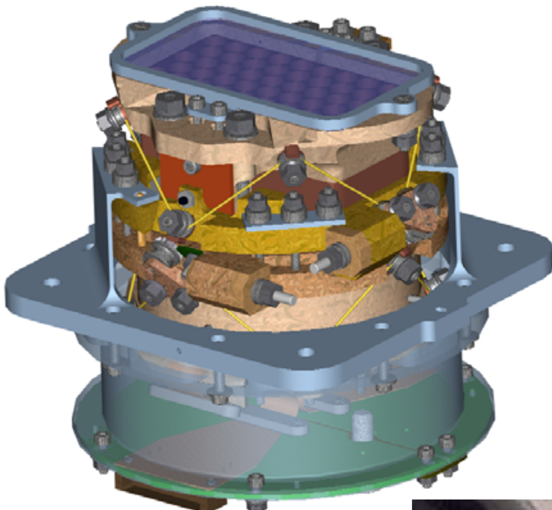
HSO/PLANCK

SPIRE Instrument Detector Arrays CDR

July 30-31, 2001



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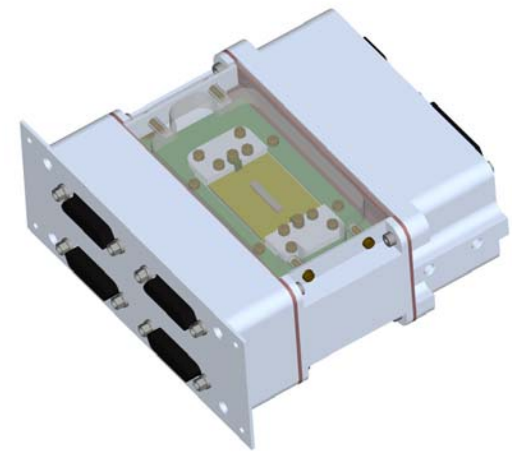

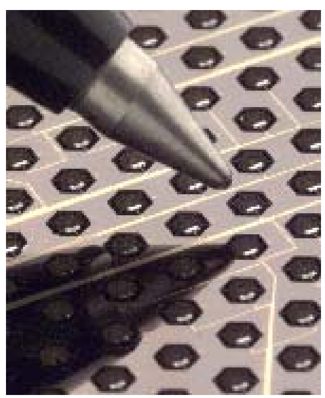

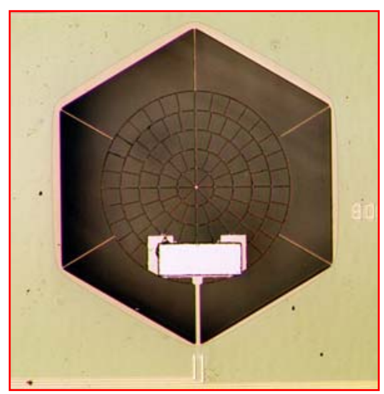

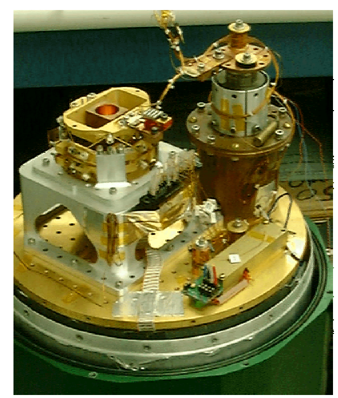

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1.0
Introduction

Gerald Lilienthal

Charter

- Evaluate the readiness of the SPIRE Detector Subsystem to proceed into CQM fabrication, assembly and test
  - Previous concerns and deficiencies considered and resolved
  - Requirements flowdown from instrument
    - Requirements traceability and compliance matrix
    - Documentation of requirements and interfaces
  - Detailed design is adequate stable and well documented
    - Detailed design responds to requirements
    - Tradeoffs understood
    - Demonstration of technology
    - Configuration control
    - Implementation documentation is adequate (AIDS, Process Sheets, Travellers)
    - Manufacturing process design
    - GSE design and certification of test equipment
    - Integration and test plans
    - Reliability analysis and qualification plans
    - Delivery, handling and shipping plans
  - Product assurance plans are adequate
  - Risks understood and plans exist for managing them

Success Criteria

- Designs and processes meet requirements and are sufficiently defined and documented to proceed with development within the risk policy of the project
- Plans for resolving remaining problems are consistent with available resources and risk policy
- Test approach and test product status is thorough and acceptable with verifying compliance with the requirements
- Technology has been demonstrated by test and correlated to the analyses

Agenda July 30

Start	End	Dur.	Item	Presenter
8:00	8:10	10	1.0 Introduction and Objectives	Gerald Lilienthal
8:10	9:10	60	2.0 Overview	
		|	2.1 Scientific Goals	James Bock
		|	2.2 Instrument Design	James Bock
		|	2.3 Rec/Dels	James Bock
		|	2.4 Requirements	James Bock
		|	2.5 Interfaces	James Bock
9:10	9:20	10	2.6 SPIRE at NASA/Herschel Science Center	Ken Ganga
9:20	9:40	20	3.0 Management Overview	Gerald Lilienthal
9:40	10:00	20	4.0 Interfaces	Dustin Crumb
10:00	10:15	15	**-------Break--------**	
			5.0 BDA	
10:15	11:15	60	5.1 Mechanical Design & Analysis	Dustin Crumb
11:15	11:35	20	5.2 Feedhorn design and test	Jason Glenn
11:35	11:50	15	5.3 BDA thermal model and test results	Terry Cafferty
11:50	12:10	20	5.4 Detector Array Fabrication	Minhee Yun
12:10	1:10	60	**-------Lunch-------**	
1:10	1:30	20	5.5 Detector Development	Hien Nguyen
1:30	1:40	10	5.6 Load Resistor Fabrication	Anthony Turner
1:40	1:50	10	5.7 Kapton Cable Design and Status	Anthony Turner
1:50	2:10	20	5.8 BDA Manufacture and Assembly	Len Husted
			6.0 JFET Modules	
2:10	2:30	20	6.1 JFET Testing Status	James Bock
2:30	2:45	15	6.2 JFET Thermal Model	Terry Cafferty
2:45	3:00	15	6.3 JFET Membrane Fabrication	Anthony Turner
3:00	3:15	15	**-------Break-------**	
3:15	3:25	10	6.4 JFET and RF Module Mechanical Design	Dustin Crumb
3:25	3:40	15	6.5 JFET Module Assembly	Len Husted
3:40	4:05	25	7.0 Harness Definition and Test Procedures	Viktor Hristov
			Board Discussion	

Agenda July 31st

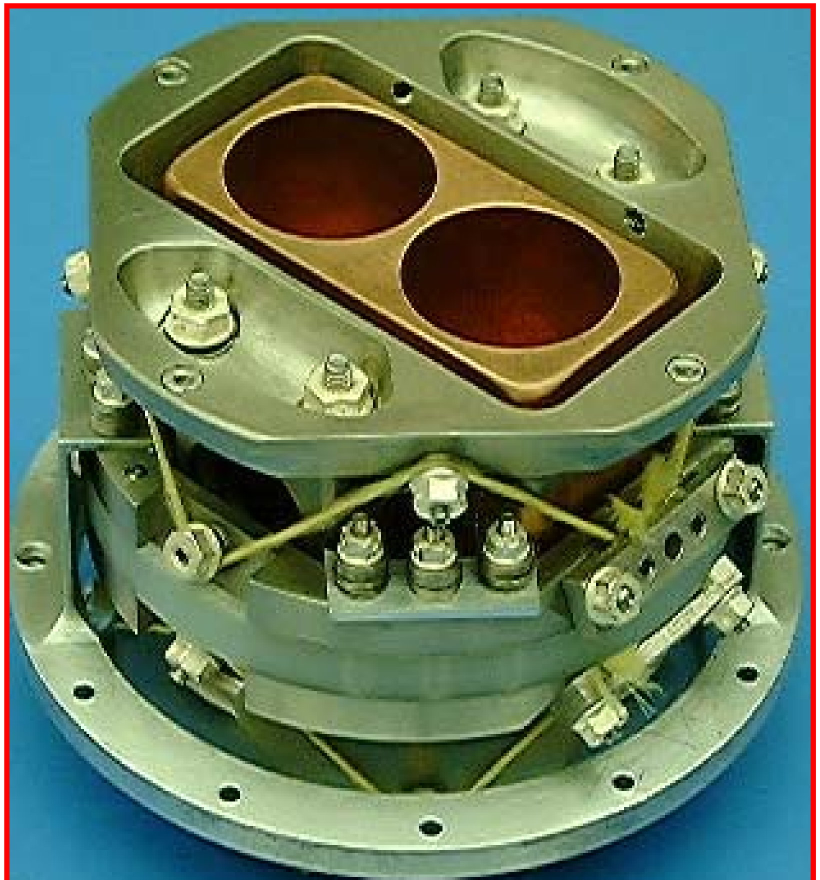
Start	End	Duration	Item	Presenter
8:00	8:20	20	8.0 Warm Electronics	Frederic Pinsard
8:20	8:50	30	9.0 Test program	Kalyani Sukhatme
			9.1 Overview	
			9.2 Verification Matrix	
			9.3 HRCR	
			9.4 Integration and Test Plan	
			9.5 EM Testing and Facilities	
8:50	9:05	15	10.0 Test facilities	Hien Nguyen
9:05	9:45	30	11.0 Mission Assurance	Gordon Barbay
9:45	10:00	15	12.0 Implementation Plan	Jerry
10:00	10:15	15	**-------Break-------**	
10:15	10:30	15	13.0 RFA Summary	James Bock
10:30	10:50	20	14.0 Summary/Objectives	Gerald Liliethal
10:50	11:50	60	**-------Board Report--------**	George Rieke

2.0
Instrument Overview

Jamie Bock

Overview of SPIRE Bolometer Arrays

James J. Bock
Jet Propulsion Laboratory



- SCIENTIFIC GOALS
- INSTRUMENT DESIGN
- REC/DELS
- REQUIREMENTS
- INTERFACES

The SPIRE Consortium

- Caltech/Jet Propulsion Laboratory, Pasadena, USA
- Cardiff University, Cardiff, Wales, UK
- CEA Service d’Astrophysique, Saclay, France
- Institut d’Astrophysique Spatiale, Orsay, France
- Imperial College, London, UK
- Instituto de Astrofisica de Canarias, Tenerife, Spain
- Istituto di Fisica dello Spazio Interplanetario, Rome, Italy
- Laboratoire d’Astronomie Spatiale, Marseille, France
- Mullard Space Science Laboratory, Surrey, UK
- NASA Goddard Space Flight Center, Maryland, USA
- Observatoire de Paris, Meudon, Paris
- UK Astronomy Technology Centre, Edinburgh, UK
- Rutherford Appleton Laboratory, Oxfordshire, UK
- Stockholm Observatory, Sweden
- Università di Padova, Italy
- University of Saskatchewan, Canada

The U.S. SPIRE Team

INSTRUMENTATION TEAM

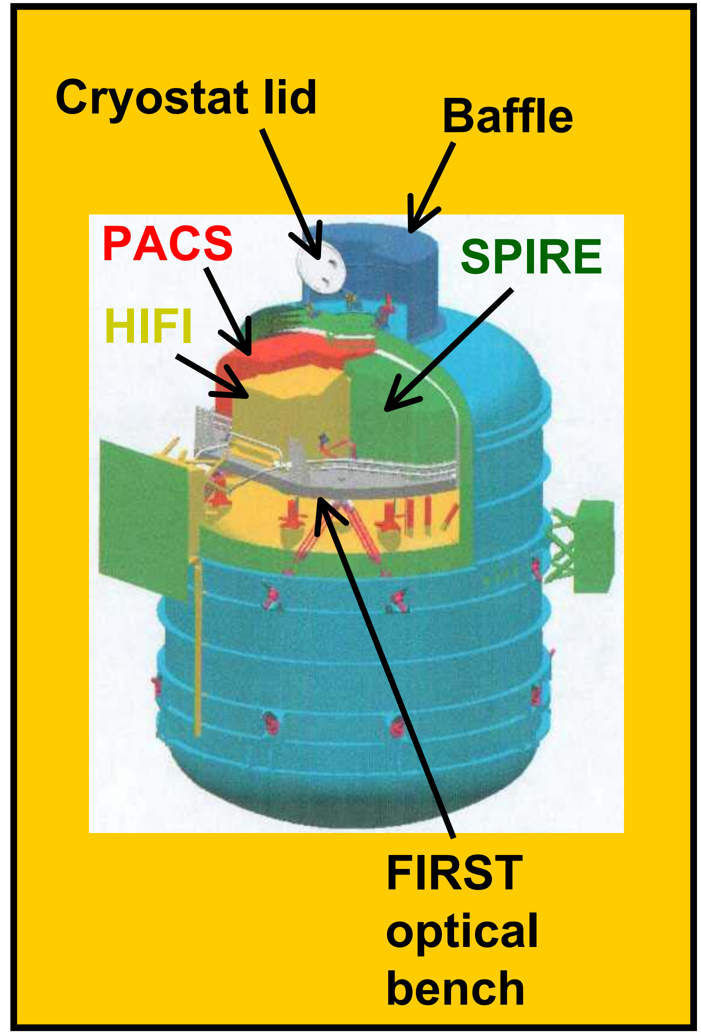
Gordon Barbay	Reliability	JPL
Peter Barrett	Reliablity	JPL
James Bock	SPIRE co-I	JPL
Karsten Browning	Structural Analyst	Swales
Terry Cafferty	Thermal Engineer	TC Tech.
Dustin Crumb	Mechanical Engineer	Swales
Charles Davis	Configuration Control	JPL
Steven Elliott	Cryogenic Technician	JPL
Ed Erginsoy	Parts Program	JPL
Jason Glenn	Feedhorn Design, SPIRE AS	U. Colorado
Viktor Hristov	Electrical Engineer	Caltech
Len Husted	Electronic and Mechanical Assembly	JPL
Eric Jones	Micro-fabrication Engineer	JPL
Michael Knopp	Materials & Processes Engineer	JPL
Andrew Lange	Senior Scientist	Caltech
Timothy Larson	Mission Assurance	JPL
Karan L'Heureux	Safety	JPL
Gerald Lillienthal	Project Element Manager	JPL
Donna Markley	Quality Assurance	JPL
Hien Nguyen	Bolometer Testing, SPIRE AS	JPL
Harvey Moseley	U.S. PI, SPIRE co-I	GSFC
Judi Podosek	Micro-fabrication Engineer	JPL
Brooks Rownd	Feedhorn Testing	U. Colorado
Kalyani Sukhatme	Test Engineer	JPL
Anthony Turner	Micro-fabrication Consultant	Siwave
Minhee Yun	Micro-fabrication Engineer	JPL

SCIENCE ASSOCIATES

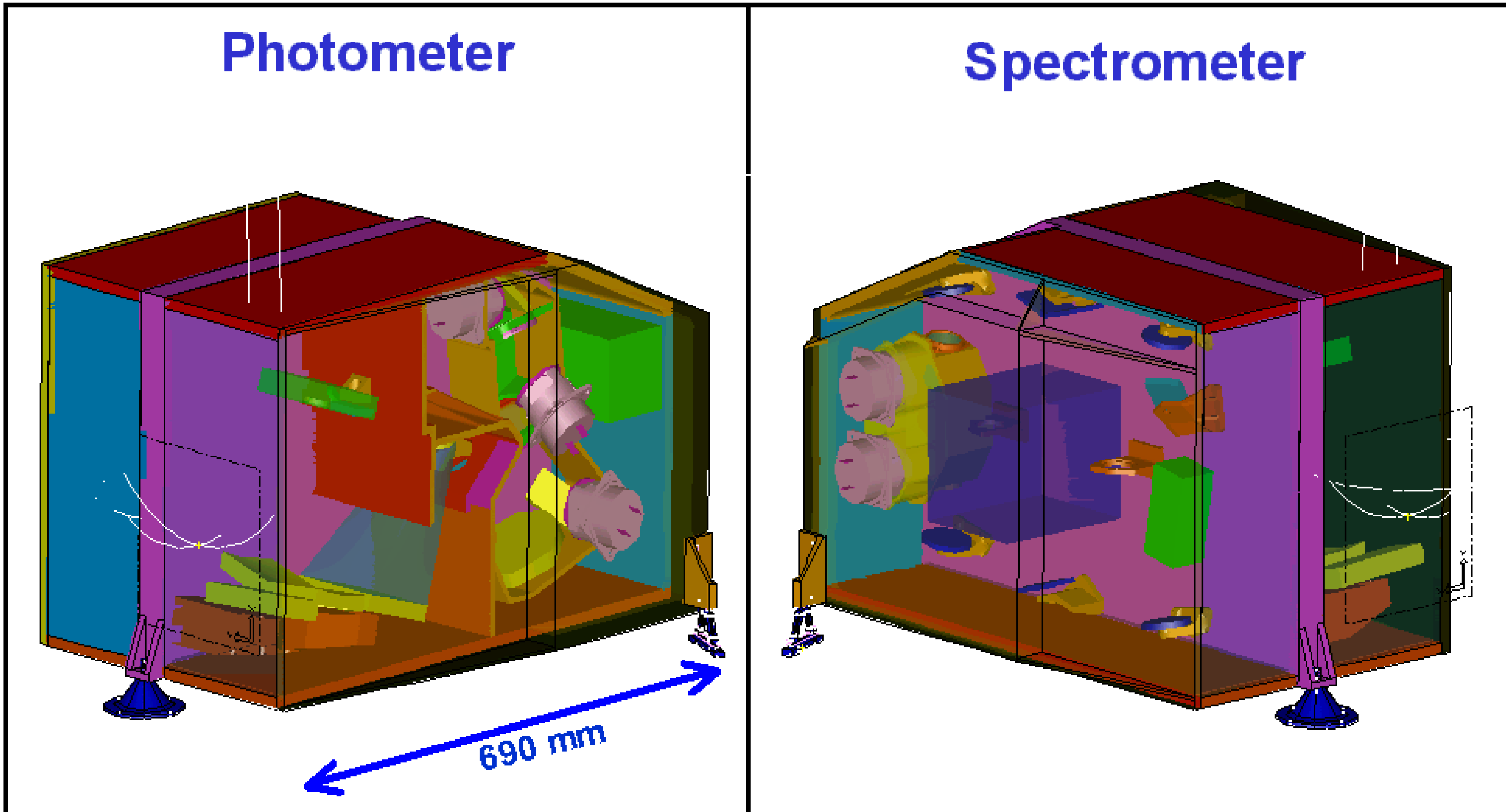
Chas Beichman	Stellar Disks	JPL
Andrew Blain	FIR Galaxy Surveys	Caltech
Sarah Church	Cluster Surveys	Stanford
Ken Ganga	Data Processing	IPAC
Phil Maloney	Interstellar Medium	U. Colorado

