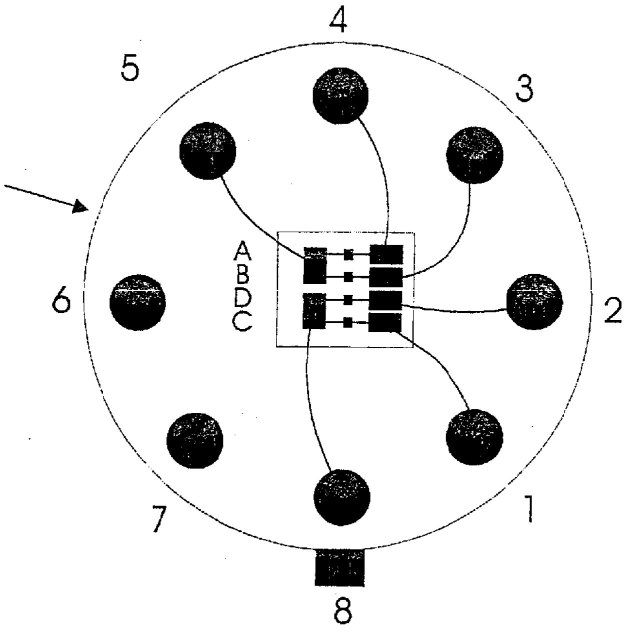
Illuminators

- ND + Edge filters for work in R-J region
- GSFC being evaluated
- Need to be modulated ~~up to~~ >10Hz
- Uniform source plate - variable temp.
- QMW dewar will have window to outside



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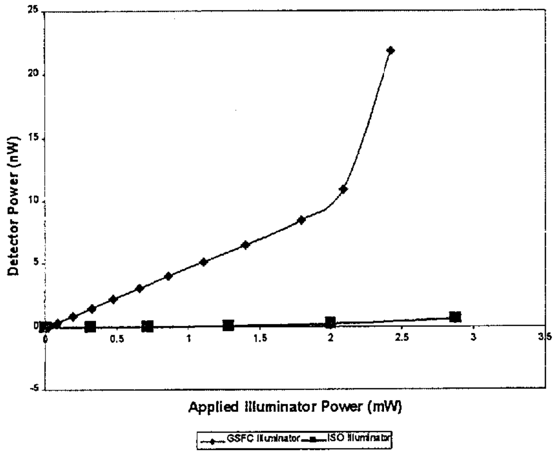
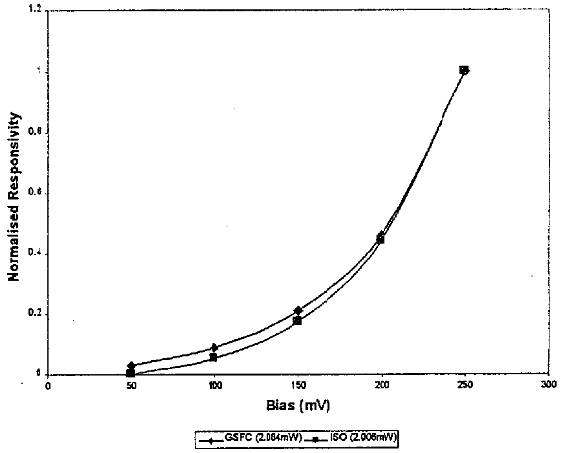
Illuminators

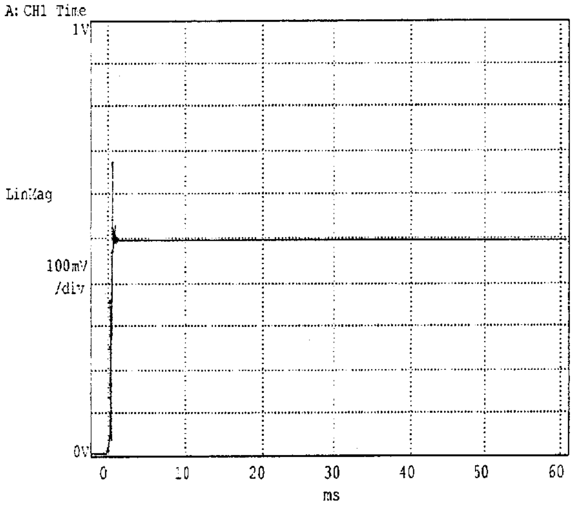
Comparison of ISO & GSFC Illuminators at 150mV Detector Bias

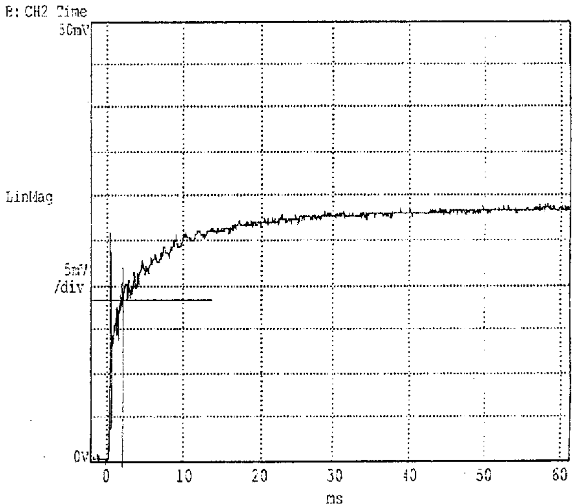


Normalised Responsivity vs Bias for Illuminator Power of 2mW



GSFC Speed of Response





Risetime=2.007ms

Connectors

- 1x79 way - for detector arrays
- 1x32 way - for illuminators
- 1x26 way - for housekeeping
- All connectors are box flange mount conforming to MIL-C-38999