SPIRE Instrument Summary

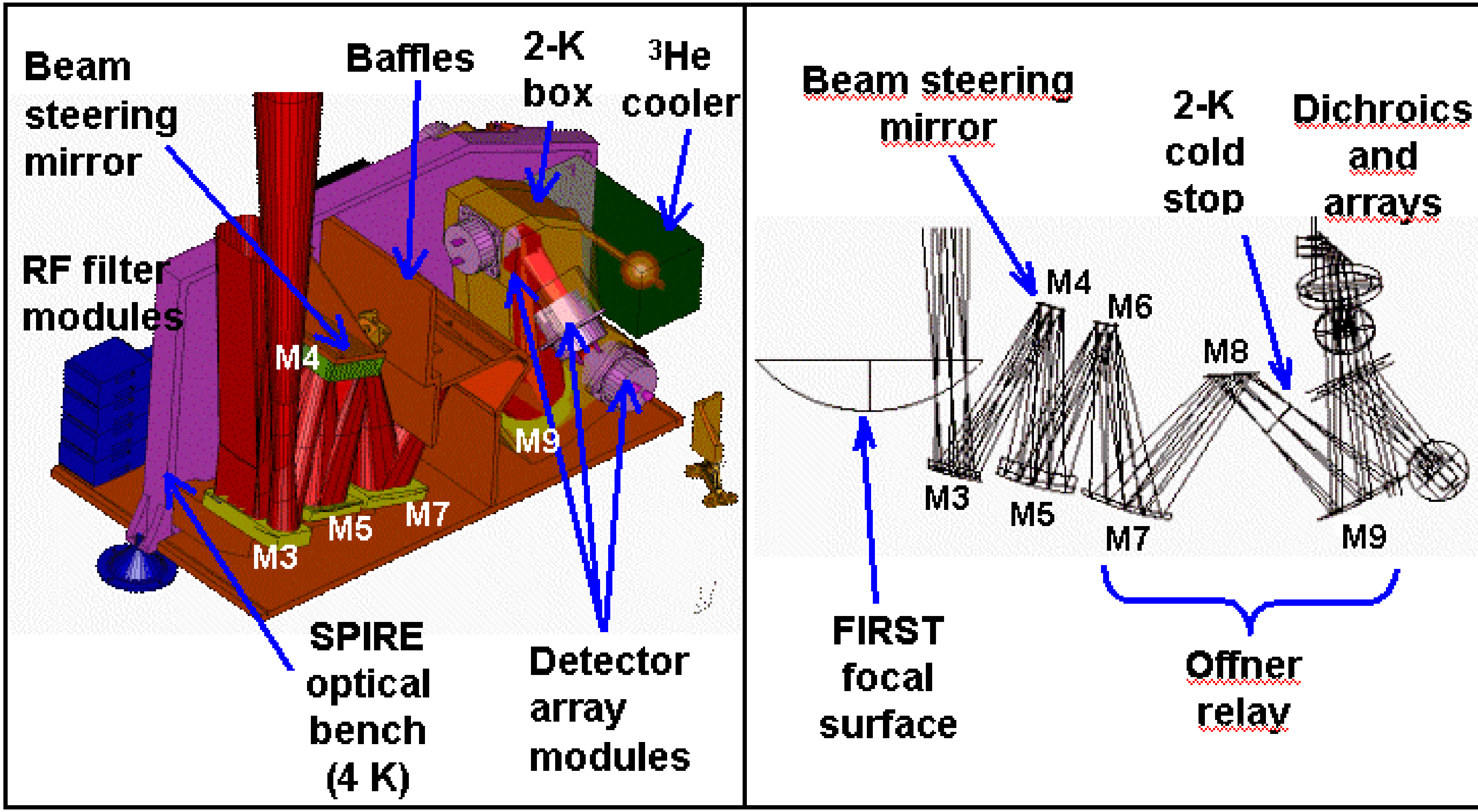
- **3-band imaging photometer**
  - 250, 350, 500 μm (simultaneous)
  - $\lambda/\Delta\lambda \sim 3$
  - 4 x 8 arcminute field of view
  - Diffraction limited beams (17, 24, 35")
- **Imaging FTS**
  - 200 - 400 μm (goal 200 - 670 μm)
  - > 2 arcminute field of view
  - $\Delta\sigma = 0.4\ cm^{-1}$ (goal $0.04\ cm^{-1}$)
    ($\lambda/\Delta\lambda \sim 20 - 100\ (1000)$ at 250 μm)
- **Design features**
  - Sensitivity limited by thermal emission from the telescope (80 K; $\varepsilon = 4\%$)
  - Feedhorn-coupled 'spider web' bolometers at 0.3 K
  - Minimal use of mechanisms
  - Simple observing modes



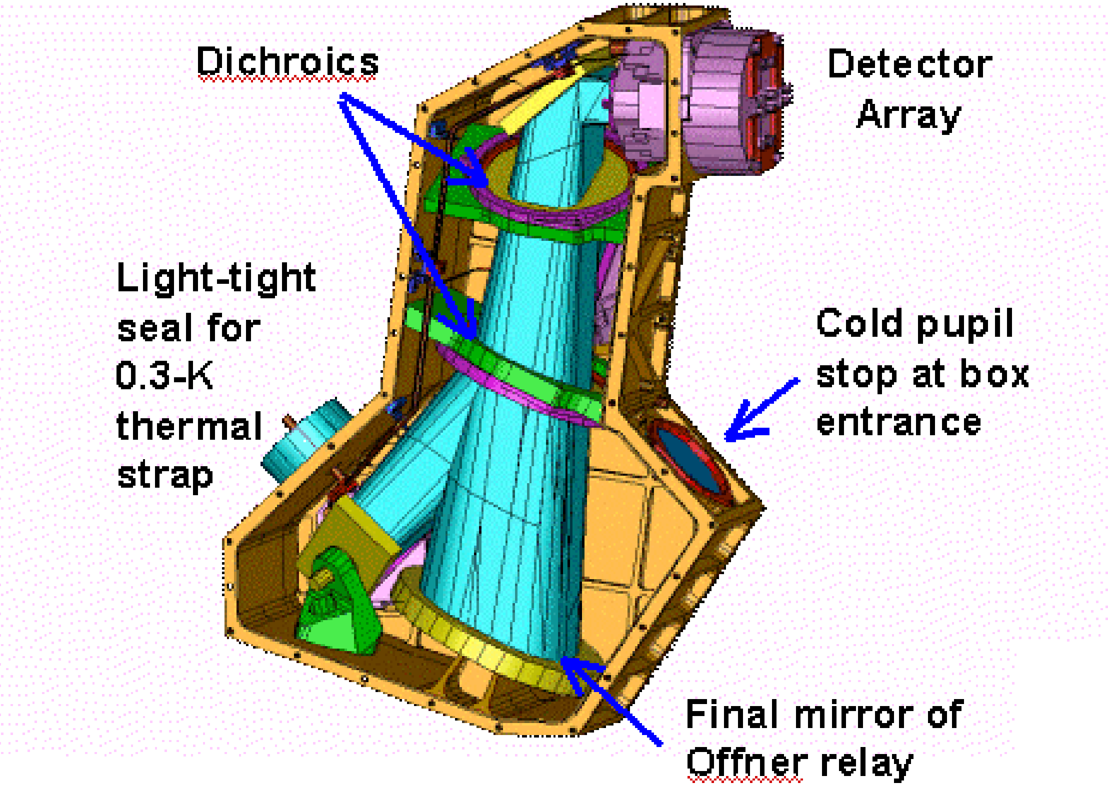
SPIRE FPU



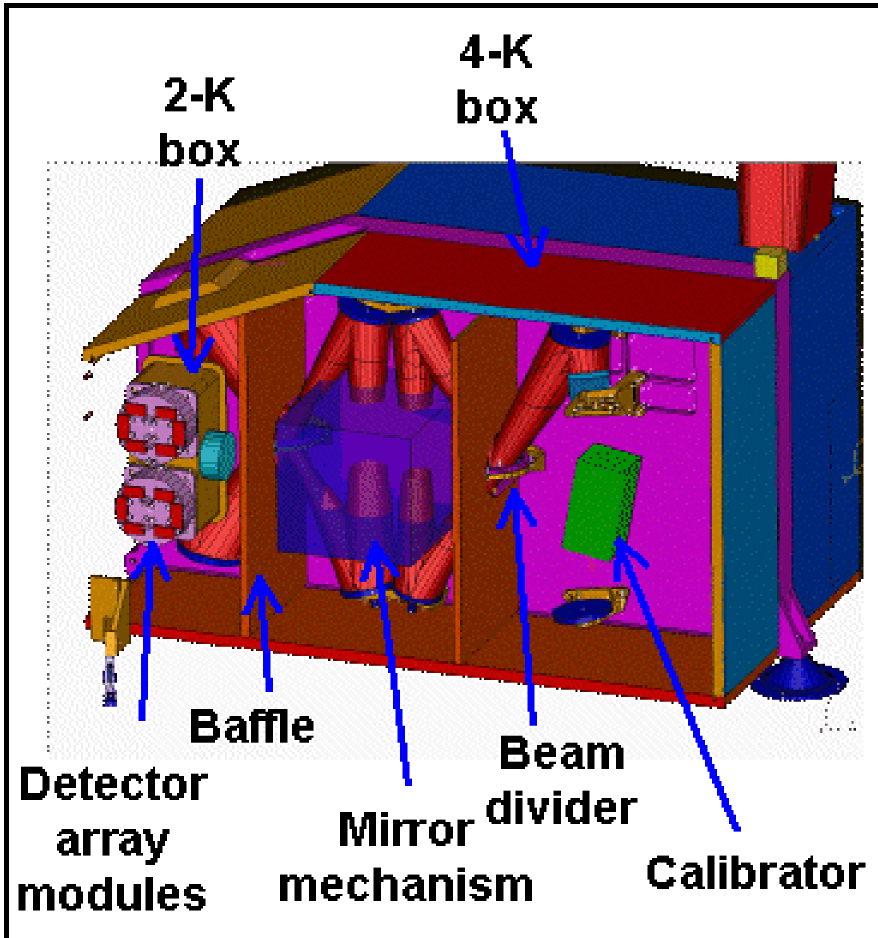
Photometer Layout and Optics

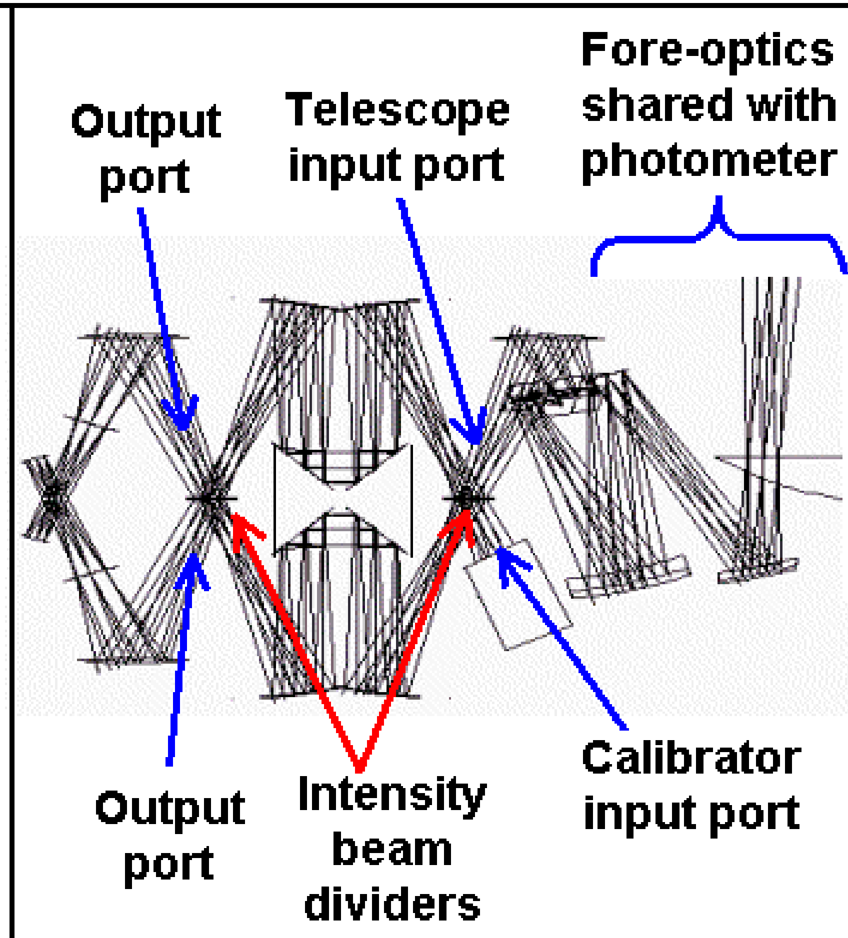


Photometer 2-K Box and 300-mK Straps



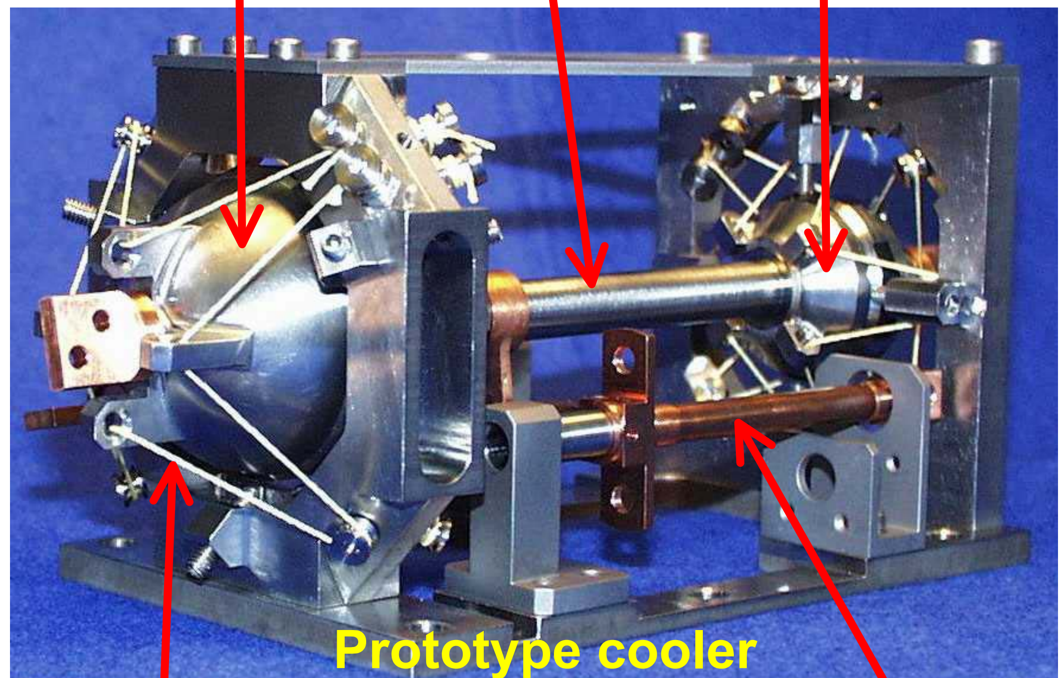
FTS Layout and Optics



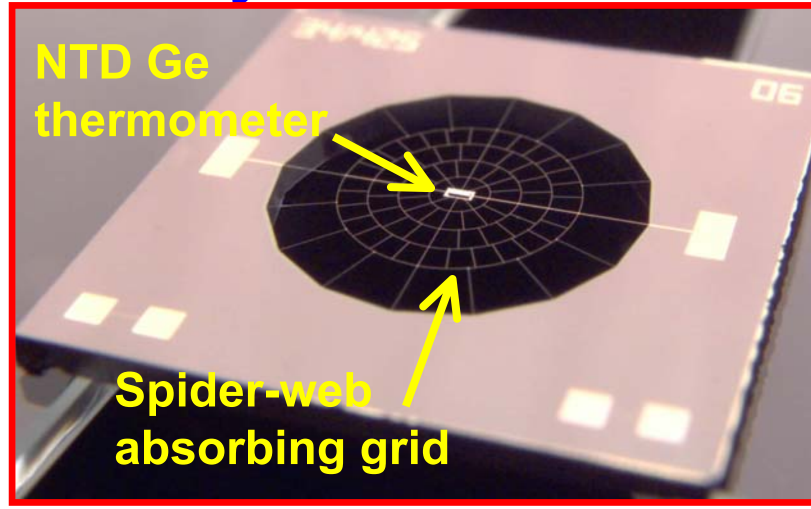


^{3}He Cooler

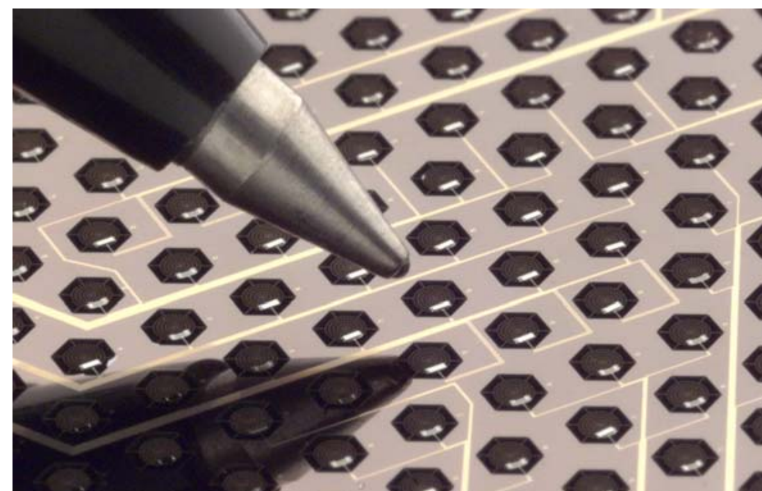
- **Cold stage temp. < 280 mK**
- **Hold time > 46 hrs**
- **Cycle time < 2 hrs**
- **Average load on ^{4}He tank < 3 mW**
- **Heat lift > 10 μW**
- **Gas-gap heat switches (no moving parts)**



NTD Ge Bolometer Arrays



Spider-web architecture provides
- low absorber heat capacity
- minimal suspended mass
- low-cosmic ray cross-section
- low thermal conductivity
  = high sensitivity


Bolometer array wafer

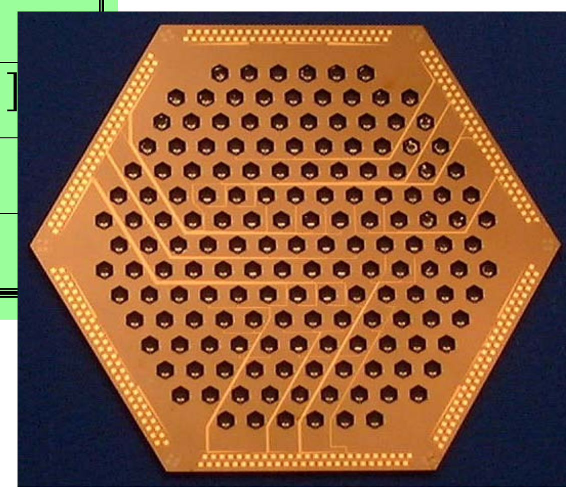
Sensitivities and heat capacities achieved:

NEP = 1.5 x 10^{-17} W/√Hz
C = 1 pJ/K at 300 mK

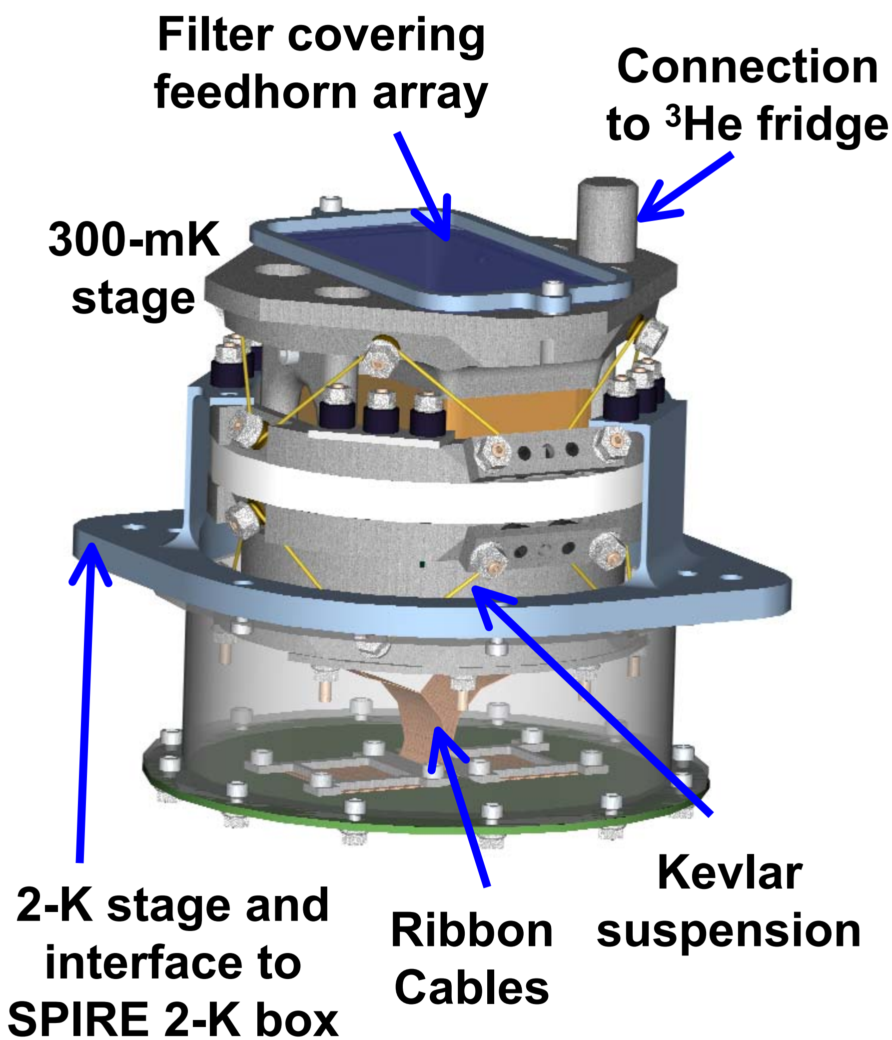
NEP = 1.5 x 10^{-18} W/ √ Hz
C = 0.2 pJ/K at 100mK

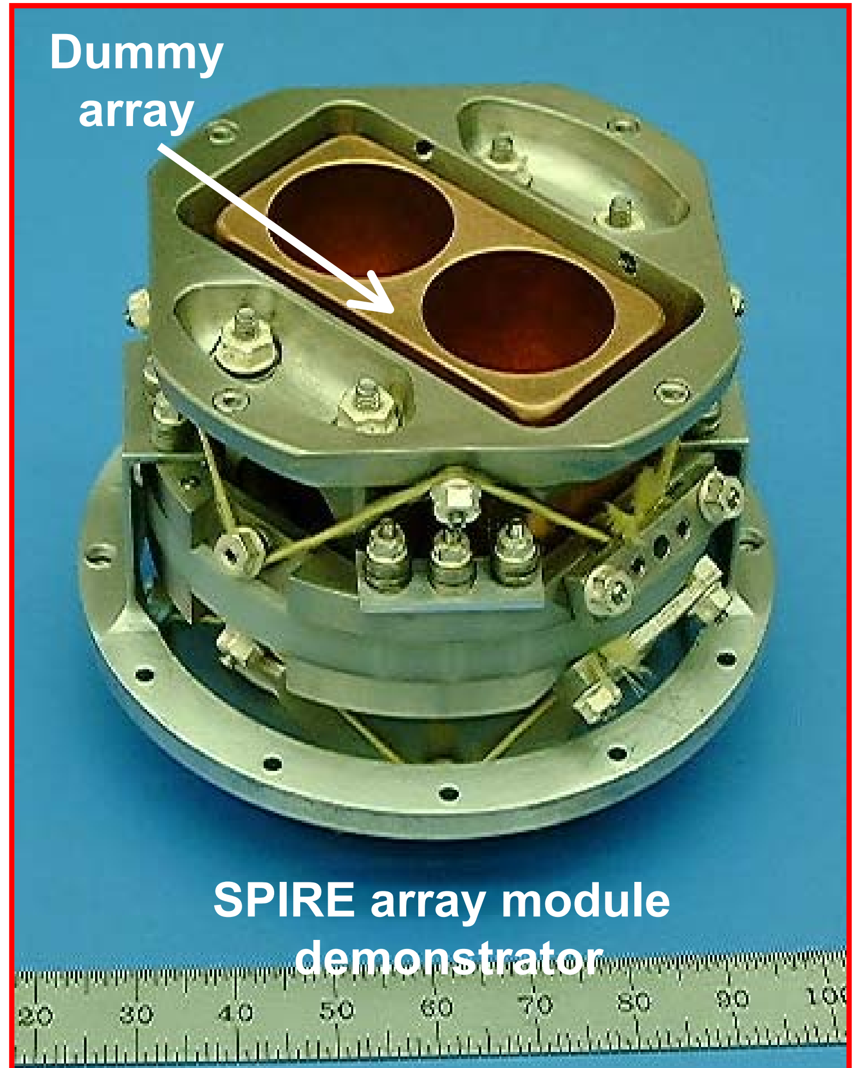
NTD Ge Bolometer Array Development

Quantity	Measured Value	Target	Units
Dark $\langle NEP_{bol} \rangle$	2.7×10^{-17}	2.5×10^{-17}	[W/√Hz]
Dark $\langle S_e \rangle$	5.88×10^{8} (± 6 %)		[V/W]
Yield	0.9	0.9	
$\langle G_0 \rangle$	54.8 ± 7.6	60	[pW/K]
$\langle C_0 \rangle$	0.96 ± 0.24	1.0	[pJ/K]
τ	11.7 ± 0.8	8 / 30	[ms]
η_{bol}	0.46 – 0.64	0.8	
1/f knee	~30	100	[mHz]
NEP_{bol}/NEP_{blip}	1.10 (+0.05, –0.15)	1.15	
DQE	0.38 - 0.53	0.60	



Bolometer Array Module

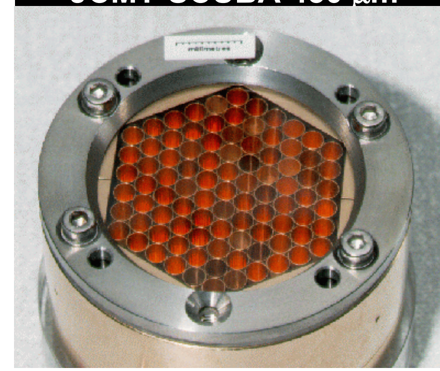




Sky Sampling with Feedhorn Arrays

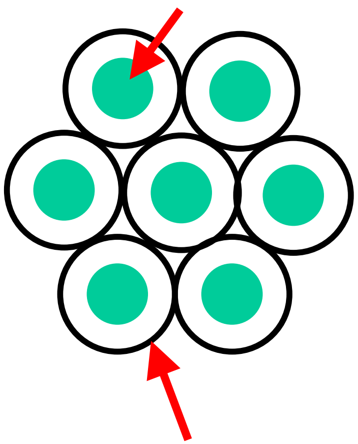
Full sampling of the image requires scanning or "jiggling" of the telescope pointing

JCMT-SCUBA 450 µm



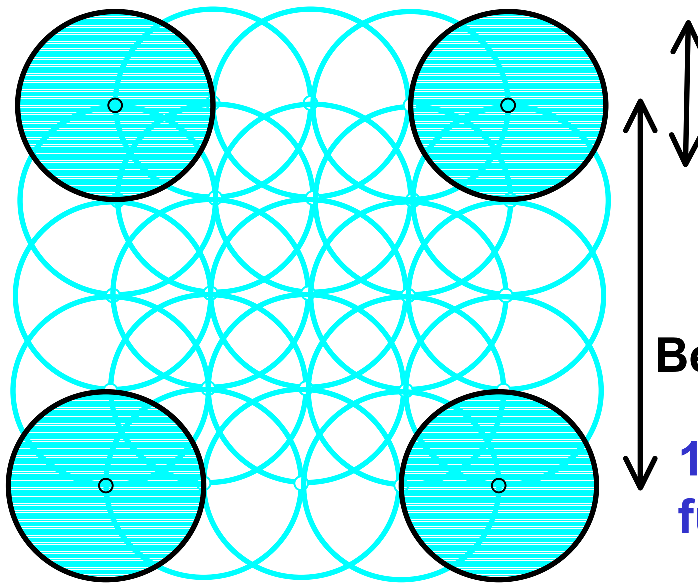
Feedhorns adjacent in the focal plane

FWHM



2fλ horn aperture

FWHM beams on the sky don't overlap



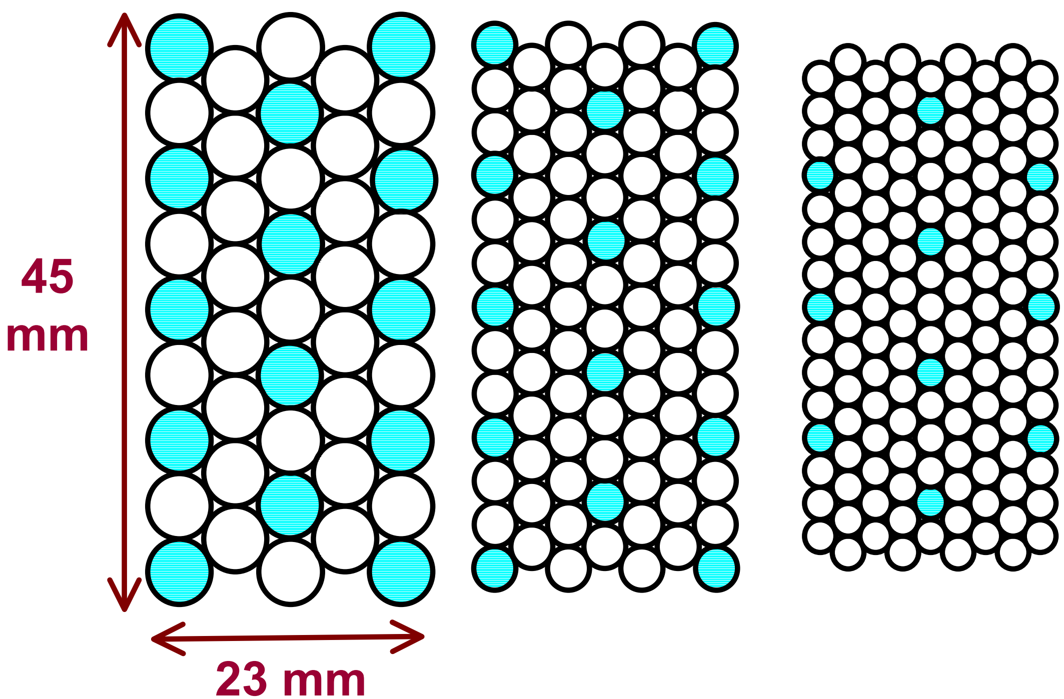
Beam FWHM = λ/D

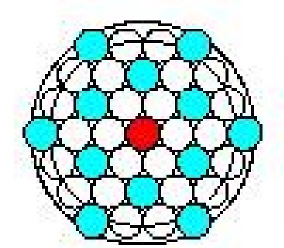
Beam separation = 2λ/D

16 pointings needed for fully-sampled image

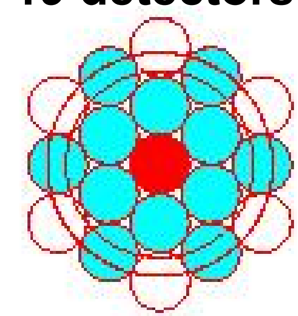
Detector Arrays (2Fλ Feedhorns)

Photometer			Spectrometer
500 μm 43 detectors	350 μm 88 detectors	250 μm 139 detectors	200-300 μm 37 detectors





300-670 μm
19 detectors



⇒ Overlapping beams

Photometer Observing Modes

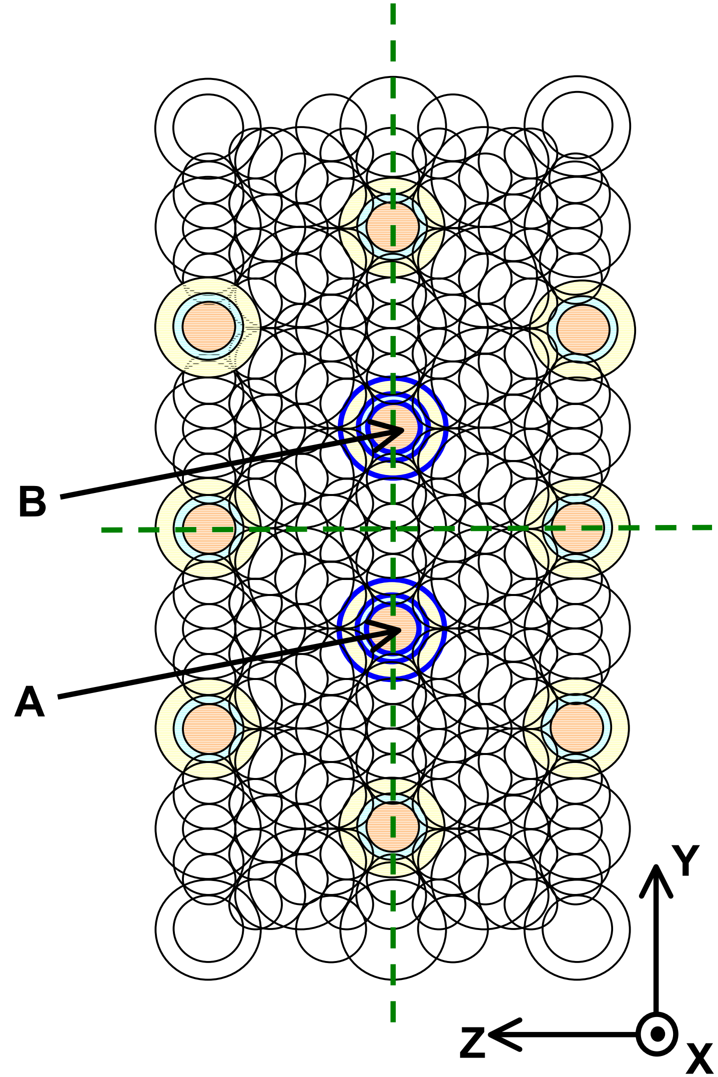
- **Point source photometry:**
  - Beam steering mirror chops 125” between overlapping sets of detectors
  - Seven-point jiggle can be done if desired

- **Field mapping:**
  - Beam steering mirror chops up to 4’ and performs 64-point “jiggle”
  - Available fov = 4’ x 4’

- **Scan mapping:**
  - Beam steering mirror not operated
  - Telescope drift scanning at up to 60”/second
  - Scan angle wrt array axis set to give full spatial sampling

Point Source Photometry

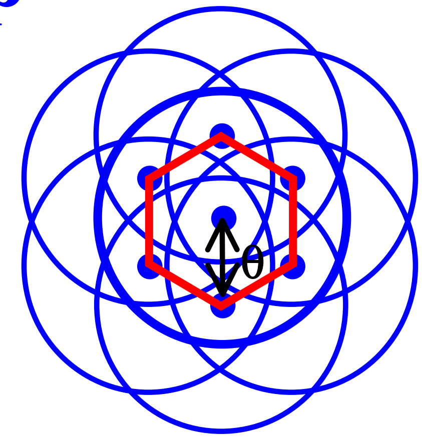
- Telescope pointing fixed
- Chopping in Y-direction between A and B (126”)
- Simultaneous observation in the three bands with two sets of co-aligned detectors
- Chop without jiggling is OK if the pointing is accurate enough (~ 1.5”)

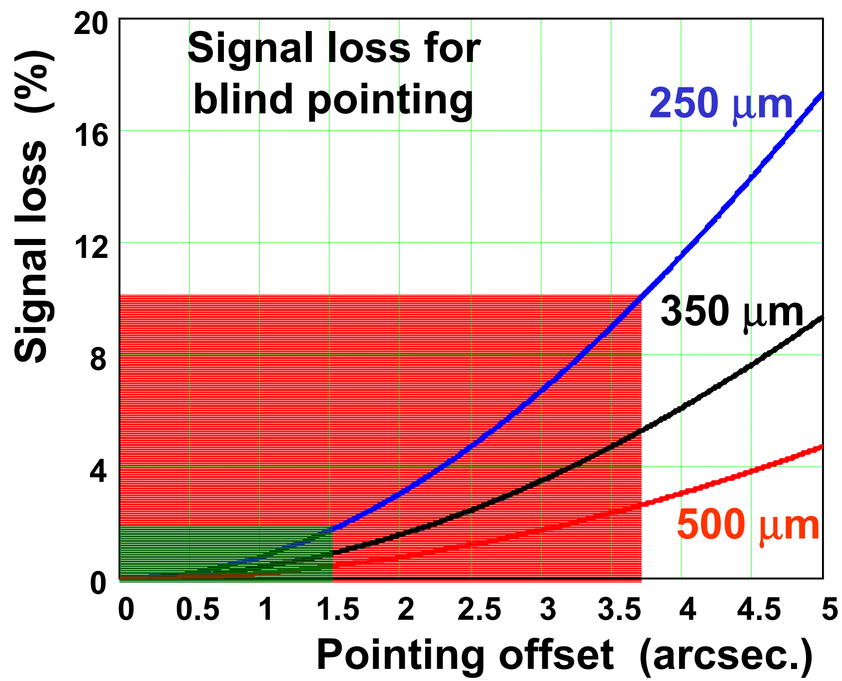


7-point Jiggle Map

- Chopping 126"
- 7-point jiggle pattern
- Angular step θ ~ 4 - 6 arcseconds (> pointing or positional error)
- Total flux and position can be fitted
- Compared to single accurately pointed observation, S/N for same total integration time is only degraded by

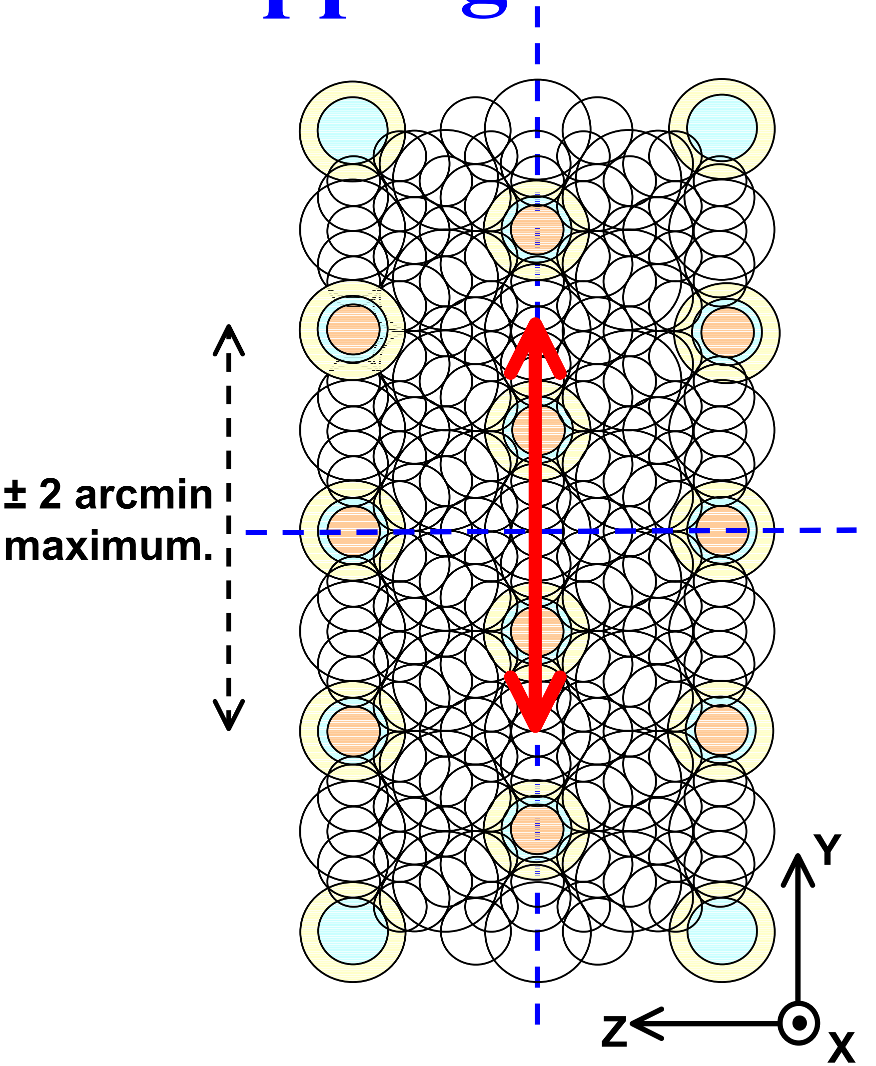
~ 20%	at	250 μm
~ 13%	at	350 μm
~ 6%	at	500 μm





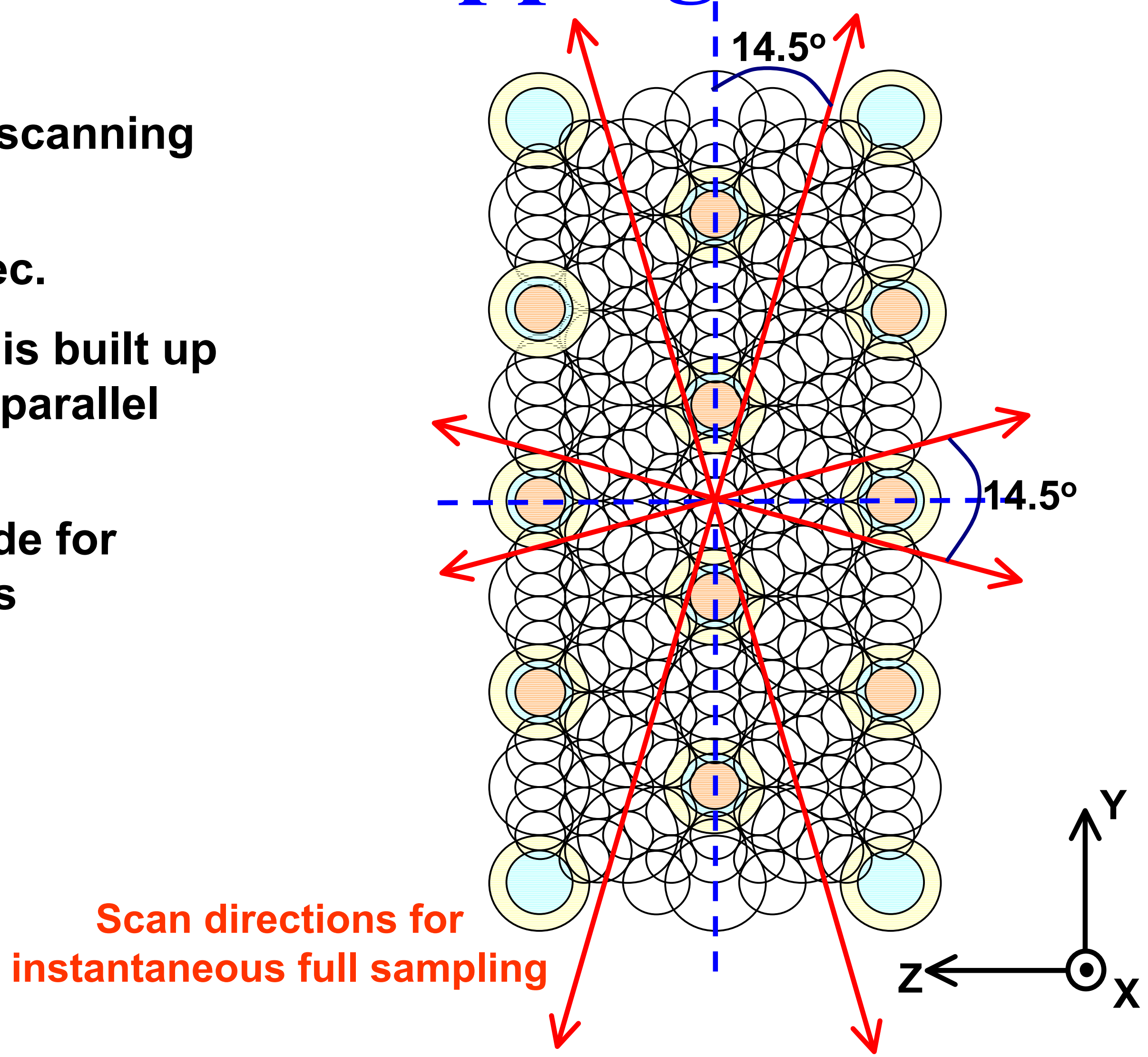
Field Mapping

- Telescope pointing fixed or in raster mode
- Chopping up to 4 arcmin amplitude in Y direction
- 64-point "jiggle" pattern for full spatial sampling