BACUS Capabilities

- V-Is - blanked or with uniform background (not CEA)
- Speed of response
- Flat fielding / array uniformity
- Cross talk
- Sensitivity
- Dynamic Range
- Linearity

- Optical NEP
- Spectral response
- Fringing between optical elements
- Calibration of detector responsivity (external black body)
- Connection to telescope simulator

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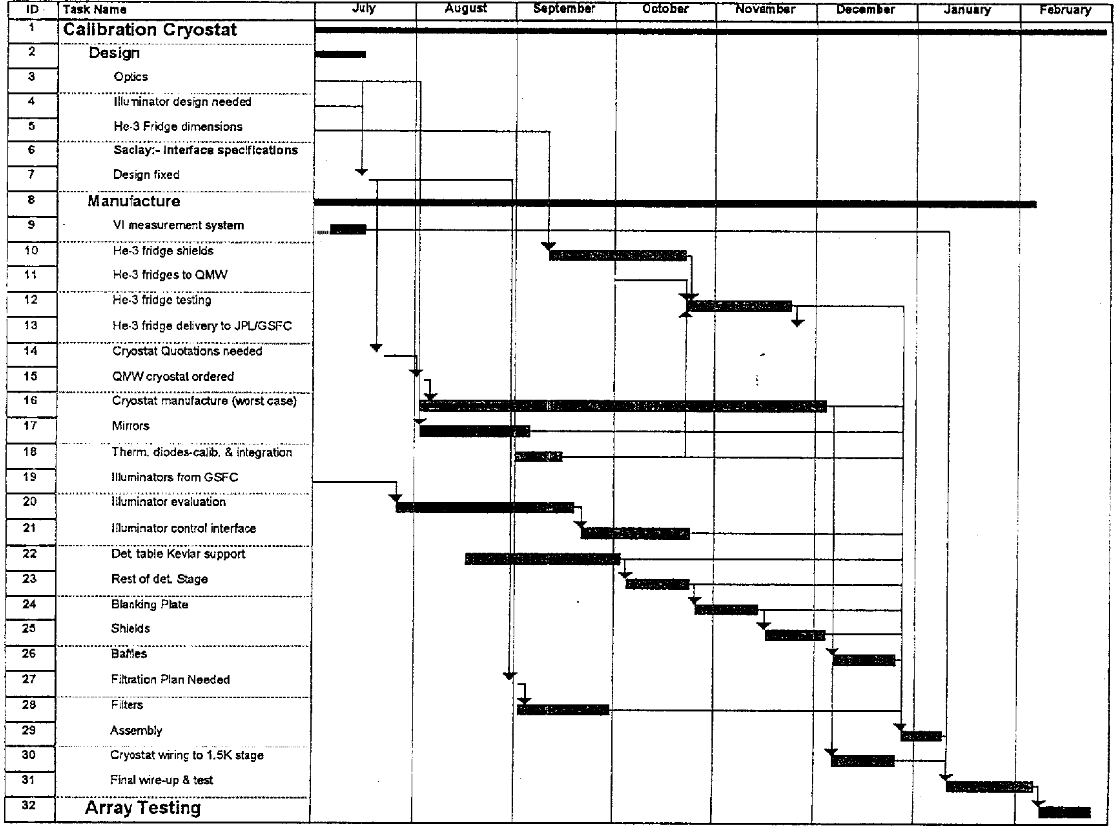
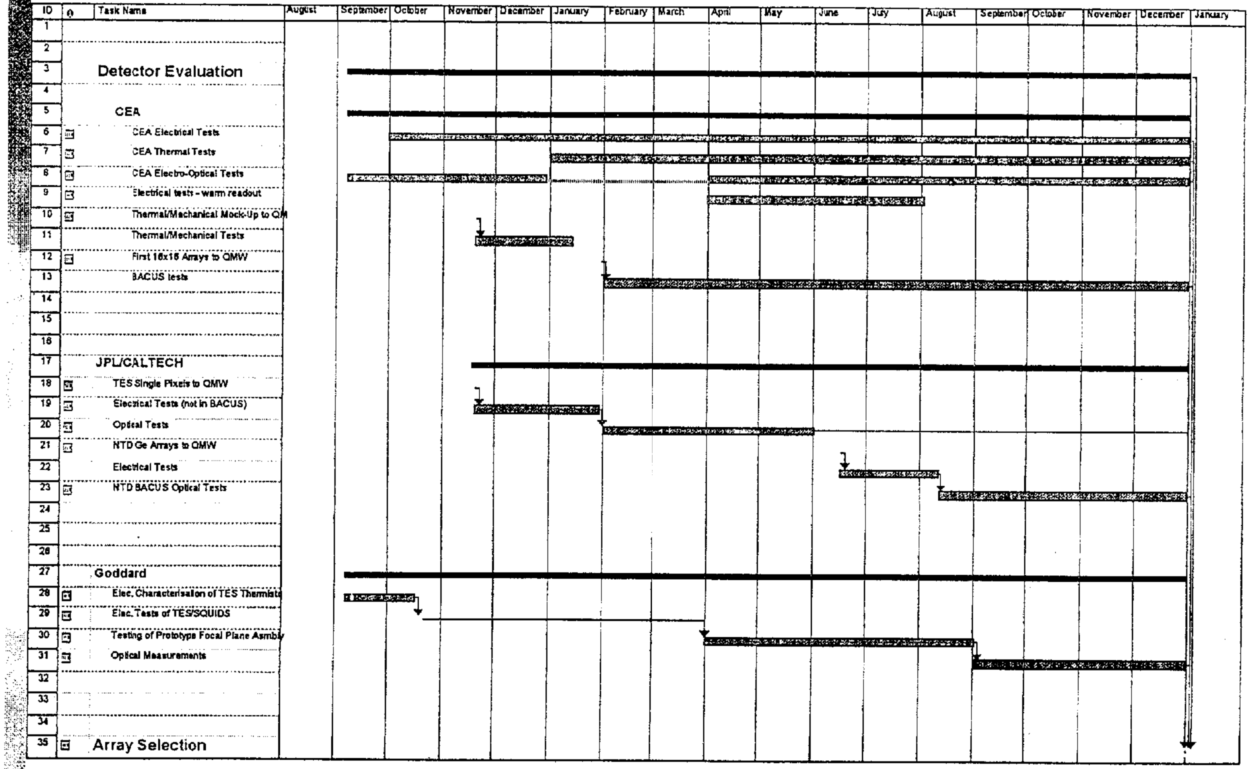
BACUS Schedule