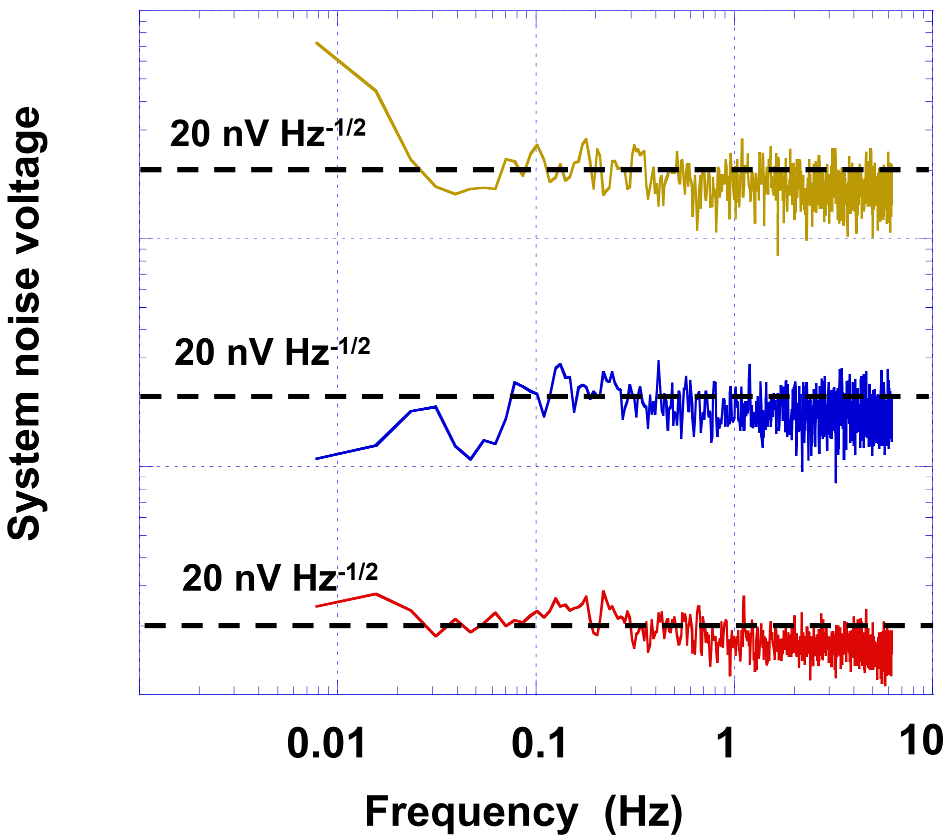


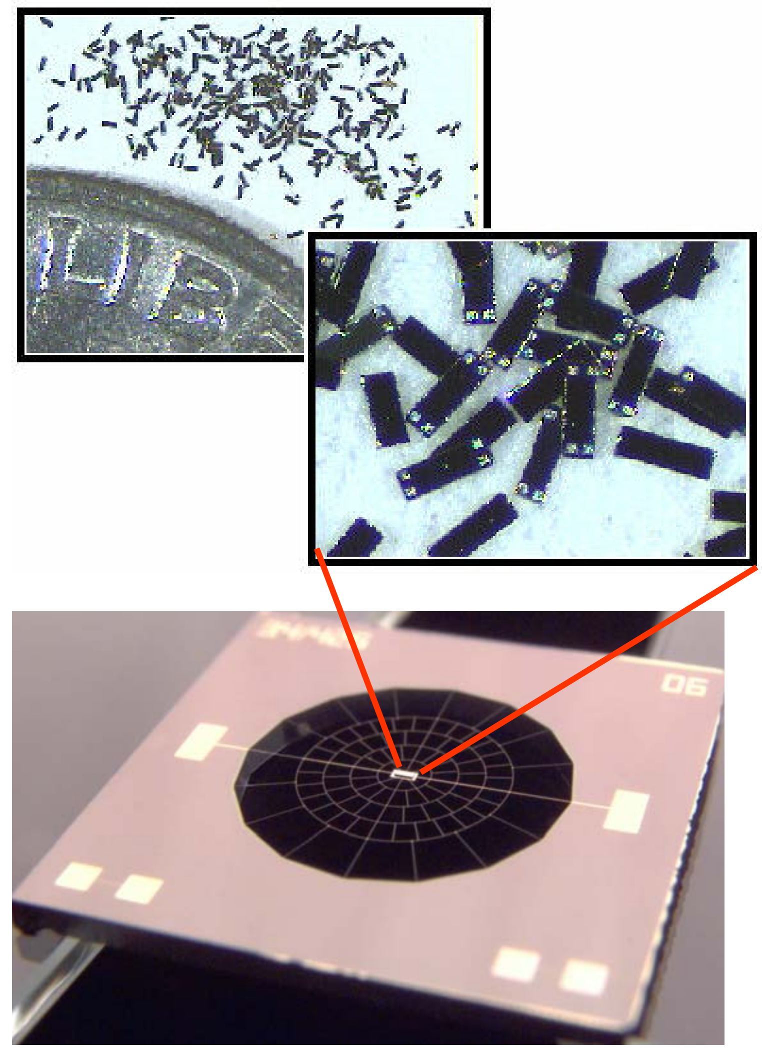
Scan Mapping

- Telescope in line scanning mode
- Scan rate < 60"/sec.
- Map of large area is built up from overlapping parallel scans
- Most efficient mode for large-area surveys

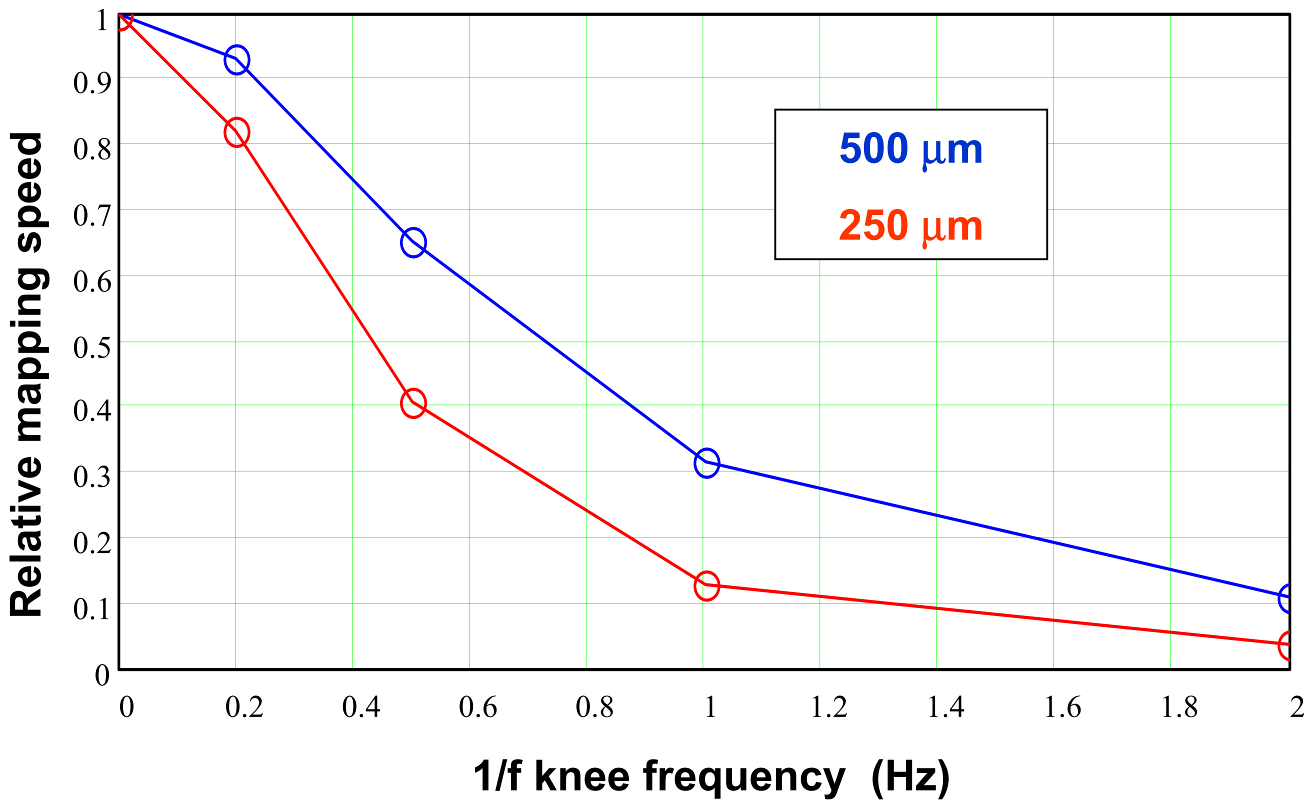


High 1/f stability with NTD Germanium





Simulations of Scan Mapping



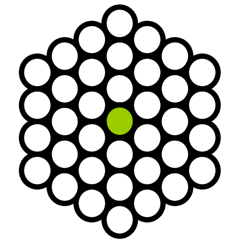
FTS Observing Modes

- Mirror scan rate = 1 mm s^{-1}
- Signal frequency range 6 - 20 Hz
- Maximum scan length = 3.5 cm (14 cm OPD)
- $\Delta\sigma$ = 0.04 - 2 cm^{-1} by adjusting scan length
- Calibrator in second port nulls telescope background

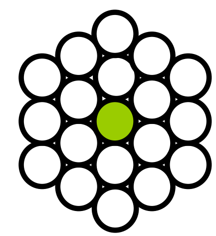
- Point source spectroscopy/spectrophotometry
  - Telescope pointing fixed
  - Background characterized by adjacent pixels

- Imaging spectroscopy
  - Beam steering mirror adjusts pointing between scans to acquire fully-sampled spectral image

200-300 μm
37 detectors



300-670 μm
19 detectors



Estimated Instrument Sensitivity

Photometry (all bands)

Flux density (mJy, 5-σ; 1 hr)

Point source	4.0 (req.)	2.0 (goal)
Map (4'x 4')	16 (req.)	8.0 (goal)

FTS: Spectroscopy 200 - 400 μm $\Delta\sigma$ = 0.04 cm^{-1}

Line flux (W m^{-2} x 10^{-17}, 5-σ; 1 hr)

Point source	6.0 (req.)	3.0 (goal)
Map	18 (req.)	9.0 (goal)

FTS: Spectrophotometry 200 - 400 μm $\Delta\sigma$ = 1 cm^{-1}

Flux density (mJy, 5-σ; 1 hr)

Point source	200 (req.)	100 (goal)
Map	600 (req.)	300 (goal)

FTS sensitivity declines by factor of ~ 2 between 400 and 670 μm

SPIRE Large-Area Survey Sensitivity

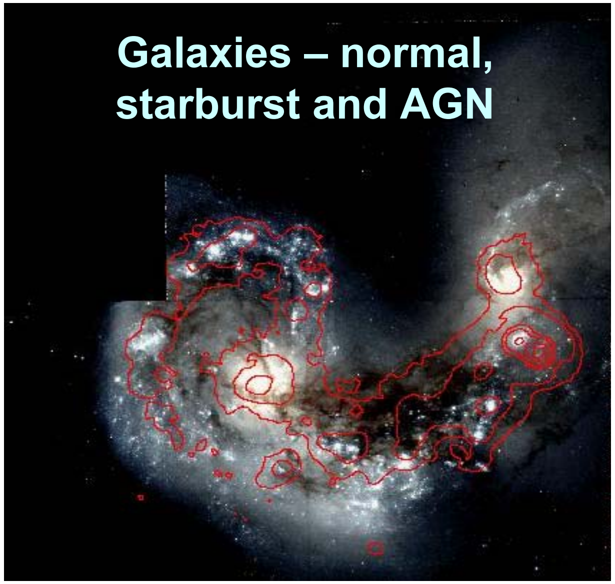
λ (μm)	FWHM (arcsec.)	5σ; 1hr limit (scan-map mode) (mJy)	Confusion limit (1 source per 40 beams) (mJy)	Time to reach confusion limit for one field at 5-σ (min.)	Time to map 1 sq. deg. to confusion limit (days)
250	18	7.3	19	9	1.3
350	25	7.4	20	8	1.2
500	36	7.4	15	14	2.1

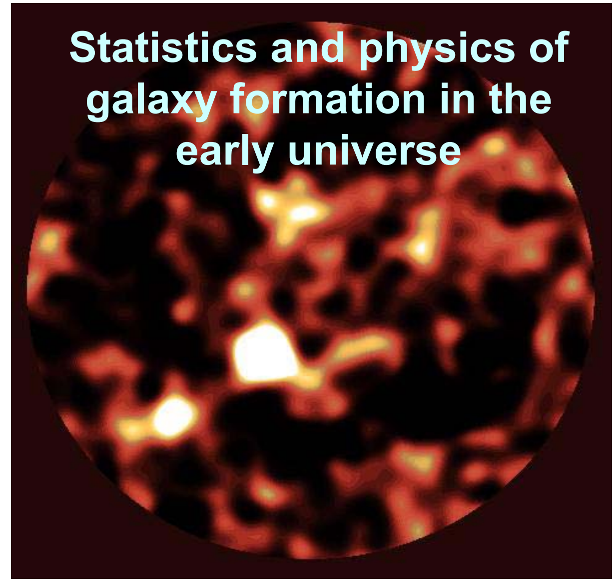
Confusion limits are from the models of M. Rowan-Robinson (*Ap. J., in press*)

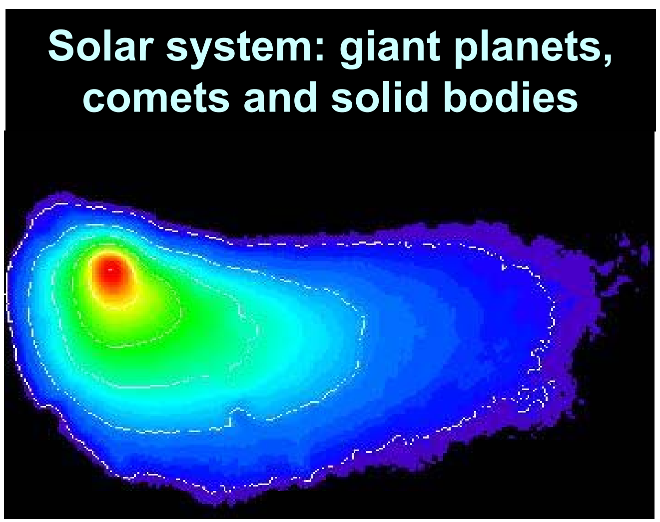
Assumptions

- Scan-map mode
- 90% observing efficiency
- 21 hrs observing/day
- 25% field overlap
- 75% detector yield

SPIRE Scientific Goals







Star formation and interstellar matter

Protostars and YSOs:
Spectral Coverage and Capabilities

- **Unbiased surveys of nearby molecular clouds**
- **Complete census of protostellar condensations within ~ 1 kpc**
- **Temperature and density distributions**
- **Total luminosities**
- **Dust properties**
- **Star formation rate and efficiency**
- **Initial mass function**

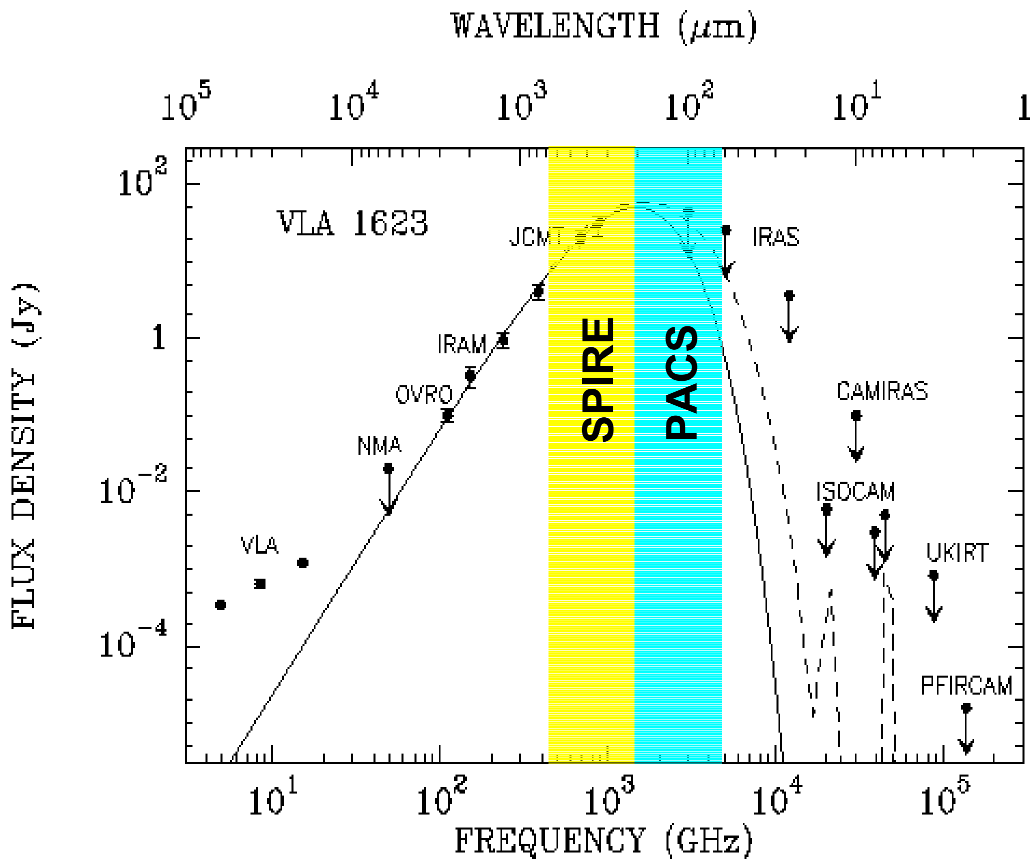
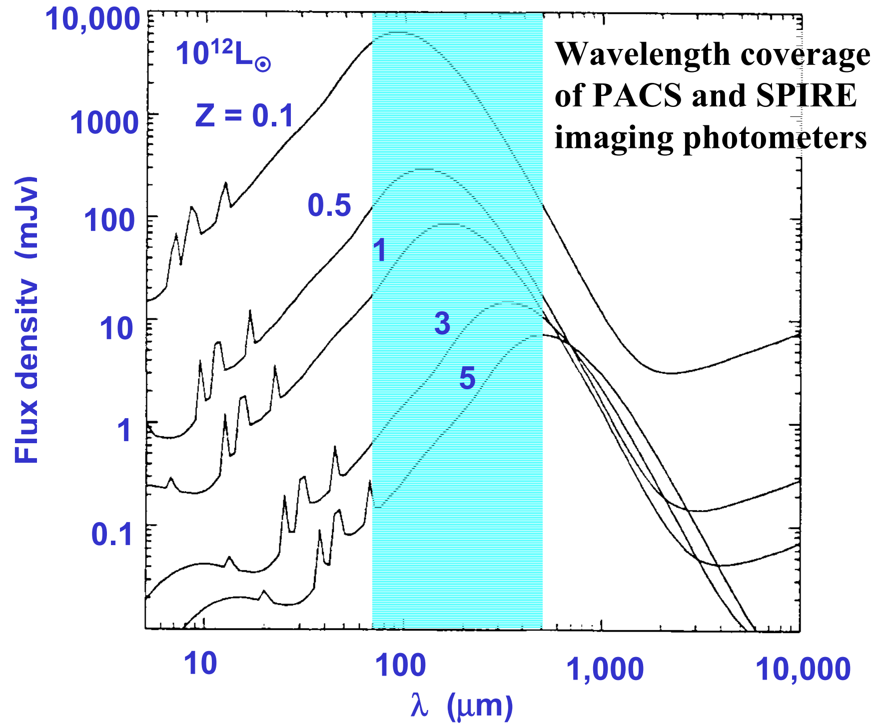


Figure by Philippe André

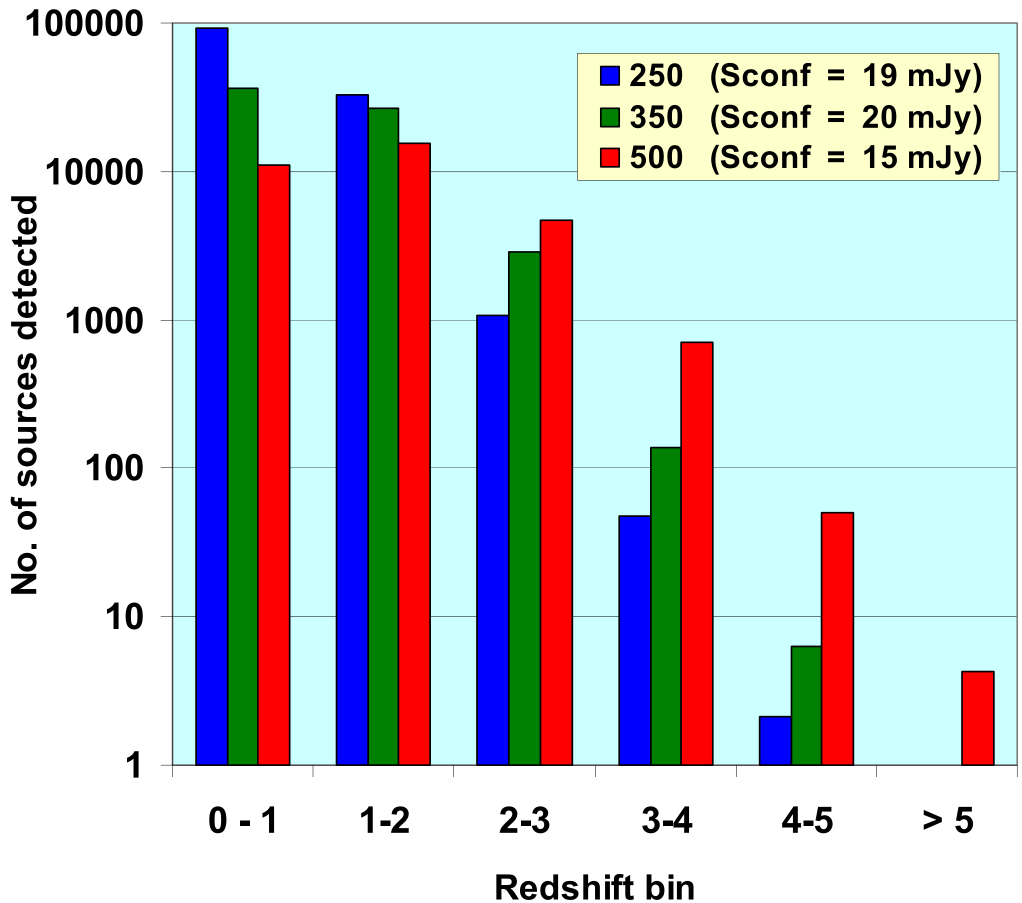
FIR Galaxy Surveys with SPIRE

- Unbiased survey of population of high-z dusty star-forming galaxies missed by current (and future) optical and near-IR surveys
- Large-scale structure in the high-redshift universe
- Star-formation history in galaxies at z out to 5



After Guiderdoni *et al*. MNRAS 295, 877, 1998

Possible SPIRE Survey and Outcome



Source count models of M. Rowan-Robinson

- 100 sq. deg.
- Confusion-limited
- 100 - 200 days
- $\Delta S_{5\sigma} <$ 15 mJy

1,300 sources/sq. deg.
660 sources/sq. deg.
320 sources/sq. deg.

Assumptions

- Scan-map mode
- 90% observing efficiency
- 21 hrs observing/day
- 25% field overlap
- 75% detector yield

STM Receivables and Deliverables

Structural Thermal Model:

verify the temperature distribution and instrument structure

Item	Del. By	Rec. By
P/LW EM BDA[1]	JPL	RAL
P/MW STM BDA[2]	JPL	RAL
P/SW STM BDA[2]	JPL	RAL
S/LW STM BDA[2]	JPL	RAL
S/SW STM BDA[2]	JPL	RAL
15 JFET STM modules	JPL	RAL
5 (TBC) RF modules for FPU	JPL	RAL
3 (TBC) RF modules for JFETs	JPL	RAL
15 BDA-JFET Harnesses	JPL	RAL
Back Harnesses for JFET rack	JPL	RAL

[1]Kevlar suspended
[2]Structural, thermal, & electrical equivalents

CQM Instrument Philosophy

Cryogenic Qualification Model:

Integration: Optical Alignment
Mechanical & Electrical I/F
Commanding and data transfer
FPU and JFET bake out

Functional: Thermal characterization and dissipation

Performance: ***Interaction of subsystems***
Electronics, cabling, 3He cooler, FTS, BSM
Optical focus & straylight
Microphonics
Scientific Performance (sensitivity, spectral response etc.)

Environmental: Operation of FPU over thermal range
EMC susceptibility

Operational: Observing modes
Operational modes

CQM Receivables and Deliverables

Cryogenic Qualification Model:

model of the instrument intended for qualification of cryogenic performance

Item	Del. By	Rec. By
P/LW CQM BDA[6]	JPL	RAL
P/MW CQM BDA[7]	JPL	RAL
P/SW CQM BDA[7]	JPL	RAL
S/LW CQM BDA[6]	JPL	RAL
S/SW CQM BDA[7]	JPL	RAL
S/SW CQM BDA[8]	JPL	RAL
3 JFET CQM modules[9]	JPL	RAL
P/LW far-infrared filter	CARDIFF	JPL
S/LW far-infrared filter	CARDIFF	JPL
S/SW far-infrared filter	CARDIFF	JPL

[6]Fully functional, re-used for FS. Reduced performance acceptable for CQM, not FS.
[7]Kevlar suspended unit without detectors. Returned to JPL for FS delivery.
[8]Fully functional but delivered without testing. Returned to JPL for PFM delivery.
[9]Fully functional, re-used for FS. Reduced performance acceptable for CQM, not FS.

PFM Receivables and Deliverables

Proto Flight Model:

model of the instrument intended for launch and astronomical observations at L2

Item	Del. By	Rec. By
P/LW PFM BDA	JPL	RAL
P/MW PFM BDA	JPL	RAL
P/SW PFM BDA	JPL	RAL
S/LW PFM BDA	JPL	RAL
S/SW PFM BDA	JPL	RAL
8 JFET PFM modules	JPL	RAL
5 (TBC) RF modules for FPU	JPL	RAL
3 (TBC) RF modules for JFETs	JPL	RAL
15 BDA-JFET Harnesses	JPL	RAL
Back Harnesses for JFET rack	JPL	RAL
Temperature Control[11]	JPL	RAL
P/LW BDA far-infrared filter	CARDIFF	JPL
P/MW BDA far-infrared filter	CARDIFF	JPL
P/SW BDA far-infrared filter	CARDIFF	JPL
S/LW BDA far-infrared filter	CARDIFF	JPL
S/SW BDA far-infrared filter	CARDIFF	JPL

[11]Control and monitor thermometers, heaters, fixtures, cable provided pending evaluation of CQM performance

FSM Receivables and Deliverables

Flight Spare Model:

duplicate model of the instrument in event of major failure of PFM instrument

Item	Del. By	Rec. By
P/MW FSM BDA	JPL	RAL
P/SW FSM BDA	JPL	RAL
S/SW FSM BDA	JPL	RAL
Temperature Control[11]	JPL	RAL
P/MW BDA far-infrared filter	CARDIFF	JPL
P/SW BDA far-infrared filter	CARDIFF	JPL
S/SW BDA far-infrared filter	CARDIFF	JPL

[11]Control and monitor thermometers, heaters, fixtures, cable provided pending evaluation of CQM performance

Performance Requirements

The BDA-Sub-System Specification Document (BDA-SSSD) defines:

- Performance criteria are designed to maximize mapping speed
  - "Design values" based on ideal operation
  - "Minimum performance" based on the best current data with margin
  - *No* requirements on performance levels
- The instrument maintains a margin on resource design values. Resource discrepancies are to be resolved at instrument level
- Requirements on other subsystems to meet performance levels
  - operating temperature and stability
  - warm electronics performance
  - mechanical interface requirements
  - RF environment
  - EMI/EMC
- Environmental verification matrix

Detector Performance Criteria

	P/LW		P/MW		P/SW		S/LW		S/SW		
$(NEP_{blip}/NEP_{total})^2$	0.66	0.55	0.73	0.61	0.79	0.66	0.73	0.61	0.79	0.66	
τ	14	32	11	32	9	32	3.4	14	4.9	8	[ms]
η_{opt}	0.85	0.45	0.85	0.45	0.85	0.45	0.85	-	0.85	-	
Yield	0.9	0.75	0.9	0.75	0.9	0.75	0.9	0.75	0.9	0.75	
1/f knee	30	100	30	100	30	100	30	100	30	100	[mHz]
n-n cross-talk	1	5	1	5	1	5	1	5	1	5	[%]
Q	3.0		4.0		5.0		12.5		9.0		[pW]
JFET noise	7	8.5	7	8.5	7	8.5	7	8.5	7	8.5	[nV/√Hz]

Design value

Minimum performance

Subsystem Performance Requirements

Specific requirements are placed on subsystems impacting detector performance

3He fridge	290 mK delivered to BDA interface 10 μK/√Hz temperature stability < 0.1 mK/hr temperature drift
Optics	Performance defined under specified loading
DRCU	7 nV/√Hz total readout noise EMC requirement TBD
Structure	1.7 K delivered at BDA interface Interface plate provides ± 1 mm compensation > 1 kHz resonant frequency for cables Electrically isolated 4 K RF enclosure, 40 dB attenuation EMI requirement TBD

Detailed DRCU Requirements (1)

Requirement ID	Description	Reference	Subsystem Compliance
BDA-DRCU-01	The DRCU signal processing electronics shall have less than 7 nV/rtHz as seen post demodulation, after digitzation. Noise is referred to the input over the frequency range 0.05 to 25 Hz. This performance must be accomplished with a bias input signal to the DRCU of 10 mVrms AC, 5 mV DC, 1 V DC common-mode offset, with an input load of 7 kOhms.	JPL	TBD
BDA-DRCU-02	The input noise impedance shall be greater than 7 kΩ, post-demodulation, referred to the input over the frequency range of 0.1 to 10 Hz.	JPL	Requirement deleted
BDA-DRCU-03	Input capacitance to be less than 100 pF, measured from the DRCU DxMA connector pins without the harness.	JPL	TBD
BDA-DRCU-04	Input impedance to be larger than 1 MΩ from 50 – 300 Hz.	JPL	TBD
BDA-DRCU-05	The DRCU is to provide 5 BDA bias signals, adjustable from 0 to 200 mV_{rms}, and 1 bias signal for temperature readout, adjustable from 0 to 500 mV_{rms}. The temperature readout biases are to be divided from a common oscillator. Each bias shall be adjustable with 8-bit precision. The frequency of each bias shall be adjustable between 50 and 300 Hz, with a precision of 5 Hz.	JPL	TBD
BDA-DRCU-06	The DRCU will provide 15 commandable JFET source voltages with 256 levels. The range of Vss is from 0 V to –5 V.	JPL	TBD
BDA-DRCU-07	Vdd is to be adjustable from 1.5 to 4 V.	JPL	TBD
BDA-DRCU-08	Vdd and Vss lines individually must source 1 mA to 5 mA. Noise on Vss < 1 µV/√Hz, and noise on Vdd < 0.3 µV/√Hz within modulated band (50 – 300 Hz), measured at the DRCU DxMA connector.	JPL	TBD
BDA-DRCU-09	Each of the 15 Vdd and Vss supplies must be commandable ON/OFF for spectrometer and photometer independently, without overshoot. Each Vdd and Vss pair are turned on and off together.	JPL	TBD
BDA-DRCU-10	The DRCU will provide 2 double-wired JFET heater lines with adjustable amplitude and duration. The supplies must be able to provide 5 V and 25 mA (photometer), 3 V and 10 mA (spectrometer). Each heater line is commandable ON/OFF, with a minimum duration of 10 s.	JPL	TBD
BDA-DRCU-11	The common-mode rejection is –60 dB (50 – 300 Hz).	JPL	TBD
BDA-DRCU-12	The DRCU shall provide a dynamic range at the ADC sufficient to maintain the noise performance of the detectors under maximal signal conditions. This is estimated to be 16 ADC telemetry bits (TBC).	JPL	TBD
BDA-DRCU-13	The signal bandwidth of the photometer channels shall be 0.03 Hz to 5 Hz. The 5 Hz cutoff should have a precision of 1 %.	JPL	TBD

Detailed DRCU Requirements (2)

BDA-DRCU-14	The signal bandwidth of the spectrometer channels shall be 0.03 Hz to 25 Hz. The 25 Hz cutoff should have a precision of 1 %.	JPL	TBD
BDA-DRCU-15	The sampling of the photometer channels shall be synchronised with the bias, at a rate selectable between $\nu_{bias}/2$ to $\nu_{bias}/256$.	JPL	TBD
BDA-DRCU-16	The sampling of the spectrometer channels shall be synchronised with the bias, at a rate selectable between $\nu_{bias}/2$ to $\nu_{bias}/256$.	JPL	TBD
BDA-DRCU-17	The DRCU shall provide 2 adjustable power supplies for temperature control using a heater located at the 300 mK stage. This supply must provide at least 300 mV and 50 uA.	JPL	TBD
BDA-DRCU-18	Noise performance BDA-DRCU-01 shall be maintained under bias range 50 – 300 Hz.	JPL	TBD
BDA-DRCU-19	DRCU noise performance (BDA-DRCU-01) to be maintained under a warm electronics thermal drift of 1 K / hour (TBC).	JPL	TBD
BDA-DRCU-20	Thermal requirements on bias stability are implicit in BDA-DRCU-01.	JPL	TBD
BDA-DRCU-21	Thermal requirement on JFET power is dV/V < 500 ppm / K for Vdd and Vss.	JPL	TBD

BDA-DRCU-22	The DRCU shall not saturate at an input voltage as large as 11 (TBC) mV_{rms} at input (photometer), 17 (TBC) mV_{rms} at input (spectrometer). DRCU channels shall remain functional if one input signal goes to Vbias.	JPL	TBD
BDA-DRCU-23	Specification on isolation of power supplies, ripple, noise, EMC TBD. Specifications to flow from keeping the electrical interference and dissipation at the bolometer below fundamental noise as in Table 3-3-3.	JPL	TBD
BDA-DRCU-24	Bias, JFET power, and readout electronics for the spectrometer and photometer arrays are to run from separate dedicated power supplies, with independent, isolated grounds.	JPL	TBD
BDA-DRCU-25	The electrical cross-talk between channels in the DRCU shall be less than 0.05 % (TBC). The electrical cross-talk shall be verified by varying the input signal on one channel and measuring the response in other channels. The input signal level to each channel must be representative.	JPL	TBD
BDA-DRCU-26	Each signal input to the LIA module must be connected to ground by a diode. This provides both protection and allows the JFETs to turn on without the JFET heater.	JPL	TBD

Resource Requirements

	Achieved	Design	Requirement	Margin
BDA mass		560 g	600 g	20 %
JFET mass		235 g	305 g	20 %
RF filter mass		130 g	TBD g	20 %
BDA conduction	< 2.5 μW	2 μW	2 μW	20 %
JFET dissipation	< 11 mW	5.5 mW	5.5 mW	50 %
RF dissipation		0	0	-
Harness Thermal Conduction	-	-	-	-
BDA repeatability	50(x,y)/150 (z) μm		125/625 μm	-

Interfaces

Interface	Hardware Aspect	Agreed Documentation
Mechanical	BDA interface requirements	BDA-SSSD
	BDA	ICD
	JFET modules	ICD
	RF module	ICD
Optical	BDA	ICD
Thermal	BDA conduction	BDA-SSSD
	JFET dissipation	BDA-SSSD
	thermal stability requirement	BDA-SSSD
Environmental	Vibration levels and temperature	Test Plan
	Bake-out temperature	Test Plan
	EMI/EMC	Test Plan
Harnesses	Cryoharness wiring	HDD
	Mechanical requirement	BDA-SSSD
	JFET-BDA harness routing	ICD
Electrical	Warm electronics requirement	BDA-SSSD

Warm Electronics Interface

- There is no formal interface to JPL hardware
  - warm electronics interface to the instrument
- CEA is responsible for performance and delivery

However, the interface requires our interaction in the following ways:

- JPL sets requirements for the warm electronics in the BDA-SSSD
- JPL and CEA jointly agree to the Harness Definition Document and Grounding Network
- JPL and CEA have a memorandum of understanding that
  - EM models are developed and tested jointly at JPL
  - JPL approves the design of the CQM, PFM, and FS models
  - JPL witnesses performance of the CQM, PFM, and FS models
  - Performance is verified with an interface test dewar from JPL

2.5
SPIRE Work at the NASA/Herschel Science Center

Ken Ganga

NHSC Charter

- In its role as the NASA Herschel Science Center (NHSC), at IPAC will:
  - Provide the US community with science and observational support throughout all phases of the Herschel mission.
  - Serve as one of the advocates for the needs of the US-based observers.
  - Work to ensure the necessary resources and tools are available to take advantage of the scientific capabilities of the observatory.

Top Level NHSC Requirements

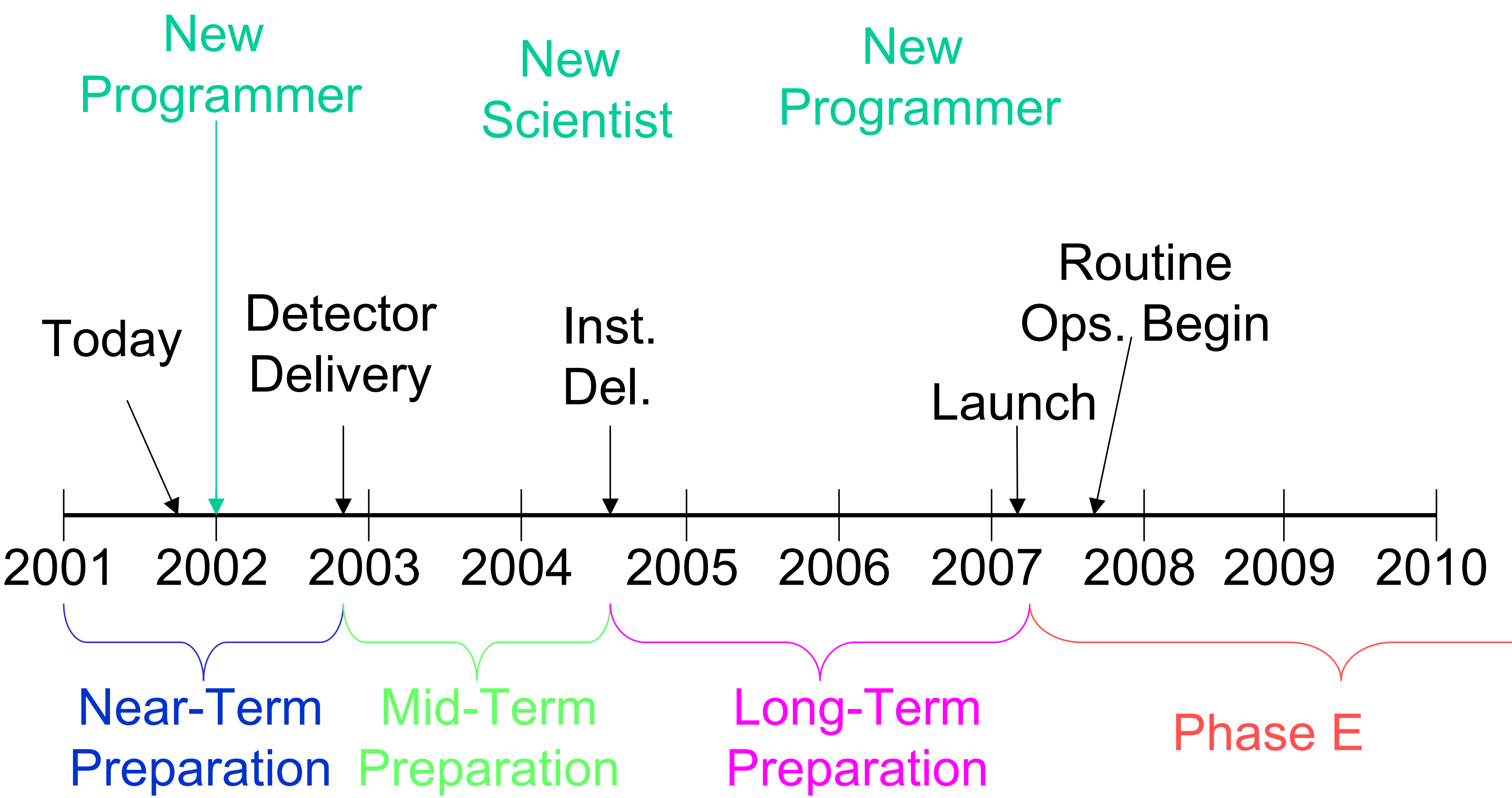
- Educate and engage the US astronomical community regarding the scientific opportunities of the Herschel mission
- Support the U.S. based Science Users with
  - Proposal Preparation
  - Observation Planning
  - Data Analysis
- Using: Expertise, Documentation, Software

Who will IPAC Serve?