ID	Task Name
1	**Calibration Cryostat**
2	**Design**
3	Optics
4	Illuminator design needed
5	He-3 Fridge dimensions
6	Saclay:- Interface specifications
7	Design fixed
8	**Manufacture**
9	VI measurement system
10	He-3 fridge shields
11	He-3 fridges to QMW
12	He-3 fridge testing
13	He-3 fridge delivery to JPL/GSFC
14	Cryostat Quotations needed
15	QMW cryostat ordered
16	Cryostat manufacture (worst case)
17	Mirrors
18	Therm. diodes-calib. & integration
19	Illuminators from GSFC
20	Illuminator evaluation
21	Illuminator control interface
22	Det table Kevlar support
23	Rest of det. Stage
24	Blanking Plate
25	Shields
26	Baffles
27	Filtration Plan Needed
28	Filters
29	Assembly
30	Cryostat wiring to 1.5K stage
31	Final wire-up & test
32	**Array Testing**

QUEEN MARY
AND WESTFIELD COLLEGE
UNIVERSITY OF LONDON

Array Testing Plan



Summary

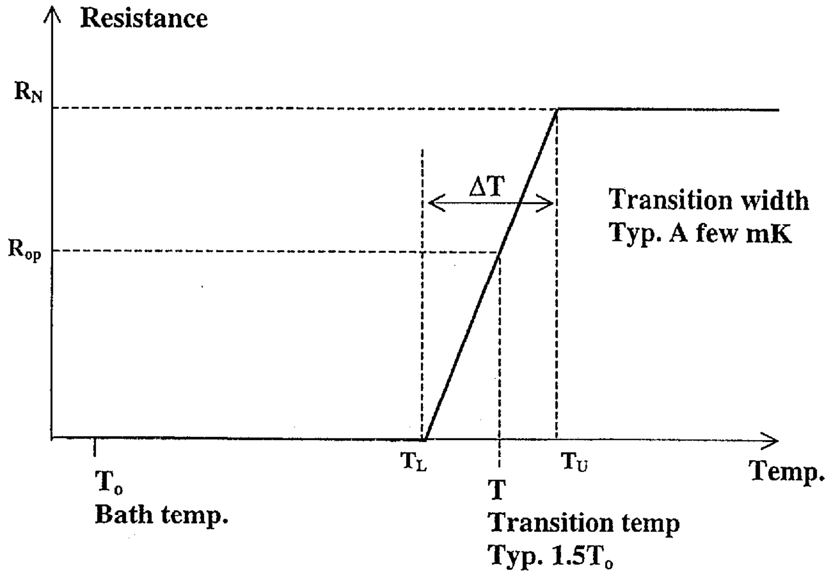
- BACUS should be operational by end January 1999
- Preliminary tests can be carried out in another dewar once He-3 fridges & shields are ready (mid-November)
- Schedule is very tight - we need realistic estimates for when we can expect devices at QMW
- “Pre-prototype” devices could be sent to QMW for pre-tests to familiarize QMW staff and avoid subsequent delays.
- 3 x BACUS MODULES ? – TBD

10a

TES detector optimisation for SPIRE

Matt Griffin

TES detector optimisation for SPIRE



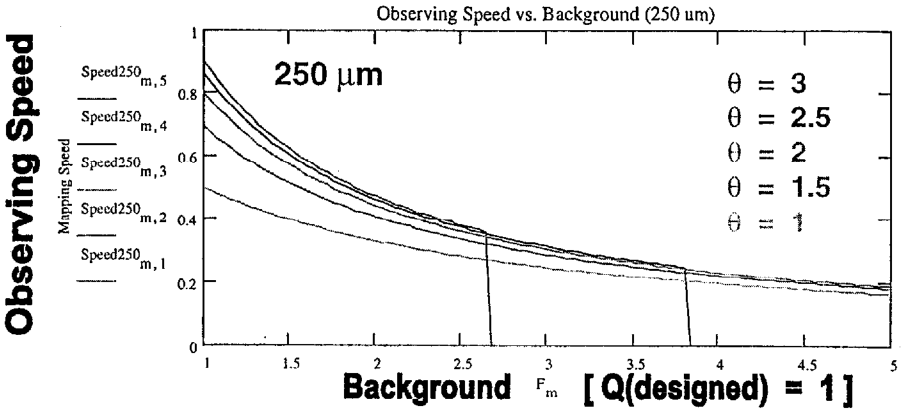
- Bias power + absorbed power $P + Q = W =$ Const.
- As Q is altered, P alters to keep W, T_{op} constant
- $W < G_s(T - T_o)$
- T and G_s are fixed by design
- T_o is fixed for ^{3}He system
- If Q is unexpectedly high, then equilibrium temperature even with zero P could be $> T_u$
  → detector does not work at all