- Observers
  - Open Time observers
  - U.S.-Based Guaranteed Time Observers
  - U.S.-Based Key Project Team members
  - International Observers (when possible)

- Any tools or insight we develop will be available to all Herschel users.

Time-Line



New Programmer
New Scientist
New Programmer
Today
Detector Delivery
Inst. Del.
Launch
Routine Ops. Begin
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Near-Term Preparation
Mid-Term Preparation
Long-Term Preparation
Phase E

Near-Term Efforts

- Near-Term Work focussed on detector testing at JPL
  - Will write software to help with detector characterization at JPL
  - Best way to start understanding the instrument
  - A real help to the US SPIRE team (we hope!)
  - Geographically sensible
- Maintain contact with consortium ("Liaison")
  - Bock has nominated Ganga as SPIRE associate
  - Involved in QLA definition
    - Via visits
    - Via e-mail, etc.
  - ISO and Planck connections are of real use here

Midterm Phase

- No real IPAC involvement in “Avionics Model”
  - We'll be busy anyway with detector characterization software
  - Different emphasis in SPIRE as compared to other instruments
- "Extended" European interaction beginning with “Cryogenic Qualification Model” testing.
  - Detector testing software may help form basis of instrument tests at RAL
  - Involvement in instrument-level tests desirable

Mid-Term Involvement

- Extended Involvement in the ICC begins
  - Software Development for Observation Planning
    - Understand science tools that will be available
    - Help define observation strategies that work for US observers
    - Focal Plane visualization
    - Background estimation
    - Interfaces with IRSA, NED, etc.
  - Data Analysis Software
    - The legacy of the detector testing
      - Instrument test help
    - Data extraction
    - Visualization
    - glitch detection
    - Filtering
    - map-making
    - noise estimation
    - source detection
    - etc.

Long-Term Efforts

User Support

– ISO support model used as a loose base
  - "Service Oriented"
  - It's improved by more intimate instrument involvement here and in Europe
  - Developing Remote Support
    – Makes it easier on us as well
  - With modifications to fit in with the HCSS concept

- IRAS / ISO / SIRTF / 2MASS / IRAS / Planck / IRSA / NED tools used where possible
  – All this data is at IPAC, and can be used synergistically
  – BOOMERanG experience will help as well
- Monitor Programs to see what's getting scheduled and what's working
  – Keep users continuously informed
- Detector/Instrument testing work helps form the flight "Quicklook"

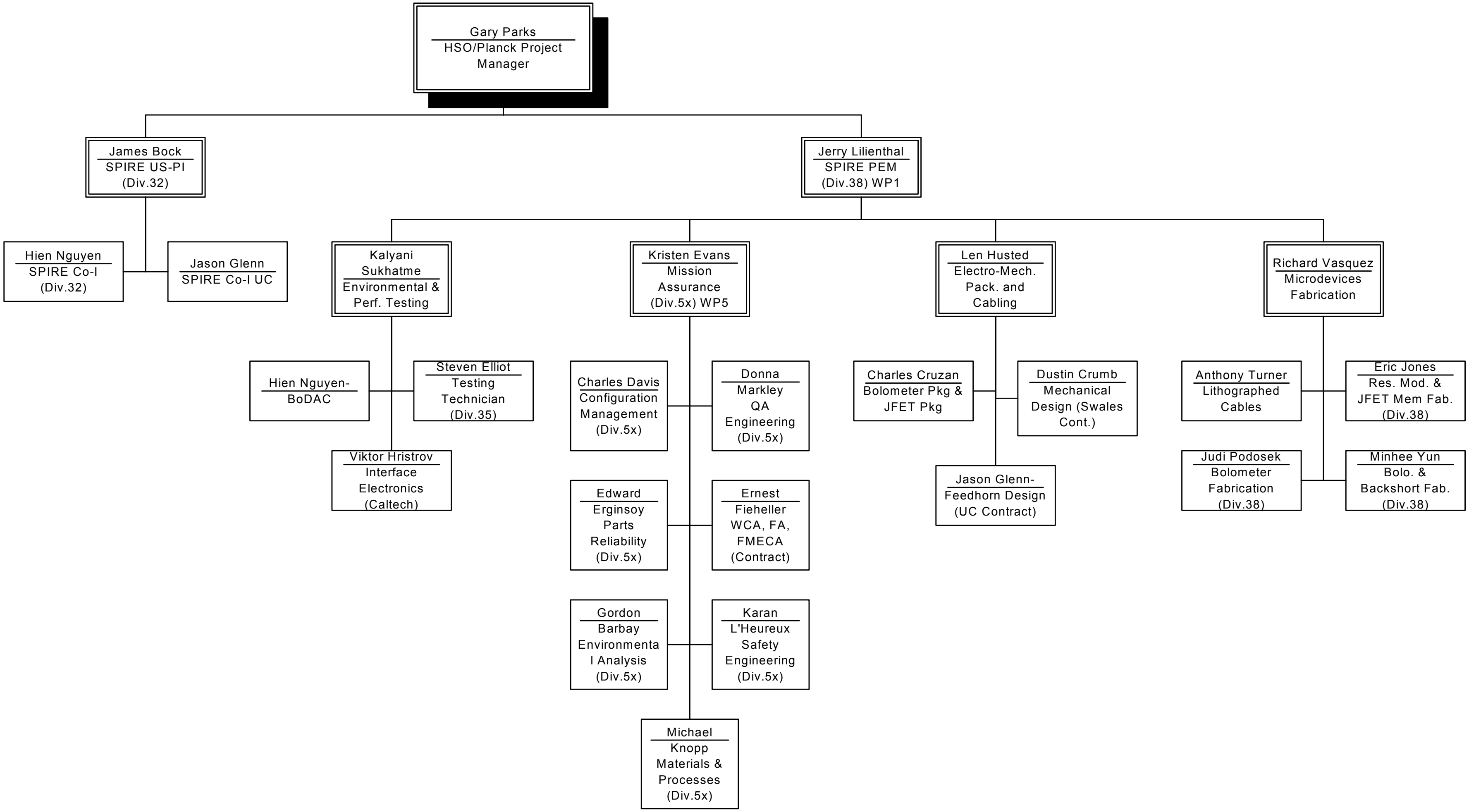
Current Status

- Getting involved
  - General understanding with US SPIRE team on near-term work
    - Near-term work is best for both IPAC and US SPIRE team
    - Near-term work will aid SPIRE team and US
  - General understanding with SPIRE team on IPAC role in near-term
    - We work with them, but no "deliveries"
- Very good relations with SPIRE team
  - In US
  - world-wide
- SPIRE is one of the leanest Herschel teams
  - Our involvement can make a real difference.
- Personal interest is high
- IPAC SPIRE Liaison is oversubscribed

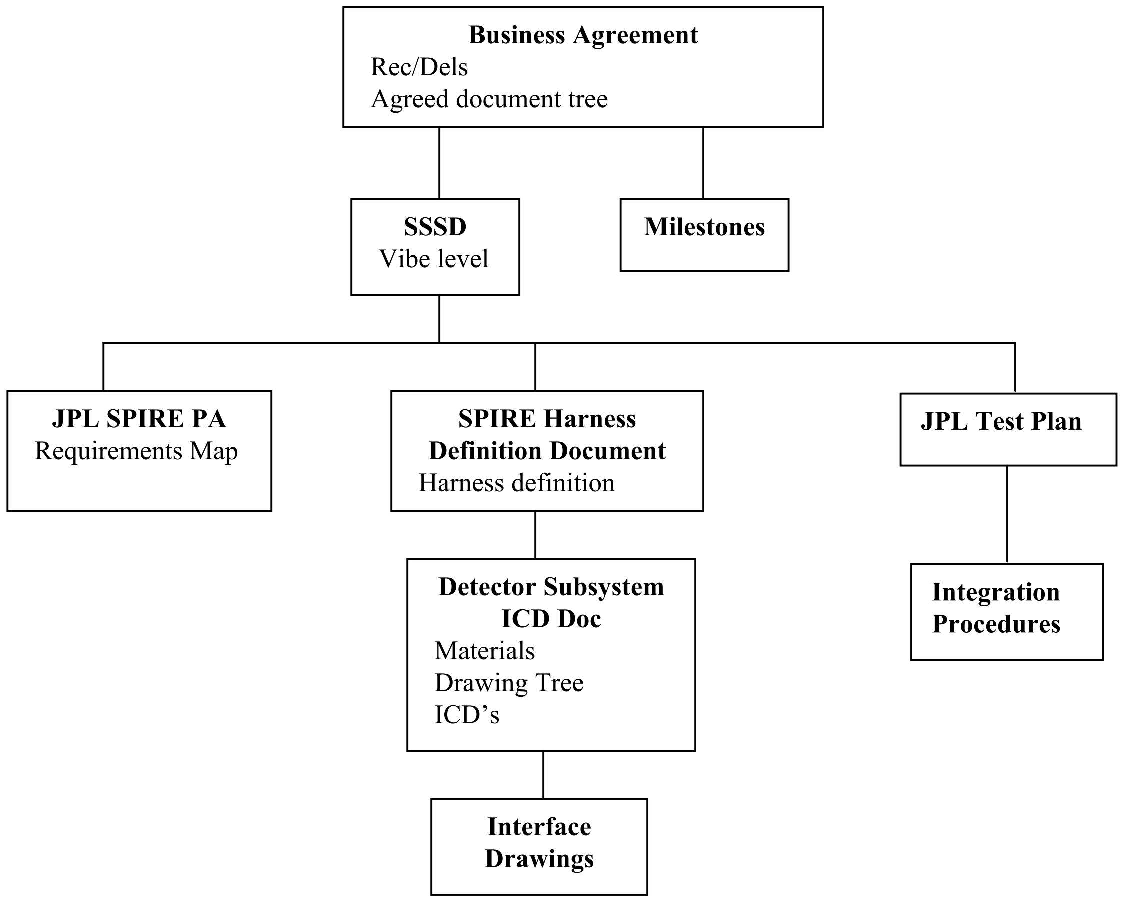
3.0
Programmatic Overview

Gerald Lilienthal

Work Breakdown Structure (WBS)



Agreed-To Documentation Tree

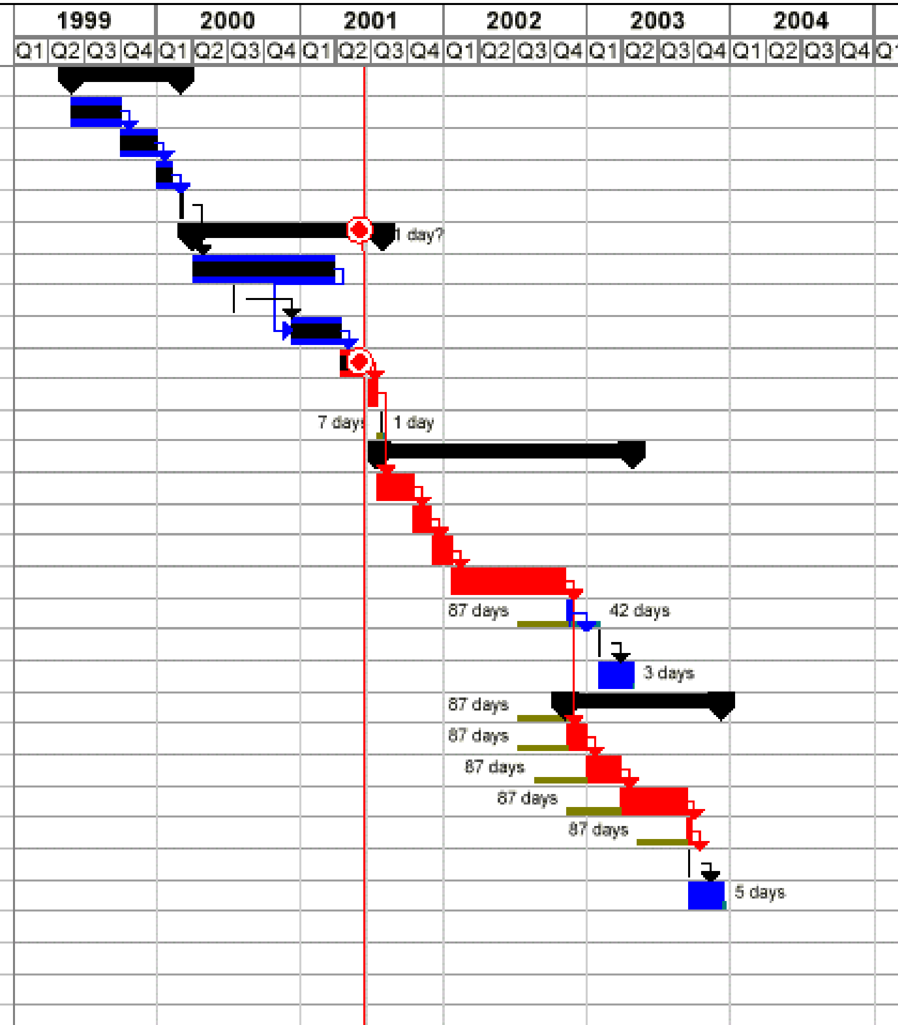


HSO/Planck Project

SPIRE Detector System

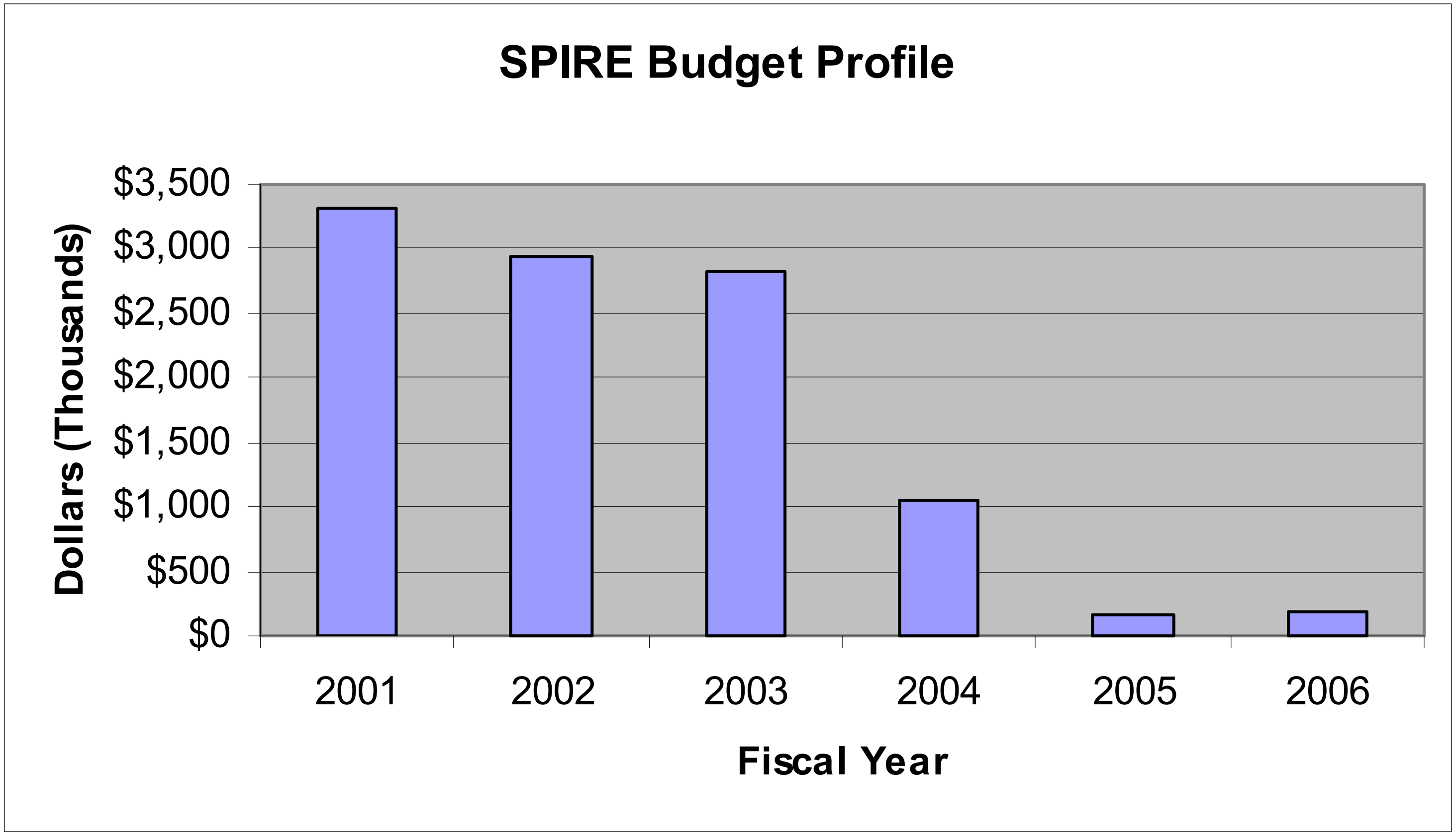
File: SPIRE 6-12-01

ID	Task Name
1	**Prototype Design and Testing Phase**
2	Design
3	Fabrication and Assembly
4	Testing and Data Reduction
5	Downselect Review
6	**Detail Design & EM Development Phase**
7	EM Design
8	PDR
9	EM Fabrication
10	EM Assembly
11	EM Testing & Data Reduction
12	CDR
13	**CQM Phase**
14	CQM/PFM/Spare Fabrication
15	CQM Assembly
16	CQM Environmental Testing & Data Reduction
17	CQM Performance Testing & Data Reduction
18	CQM HRCR & Shipment
19	CQM Required Date (Business Agreement)
20	CQM Integration Support
21	**PFM and Spare Phase**
22	PFM and Spare Assembly
23	PFM and Spare Environmental Testing and D.R.
24	PFM and Spare Performance Testing & D.R.
25	PFM and Spare HRCR and Shipment
26	PFM Required Date (Business Agreement)
27	PFM Integration Support
28	
29	
30	
31	



Page 1 of 23

Budget

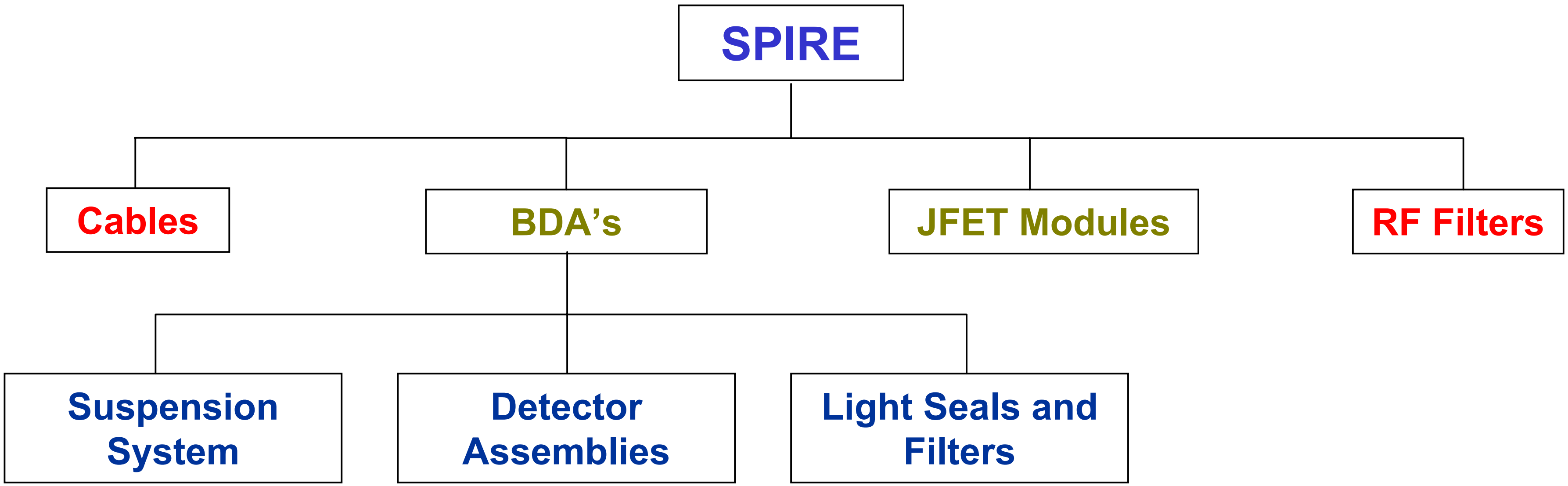


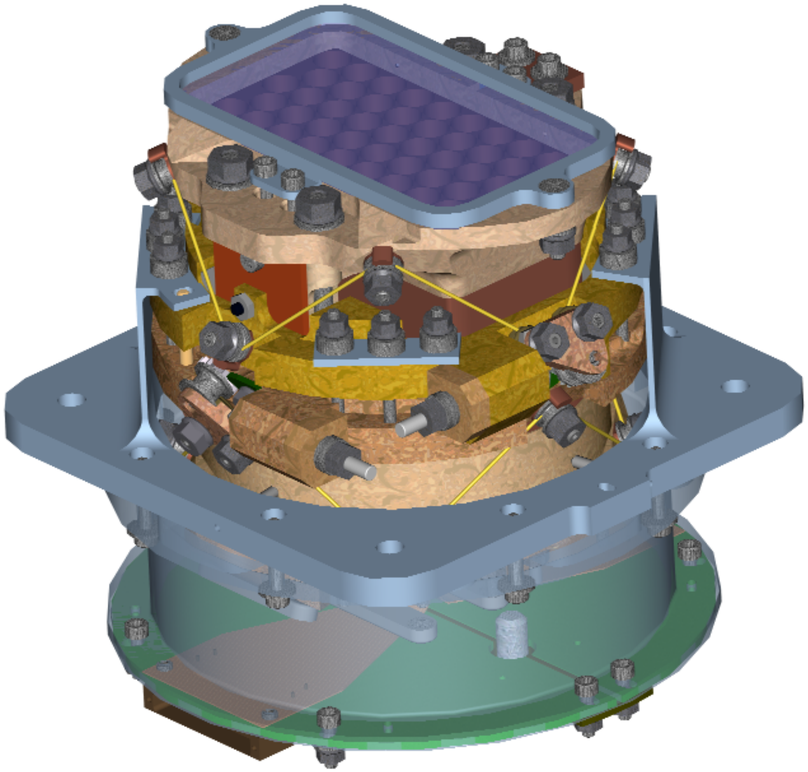
Note: Budget information will be presented in detail at the project CDR in September

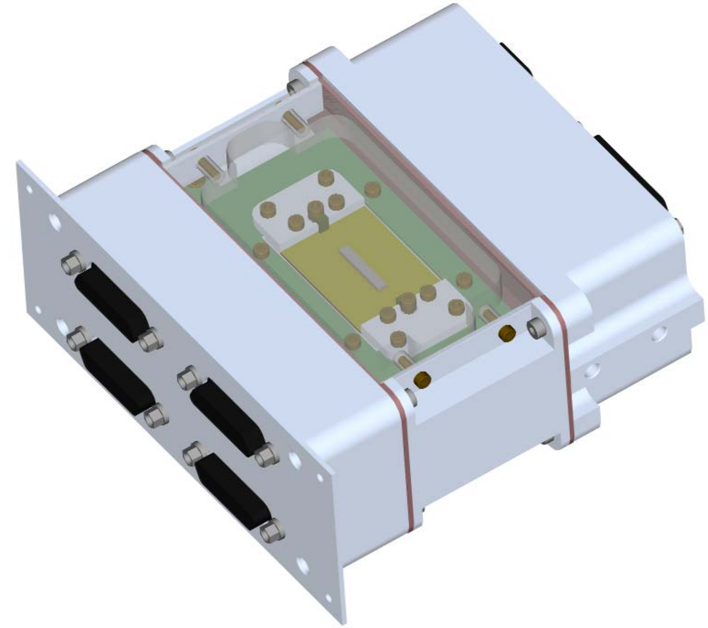
4.0
Interfaces

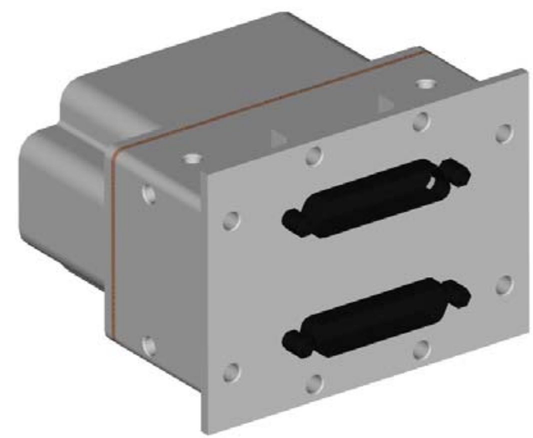
Dustin Crumb

SPIRE Subsystems







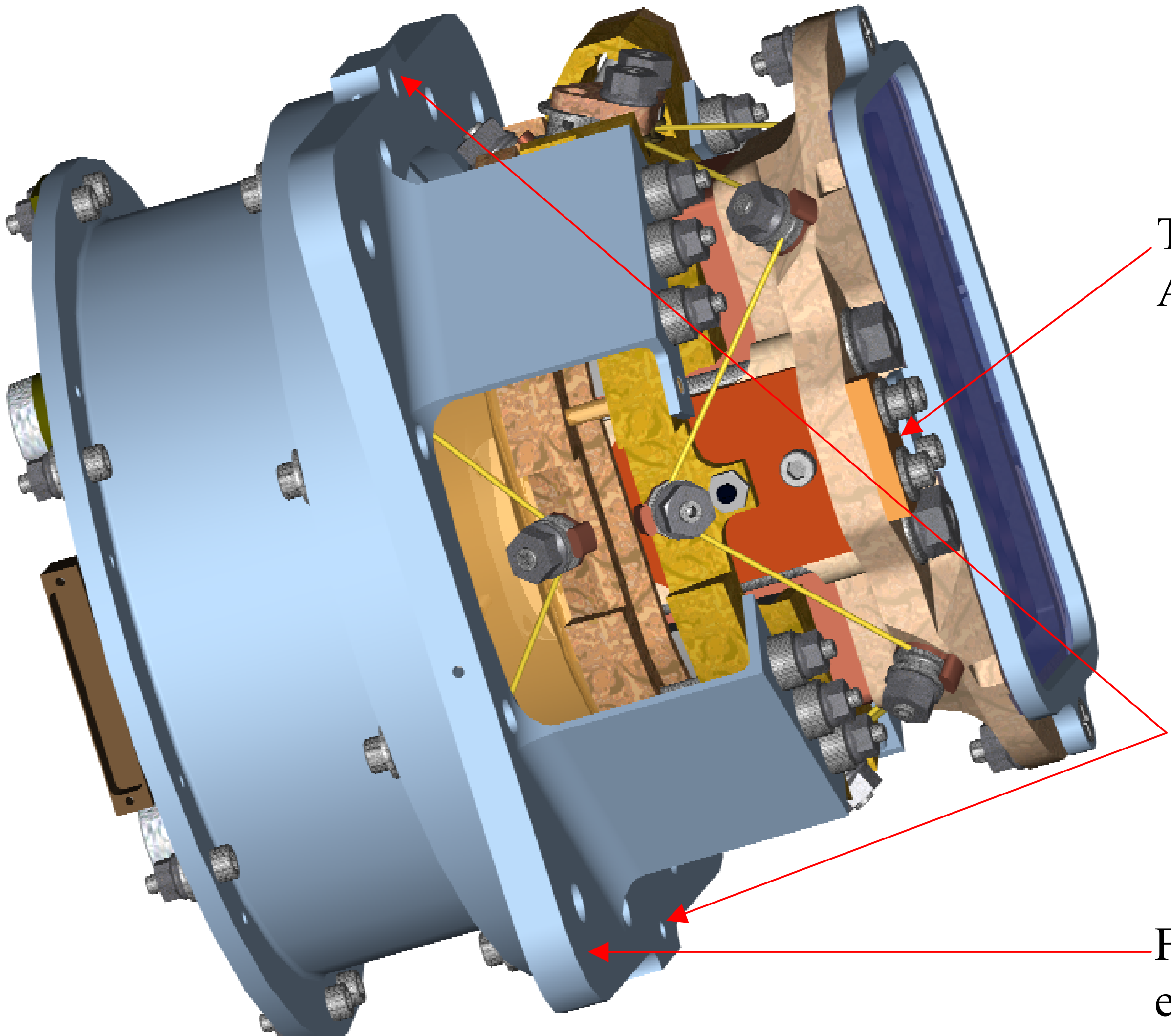


Interfaces

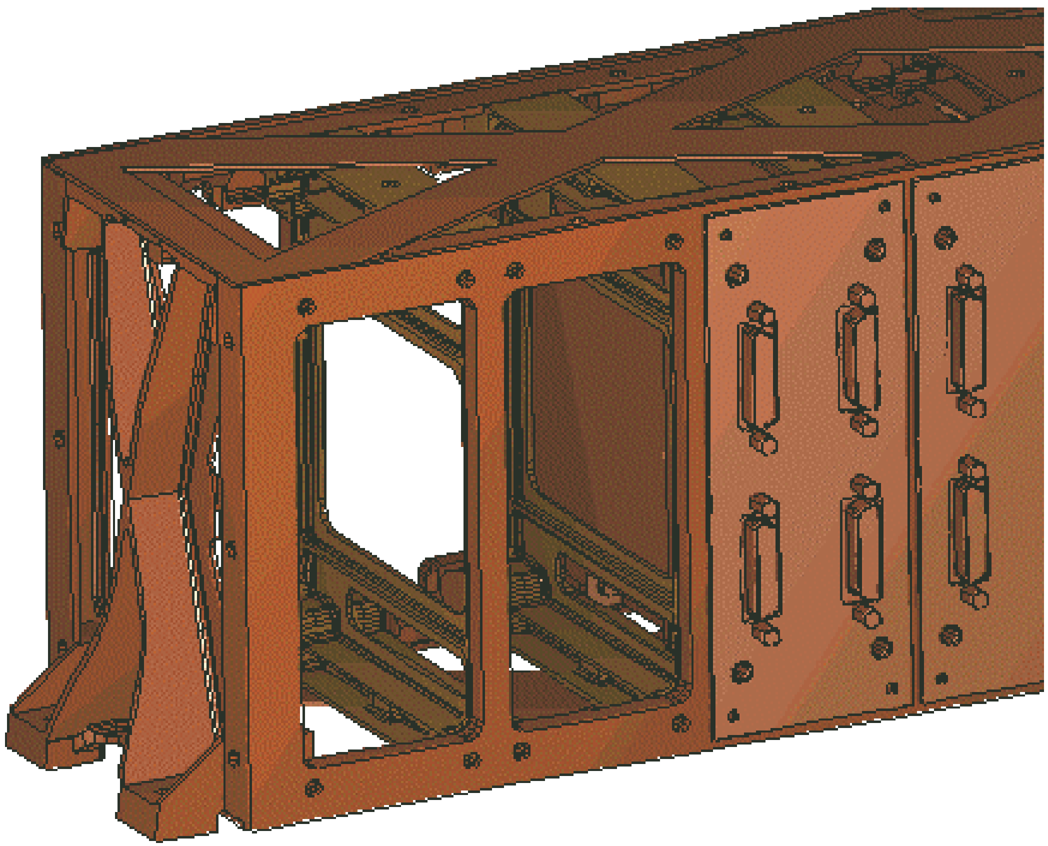
Details

Dustin Crumb

Array Design
Integration into the Instrument

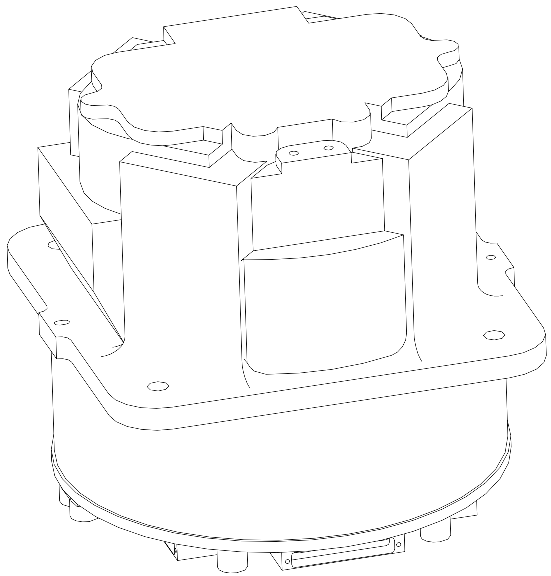


JFET Box Enclosure (RAL)



ICD’s

• 10209721- BDA	• In Check
• 10209722-JFET Module	• In Check
• 10209723-RF Filter	• In Check
• 10209725-Wiring Schematic	• In Check
• 10209726-Temperature Control	• Conceptual stage
• 10209727-Cold Cabling	• Awaiting input



GENERAL VIEW
REFERENCE ONLY

REVISIONS

LTR	ZONE	DESCRIPTION	CODE	DWN	CHK	STRUCT	MATL	THRM CONT			ENGR	DSGN SUPV	DATA MGT	RELEASE DATE
A		INITIAL RELEASE	CODE B	SEE TITLE BLOCK										

TABLE I

ARRAY	PART #	MASS	FOCUS	CGX	CGY	CGZ	CONNECTORS
P/LW	10209800-01	672	31.9	7	37.4	0.3	J05, J06
P/MW	10209800-02	615	33.3	10.2	37.5	0.4	J01, J02, J03, J04
P/SW	10209800-03	564	24.1	8.6	37.5	0.4	J01, J02, J03, J04, J05, J06
S/LW	10209800-04	482	35.9	5.8	37.6	0.6	J05
S/SW	10209800-05	466	25.7	37.6	7.8	0.5	J05,J06

6. ALL DIMENSIONS ARE BASED ON AN ASSEMBLY TEMPERATURE OF 20° C.

5. INDICATES CONNECTOR POSITION. CONNECTORS INSTALLED ARE STM 051 M6SN.

4. REFER TO TABLE I FOR DIFFERENCES BETWEEN DETECTOR ARRAYS.

3. ASSEMBLY REFERENCE DESIGNATOR, TITLE, PART NUMBER, REVISION LETTER, AND SERIAL NUMBER TO APPEAR AS SHOWN IN THIS AREA.

2. THIS IS THE INTERFACE CONTROL DRAWING FOR THE BOLOMETER DETECTOR ARRAY, JPL PART NUMBER 10209800. JPL DRAWING NUMBER 10209800 SHALL CONTAIN THE FOLLOWING NOTE: THIS ASSEMBLY MEETS THE INTERFACE REQUIREMENTS OF JPL INTERFACE CONTROL DRAWING 10209721.

1. THIS TECHNICAL DATA IS EXPORT CONTROLLED UNDER U.S. LAW AND IS BEING TRANSFERRED BY JPL TO PPARC PURSUANT TO THE NASA / PPARC LETTER OF AGREEMENT WHICH ENTERED INTO FORCE ON DECEMBER 2, 1999. THIS TECHNICAL DATA IS TRANSFERRED TO PPARC FOR USE EXCLUSIVELY ON THE NASA/PPARC SPIRE ON FIRST COOPERATIVE PROJECT, MAY NOT BE USED FOR ANY OTHER PURPOSE, AND SHALL NOT BE RE-TRANSFERRED OR DISCLOSED TO ANY OTHER PARTY WITHOUT THE PRIOR WRITTEN APPROVAL OF NASA.

NOTES: UNLESS OTHERWISE SPECIFIED

INTERFACE CONTROL DRAWING

QTY REQD	ITEM NO	REF DES	CAGE NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	MATERIAL OR NOTE	ZONE

PARTS LIST

MATERIAL

METRIC
THIRD ANGLE PROJECTION

NEXT ASSEMBLY	USED ON
	SPIRE

APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS

LINEAR TOLERANCES:

0–6	± 0.1
OVER 6–30	± 0.2
OVER 30–120	± 0.3
OVER 120–315	± 0.5
OVER 315–1000	± 0.8
OVER 1000	± 1.2

ANGULAR TOLERANCES:
± 0.5°

MACHINE FINISH (MICROMETERS) 3.2

DO NOT SCALE DRAWING
INTERPRET DWG PER ANSI Y14.100M

CONTRACT NO 960939
APPD ____ DATE ____
DWN J. PROEBSTLE 3/30/01
CHK
STRUCT
MATL
THRM CONT
ENGR
DSGN SUPV

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CA 91109
RELEASED THROUGH EDMG

BOLOMETER DETECTOR ARRAY MECHANICAL ICD SPIRE

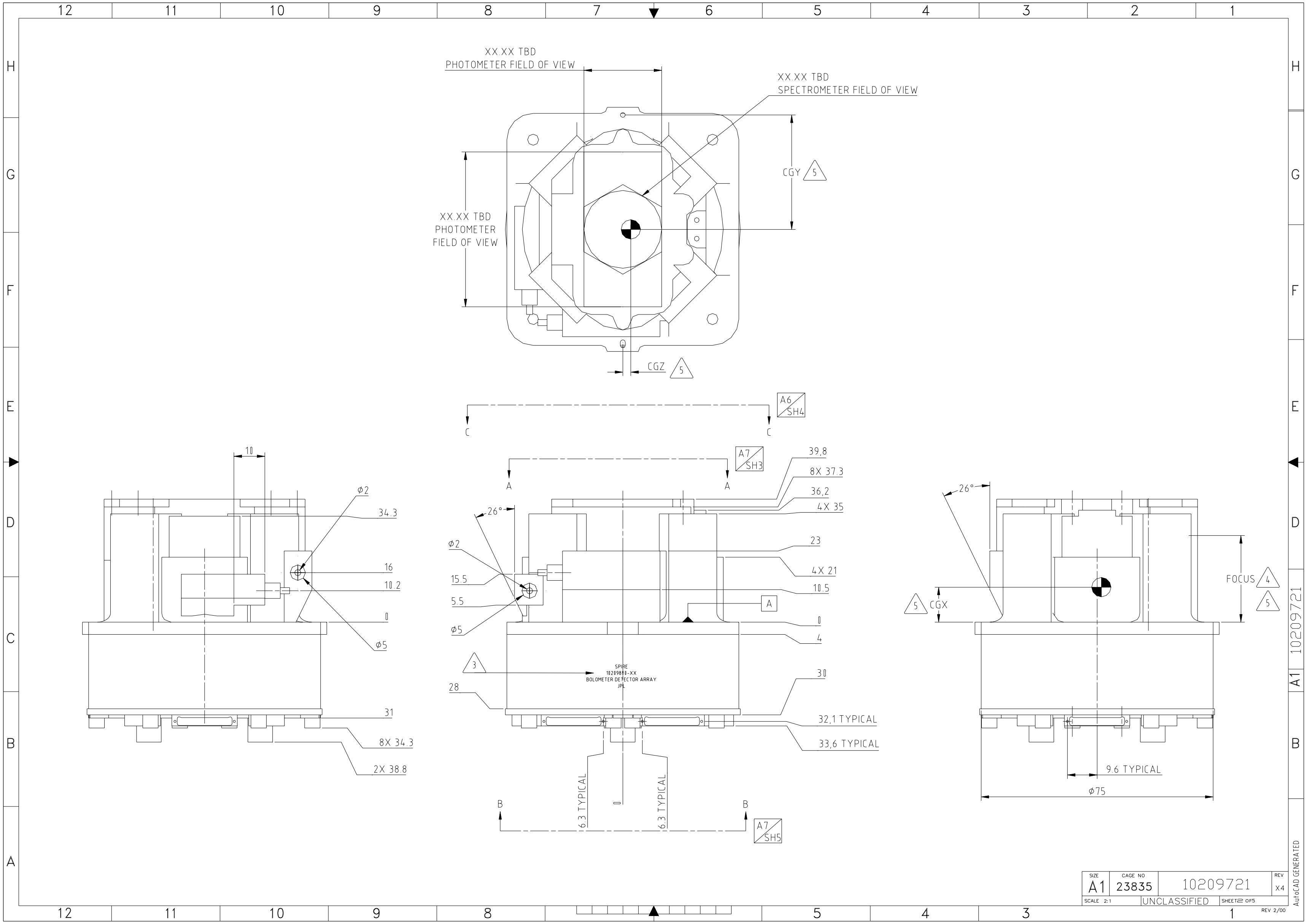
SIZE	CAGE NO		REV
A1	23835	10209721	X4

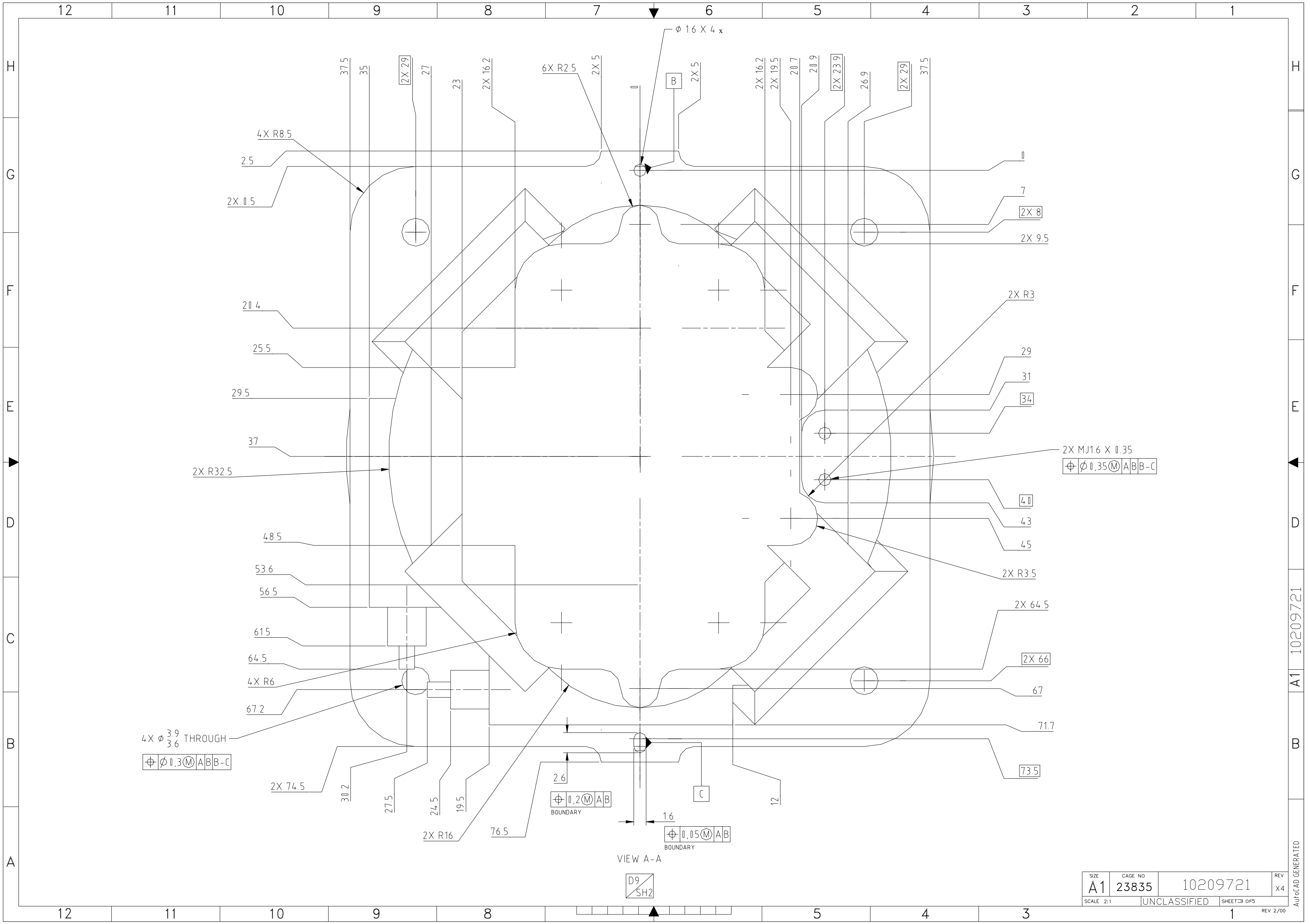
SCALE NONE | UNCLASSIFIED | SHEET 1 OF 5