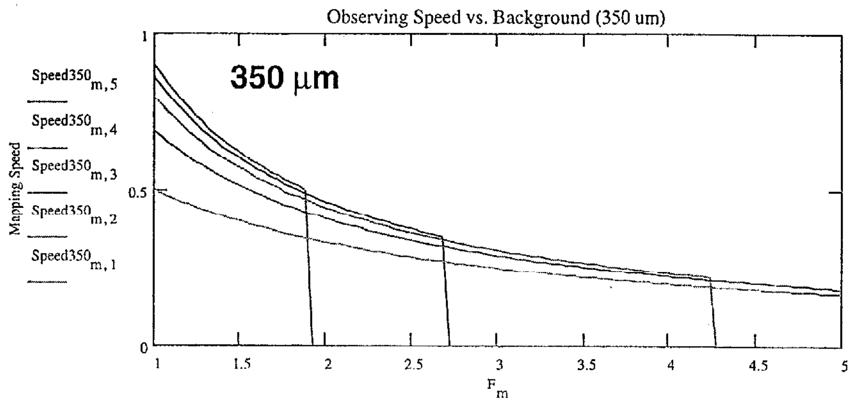
  Maximum tolerable background: $Q_{max} = G_s(T - T_o)$
- Solution: insure against high Q by making G_s large
- But $NEP_{det} \propto G_s^{1/2}$, so this degrades sensitivity

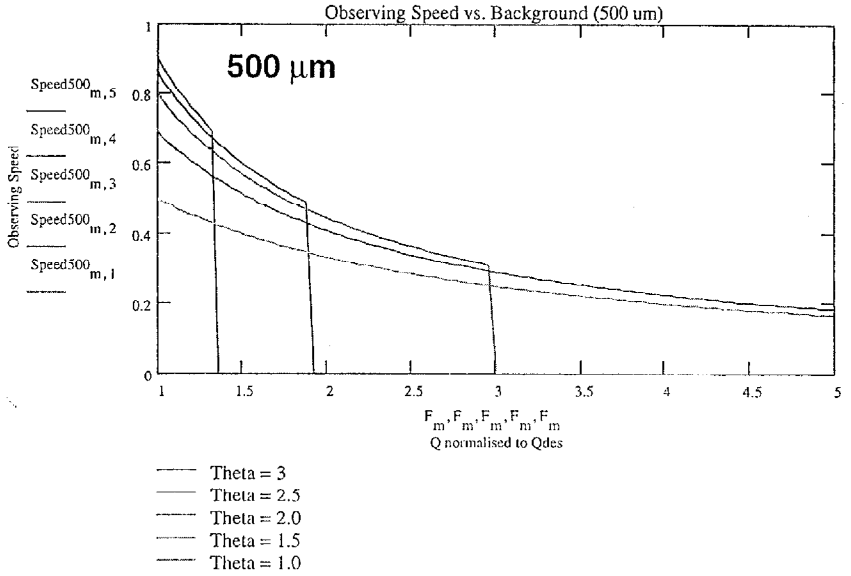
- **Assumptions for TES:**
  - Thermal conductance $G_d \propto T^{\beta}$ $\beta = 3$
  - Bath temperature $T_o = 300$ mK
  - Transition temperature T = 450 mK
  - Temp. coeff. of resistance $\alpha = (T/R)(dR/dT) = 300$
  - $NEP_{det} = (NEP_{ph\text{-}des})/\theta$ $\theta = 2$
  - NEP_{det} dominated by the phonon noise term

- **Assumptions for NTD Ge:**
  - Ideal NTD Ge bolometer (Johnson and phonon noise only)
  - $T_o = 0.3$ K
  - $P_b = 4$ pW (SPIRE 500 μm channel; feedhorn option)
  - $R_{op} = 5$ MΩ
  - $G_{so} = 25$ pW K-1 (G_s at T_o)
    (⇒ $\theta = 3.3$ - i.e., strongly photon noise limited if $Q = Q_{des}$)
  - Signal chain input short noise = 6 nV $Hz^{-1/2}$
  - Load resistance $R_L = 30$ MΩ
  - Bias voltage adjustable

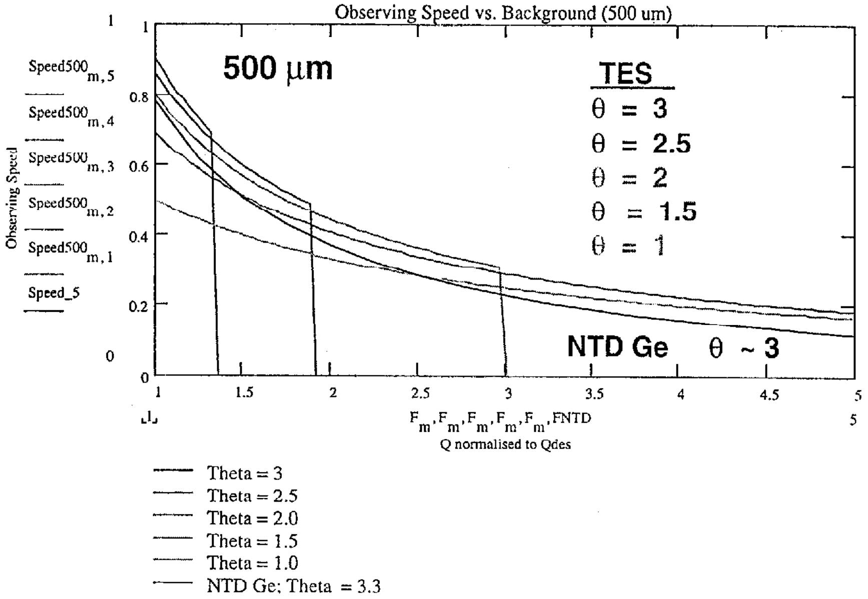
Observing speed vs. background for TES







Observing speed vs. background for NTD Ge and TES at 500 μm



Models for SPIRE surveys

3 detectors are tested

1. Fλ square pixels with flat transmission :
   - 16 × 16 array of 18"×18" pixels at 250 μm.
   - 8 × 8 array of 36"×36" pixels at 500 μm
2. Fλ/2 square pixels with flat transmission :
   - 32 × 32 array of 9"×9" pixels at 250 μm.
   - 16 × 16 array of 18"×18" pixels at 500 μm
3. 2Fλ horns (backup option) with gaussian transmission (FWHM = Fλ) :
   - 61 horns of 18" of radius at 250 μm.
   - 27 horns of 36" at 500 μm

Sources

Number counts prediction of Franceschini et al. (97) are used to simulated a 20'×20' field, diffracted by the circular aperture of the telescope (3.5 m).

Observations

All detectors are tested with :

- Same surveyed area (10'×10' by 4 patches of 5'×5')
- Same observation time : 1.07 hour by patch
- Same final resolution.

Two resolutions are tested :

1. $\lambda/2$ at 250 μm ⟶ $\lambda/4$ at 500 μm
2. $\lambda/4$ at 250 μm ⟶ $\lambda/8$ at 500 μm

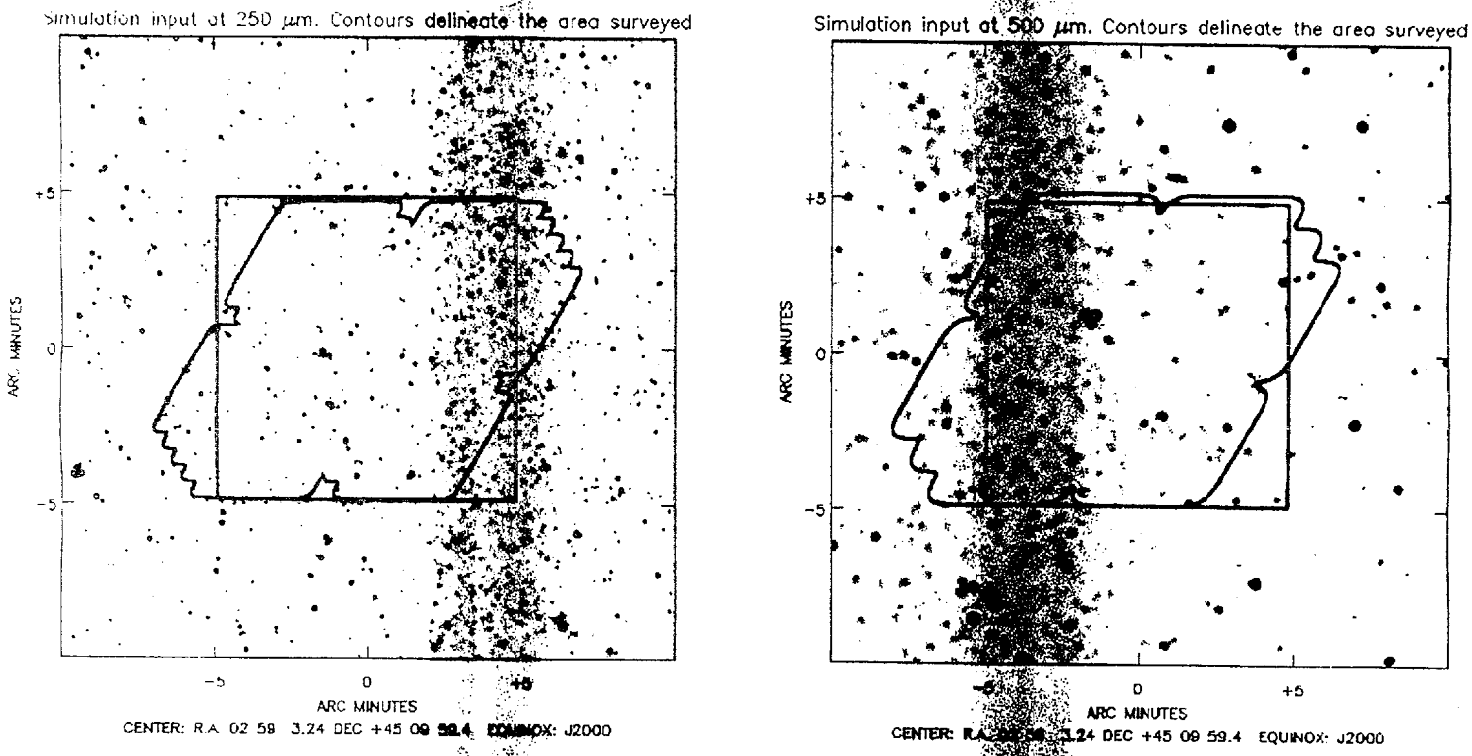
Noise model

- Detector. **NEP** = $3 \times 10^{-17} W.Hz^{-1/2}$ for all detectors.
- Photon noise. **Origin** : the telescope mirror at 80 K. Varies with wavelength and detector throughput.

Noise level (mJy/pixel/hour)

	Fλ	Fλ/2	2Fλ
250 μm	0.8	0.64	0.42
500 μm	0.8	0.73	0.76

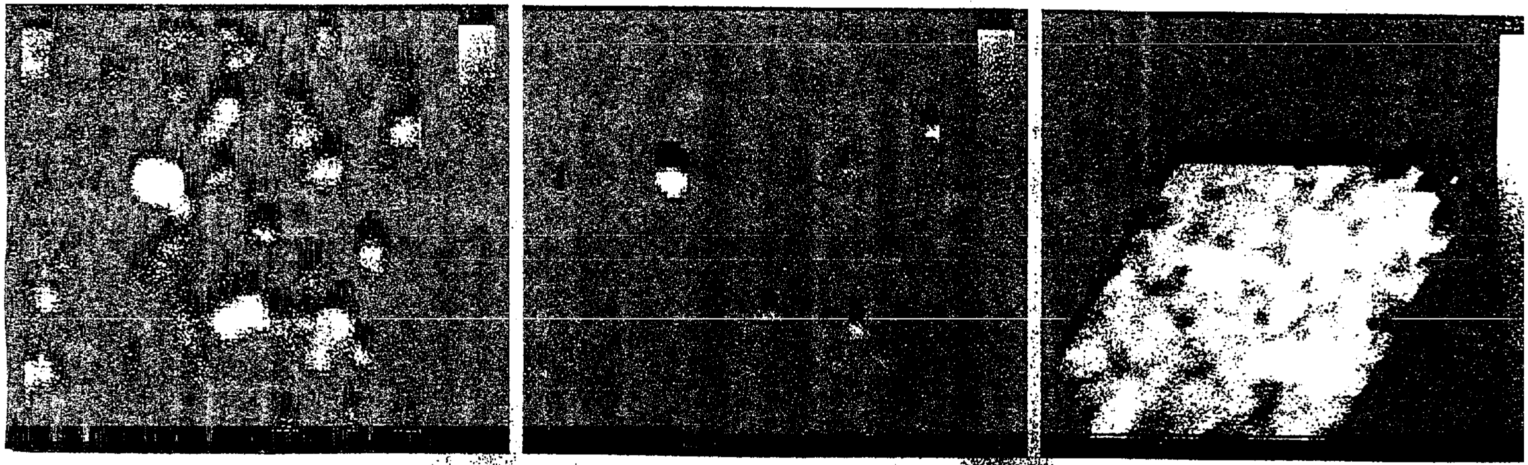
Input field of the simulations, using counts prediction of Franceschini et al. (97)



Simulation input at 250 μm. Contours delineate the area surveyed

Simulation input at 500 μm. Contours delineate the area surveyed

Result at 500 m for a $\lambda/4$ resolution



F λ Square pixels F $\lambda/2$ Square Pixels 2 F λ Horns

Displays are Log (f mJy/pixel)

Result at 250 m for a λ/4 resolution

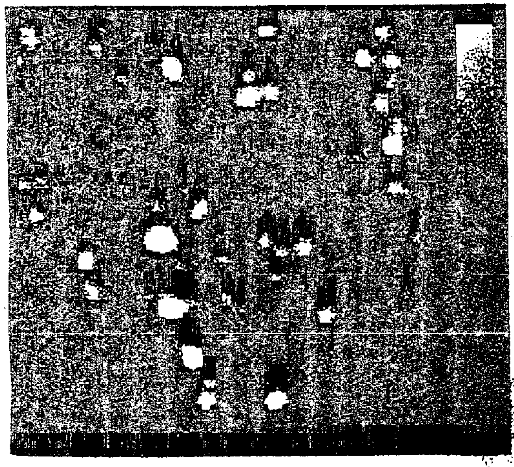
$F\lambda$ Square pixels

$F\lambda/2$ Square Pixels

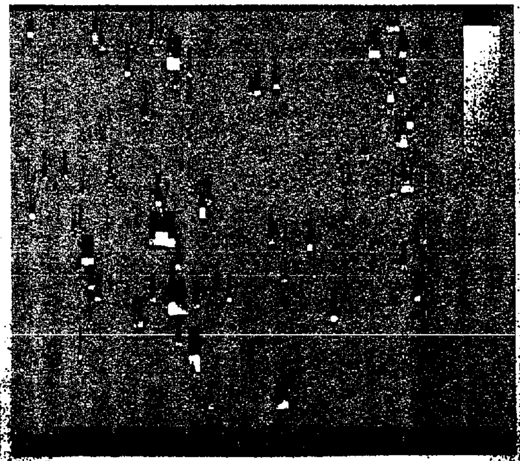
2 $F\lambda$ Horns

Displays are Log (f mJy/pixel)

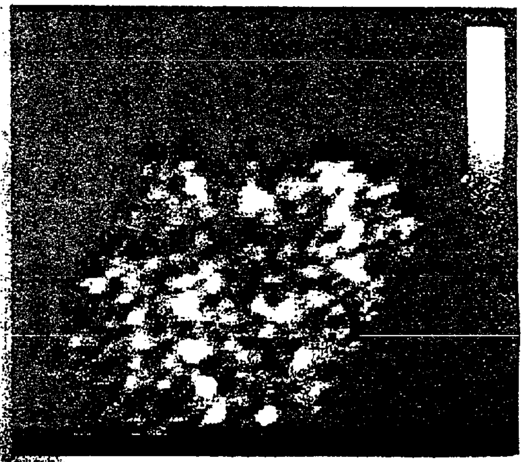
Result at 250 m for a λ/2 resolution



F λ Square pixels



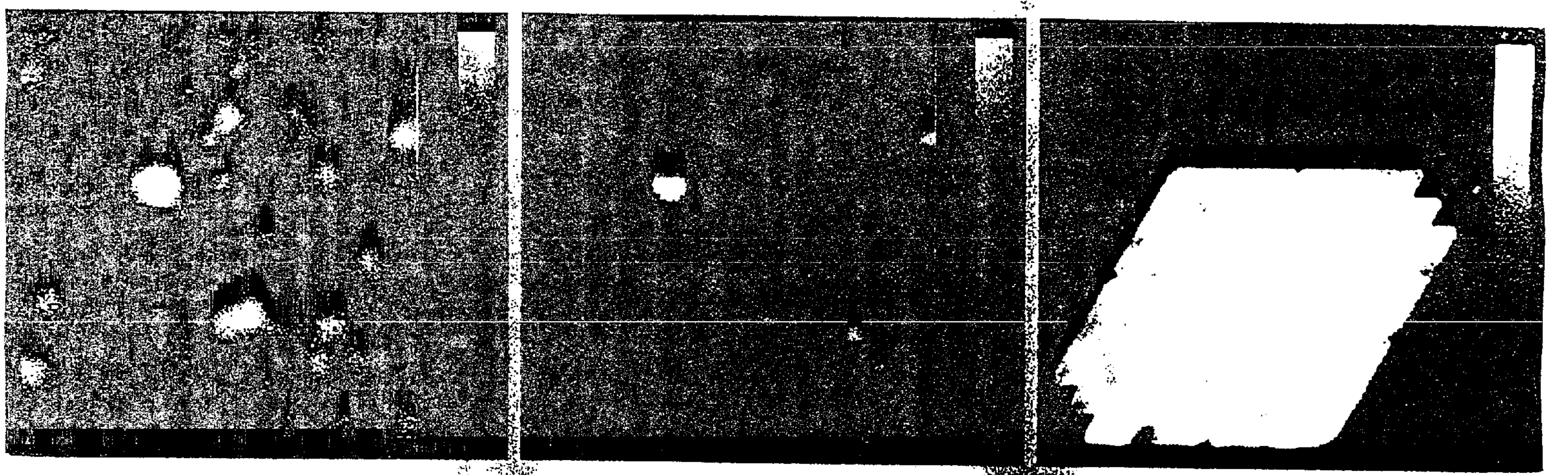
F λ/2 Square Pixels



2 F λ Horns

Displays are Log (f mJy/pixel)

Result at 500 m for a $\lambda/8$ resolution



F λ Square pixels

F $\lambda/2$ Square Pixels

2 F λ Horns

Displays are Log (f mJy/pixel)

14

Reports from splinter sessions

14a	Array test plan	Peter Hargrave
14b	Sensitivity and operating modes	Laurent Vigroux

<u>To follow</u>

14c	Feedhorn option	Jamie Bock

<u>To follow</u>

14d	Front-end electronics	Louis Rodriguez

<u>To follow</u>

15

Attachments

A. Note by M. Griffin on detector array selection criteria (to be revised following discussion at this meeting)

B. Fax from ESA on tests to be carried out on the instrument models

Detector array selection criteria for SPIRE

Matt Griffin

Draft 1 13 September 1998

1. Array selection requirements

1.1 Consortium requirements

R1. The consortium must have complete confidence that the chosen option can be successfully implemented in SPIRE, on specification and within the schedule.

R2. The CEA option will be chosen if it meets the specification, is equivalent or nearly equivalent in mapping speed to the best of the others, and if there are no fundamental problems with its implementation.

R3. A US option, if chosen, shall be fully funded by NASA.

R4. The warm analogue electronics will be built by CEA for whatever option is chosen (the exact division of responsibilities and work breakdown structure must be clarified).

1.2 Performance requirements

R5. Filled array options must be better than the 2.0Fλ feed-horn option in mapping speed by a factor of 2 or more (corresponding to a factor of $2^{1/2}$ in NEFD). Any differences smaller than this will be judged to be within the uncertainties, and the selection will then be based on other criteria.

R6. The evaluation shall be based on measurements of arrays optimised for the SPIRE 350 μm band and, if necessary, reliable and convincing extrapolations of the test results to other SPIRE wavelengths.

R7. Array prototypes or equivalent devices shall undergo testing in the laboratory prior to selection to determine performance parameters, and shall meet the requirements given below. These performance requirements refer to the operating background power and bath temperature for SPIRE. Actual measurements shall be made under conditions as similar as possible similar to those given here, but not necessarily identical provided extrapolation of the results to the nominal conditions is straightforward and uncontroversial.

Nominal operating conditions	
Bath temperature (mK)	300
Incident background power (pW)	Filled array: 1.3 2Fλfeedhorn: 5.3
Photon noise NEP (W $Hz^{-1/2}$)	Filled array: 3.8×10^{-17} 2Fλfeedhorn: 7.7×10^{-17}
Central wavelength (μm)	350
$\lambda/\Delta\lambda$	3

Requirements on measured performance		
Detector optical NEP (W $Hz^{-1/2}$) (excluding photon noise)	(a)	Filled array: 2.0×10^{-17} 2Fλ array: 4.0×10^{-17}
3-dB freq. of responsivity roll-off	(b)	≥ 20 Hz
Maximum pixel-pixel variation		Noise: 20% Responsivity: 20%
Yield (good pixels)	(c)	> 50% (for demonstration arrays only)
Crosstalk		TBD
Ionising radiation response		Shall be characterised with γ-rays and avg. projected area (cosmic ray cross section) shall be quoted for all proposed array types
Pixel angular response		Shall be characterised or modelled
EMI susceptibility		Shall be characterised or modelled
Thermal and vacuum cycling		TBD

Notes: (a) This refers to the optical NEP at a background power no less than the nominal value.
(b) This is set by the FTS requirement. For detectors specifically optimised for the photometer only, the corresponding figure is 5 Hz.
(c) A pixel yield of 90% or more is required for the flight arrays, and a reliable means of achieving this shall be identified at the time of selection.

R8. A full system design document shall be available, compliant with spacecraft resources and IID-A requirements. It is the responsibility of the array-providing group to produce this, in liaison with the Systems Team leaders (Loius Rodriguez and Colin Cunningham) and the Instrument Scientist (Bruce Swinyard). It shall include:

(i) Full description of all interfaces, budgets and requirements on other parts of the instrument and the spacecraft. The draft document *Specification Template for Bolometer Arrays (REF TBD)* by Bruce Swinyard forms a first attempt to describe what is required. These requirements will expand as the design matures and as we are required to supply information to ESA.

(ii) Conformance to the SPIRE optical, thermal and mechanical designs.

(iii) Confirmation of conformance to the operating and performance requirements.

(iv) Relevant optical, electrical, thermal, mechanical or EMC modelling.

1.3 Schedule and qualification programme requirements

R9. An array fabrication, test and delivery schedule shall be provided which is consistent with the SPIRE project schedule, and which is realistic given the technical activities and resources available to perform them. This shall extend at least to the end of CQM manufacture, and shall include the warm readout electronics. It shall be drawn up by the array groups in consultation with QMW.

R10. A credible space qualification programme and schedule for qualification shall be provided which is consistent with the ESA requirements and with the SPIRE schedule.

2. Proposed array group meeting schedule

Detector array group meetings:	January	1999	QMW
	May	1999	Saclay
	September	1999	Caltech.
Formal selection meeting:	January	2000	RAL

Full documentation to be provided by mid-December 1998 (last minute updates in January if necessary).

3. Formal selection team

Participants: All appropriate members of array providing and testing teams

Team members:	Matt Griffin	PI
	Laurent Vigroux	Co-PI
	Ken King	Project Manager
	Bruce Swinyard	Instrument Scientist
	Jamie Bock	Caltech
	Harvey Moseley	Goddard
	Walter Gear	Project Scientist
	Jean-Paul Baluteau	Project Scientist
Invited advisers:	Göran Pilbratt	ESA Project Scientist
	Ernst Kreysa ?	Independent expert

FIRST/Planck Project Telefax

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Ref. : PT-05812
Date : 8 September, 1998

From : M. Anderegg (SCI-PT)
Page : 1 of 2

To :

	Fax No :
FIRST-HIFI	
Th. de Graauw (SRON/Groningen)	050 363 4033
H. Aarts (SRON/Utrecht)	030 254 0860
FIRST-PACS	
A. Poglitsch (MPE/Garching)	49 89 3299 3292
O. Bauer (MPE/Garching)	49 89 3299 3569
FIRST-SPIRE	
M. Griffin (QMWC/London)	44 181 980 0986
K. King (RAL/Oxfordshire)	44 1235 44 6667
Planck-HFI	
J-L. Puget (IAS/Orsay)	33 16985 8675
J. Charra (IAS/Orsay)	33 16985 8675
Planck-LFI	
N. Mandolesi (TeSRE/Bologna)	39 51 639 8724
C.R. Butler (ASI/Roma)	39 6 8567 0772

Copy : ESTEC -- F. Felici, F. Vandenbussche, T. Passvogel, C. McCarthy, H. Schaap

Subject : Planned Tests with FIRST/Planck

Please find here a list of the tests we plan to make at system level. Please note that this will be discussed again during Phase B with the selected Prime Contractor.

1. Avionic Model Tests using the Avionic Models
   - Electrical Interfaces
   - Software Interactions
   - AIV and Operational Procedures

2. Planck Payload Module Tests using the Cryo-Qualification Models
   - Thermal Vacuum Test
   - Conductive EMC
   - Payload Functional Test
   - Acoustic and Vibration Tests

3. FIRST Instruments Compatibility Test using the Cryo-Qualification Models
   - Exposure to cryo environment in refurbished ISO cryostat
   - Conductive EMC

4. FIRST & Planck System Tests using the Flight Models
   - System Functional Tests
   - Acoustic and Vibration Tests
   - EMC conductive and Radiation Tests
   - Solar Simulation, Thermal Vacuum Tests

This closes the action AI-HFI/LFI-07 placed on me.

Best regards,

M. Anderegg