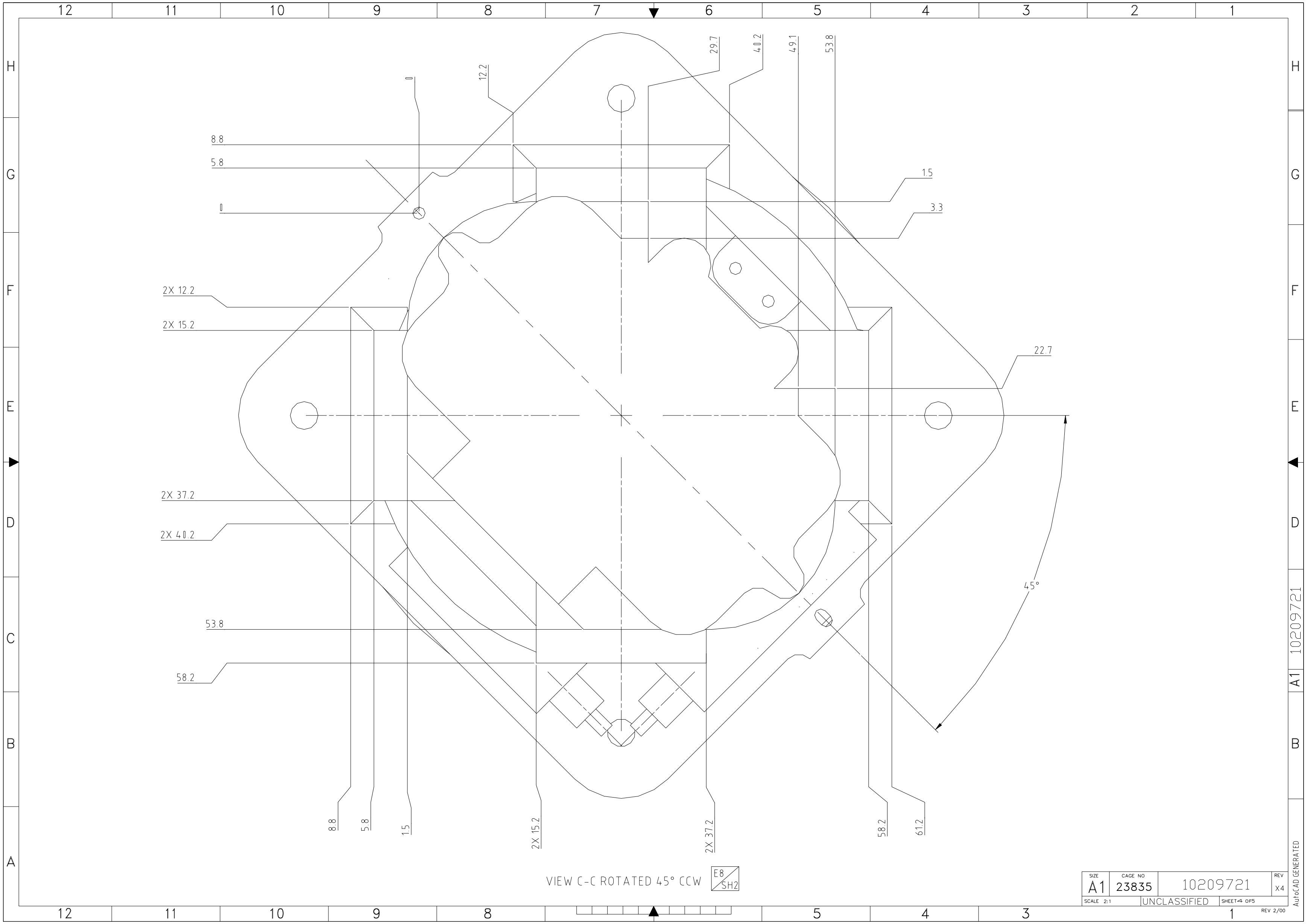
REV 2/00

A1 10209721

AutoCAD GENERATED

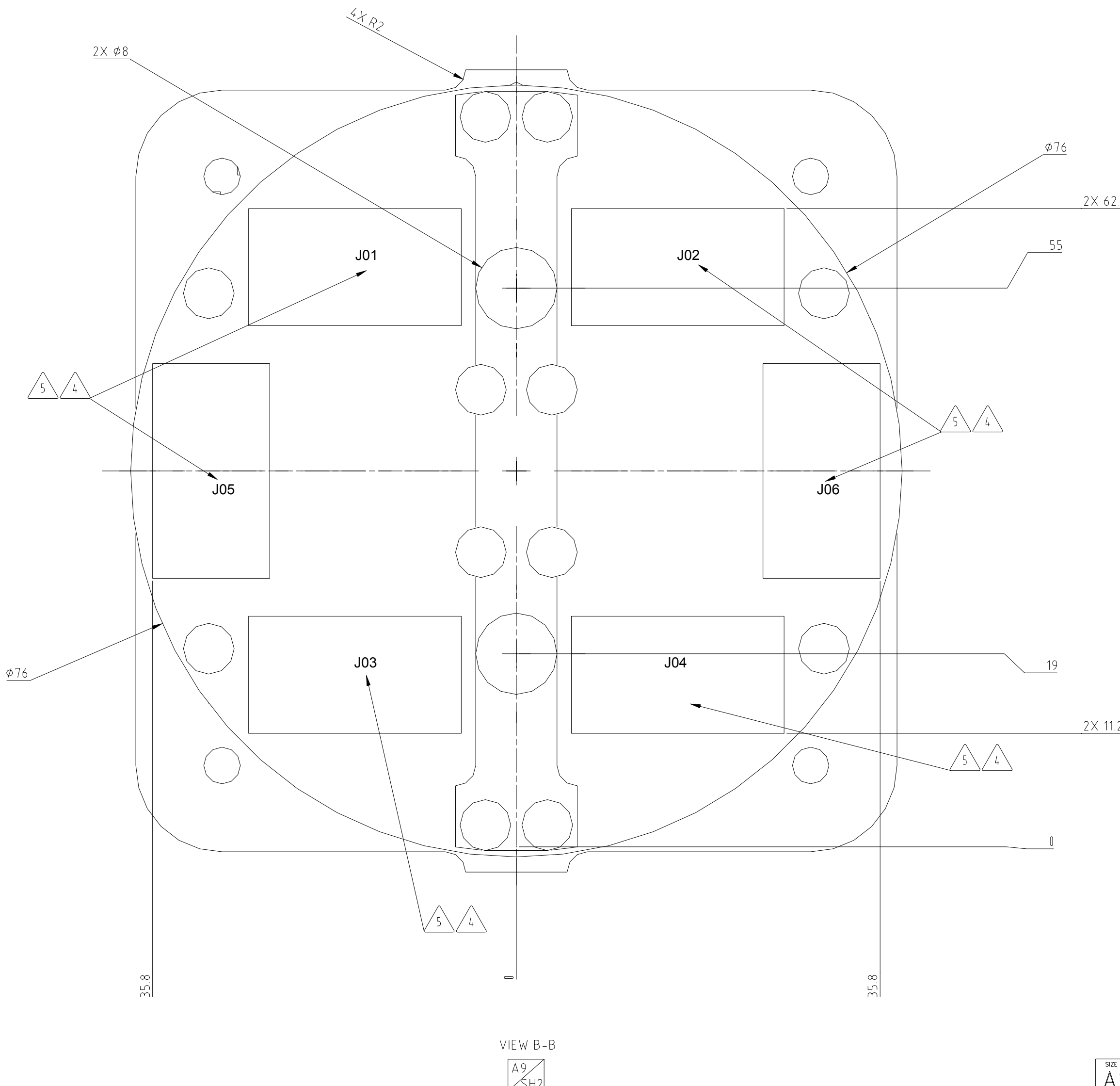

XX.XX TBD
PHOTOMETER FIELD OF VIEW
XX.XX TBD
SPECTROMETER FIELD OF VIEW
XX.XX TBD
PHOTOMETER
FIELD OF VIEW
CGY
CGZ
FOCUS
CGX
9.6 TYPICAL
φ75
32,1 TYPICAL
33,6 TYPICAL
6.3 TYPICAL
SIZE A1
CAGE NO 23835
10209721
REV X4
SCALE 2:1
UNCLASSIFIED
AutoCAD GENERATED


VIEW A-A
4X R8.5
2X R32.5
4X R6
2X R16
6X R2.5
2X R3
2X R3.5
2X MJ1.6 X 0.35
4X ⌀ 3.9/3.6 THROUGH
BOUNDARY
UNCLASSIFIED
10209721
23835
SCALE 2:1
AutoCAD GENERATED



VIEW C-C ROTATED 45° CCW
E8
SH2
45°
2X 12.2
2X 15.2
2X 37.2
2X 40.2
53.8
58.2
22.7
A1
23835
10209721
UNCLASSIFIED
SCALE 2:1
AutoCAD GENERATED

ALL CONNECTORS	
PIN #	PIN PURPOSE
1	SIGNAL 1A
2	SIGNAL 2A
3	SIGNAL 3A
4	SIGNAL 4A
5	SIGNAL 5A
6	SIGNAL 6A
7	SIGNAL 7A
8	SIGNAL 8A
9	SIGNAL 9A
10	SIGNAL 10A
11	SIGNAL 11A
12	SIGNAL 12A
13	SIGNAL 13A
14	SIGNAL 14A
15	SIGNAL 15A
16	SIGNAL 16A
17	SIGNAL 17A
18	SIGNAL 18A
19	SIGNAL 19A
20	SIGNAL 20A
21	SIGNAL 21A
22	SIGNAL 22A
23	SIGNAL 23A
24	SIGNAL 24A
25	SIGNAL V+
26	SIGNAL 1B
27	SIGNAL 2B
28	SIGNAL 3B
29	SIGNAL 4B
30	SIGNAL 5B
31	SIGNAL 6B
32	SIGNAL 7B
33	SIGNAL 8B
34	SIGNAL 9B
35	SIGNAL 10B
36	SIGNAL 11B
37	SIGNAL 12B
38	SIGNAL 13B
39	SIGNAL 14B
40	SIGNAL 15B
41	SIGNAL 16B
42	SIGNAL 17B
43	SIGNAL 18B
44	SIGNAL 19B
45	SIGNAL 20B
46	SIGNAL 21B
47	SIGNAL 22B
48	SIGNAL 23B
49	SIGNAL 24B
50	SIGNAL V-
51	SIGNAL BIAS GND



SIZE	CAGE NO		REV
A1	23835	10209721	X4
SCALE 2:1		UNCLASSIFIED	SHEET 5 OF 5

AutoCAD GENERATED

REV 2/00

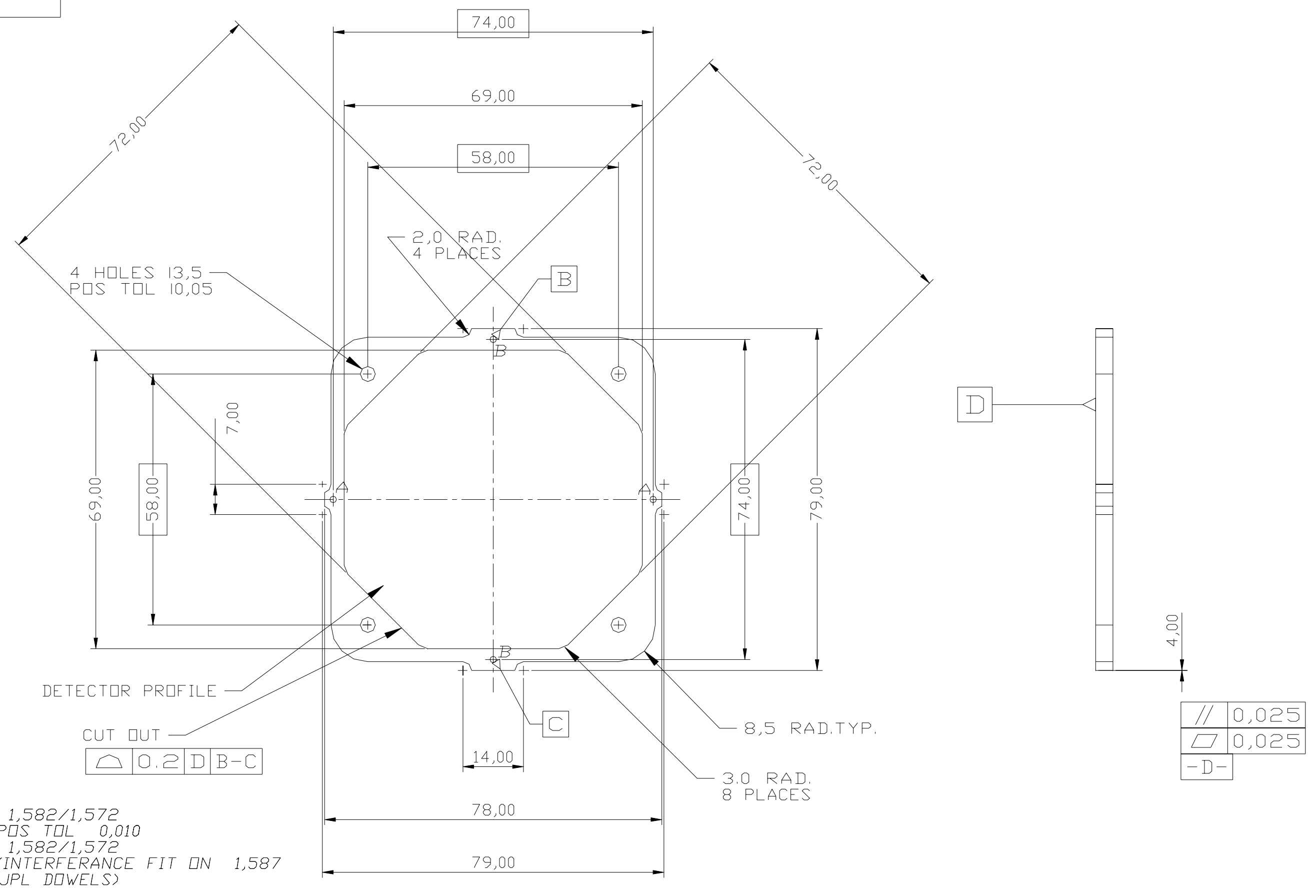
DRAWING No. A3 5264 911

THIRD ANGLE PROJECTION

DO NOT SCALE

USED ON

SPIRE (FIRST)



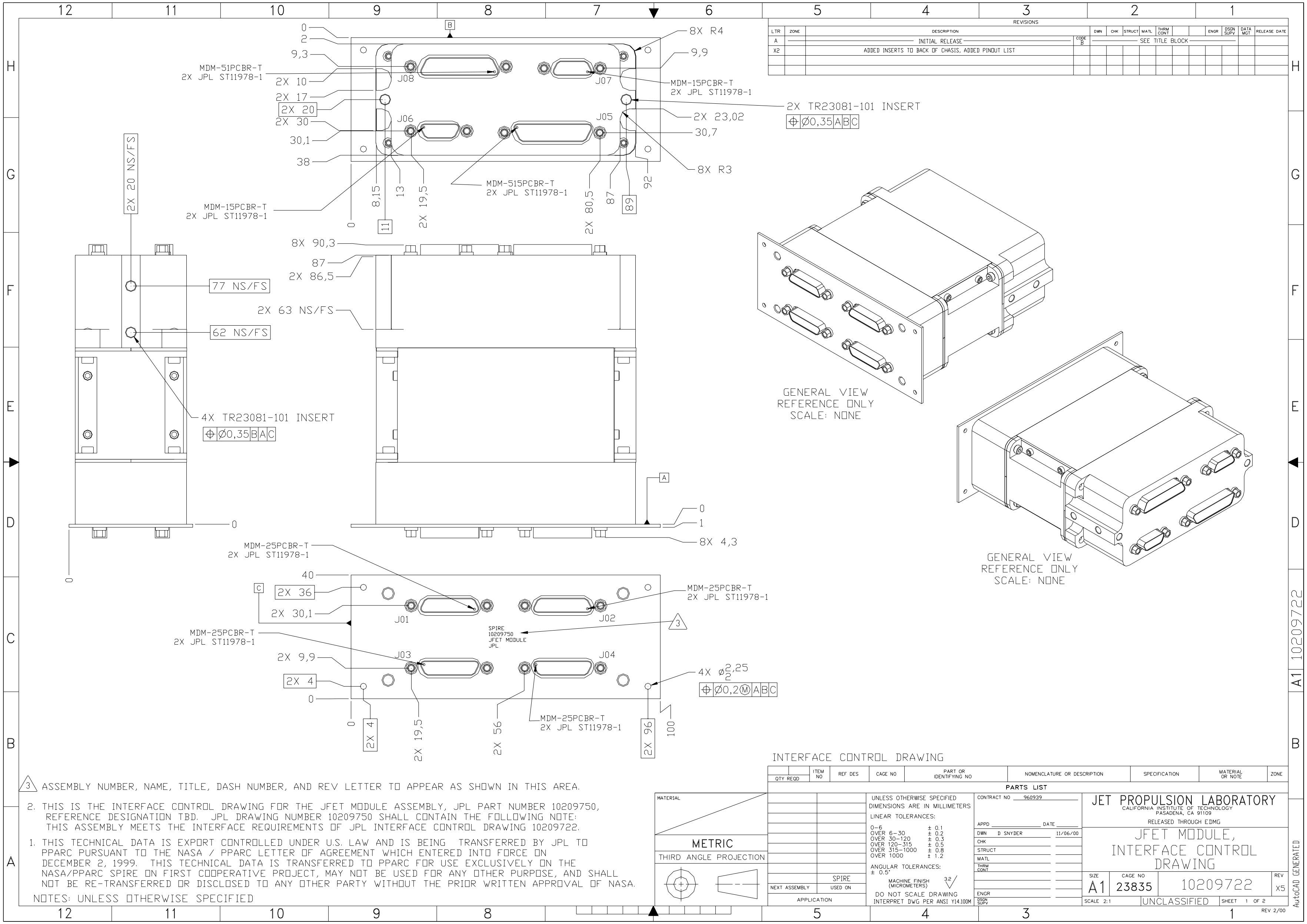
2 OFF HOLES "A" 1,582/1,572
POS TOL 0,010
2 OFF HOLES "B" 1,582/1,572
(INTERFERANCE FIT ON 1,587
JPL DOWELS)
POS TOL∅ 0,010

CHECKED				PROTECTIVE FINISH: ALOCROM 1200	MATERIAL & SPEC.: ALUM, ALLOY TO:- BS1470 6082T6	TOLERANCES UNLESS OTHERWISE STATED - LINEAR +/- 0.10; ANGULAR +/- 0°15'
TRACED	2	2/3/01	CUT OUT AND DOWEL HOLES MODIFIED TO JPL DIMS.			
DRAWN: AJC	ISSUE	DATE	AMENDMENT			
	1	19/12/00	ESTD. WT.	ACTL. WT.	DIMENSIONS IN mm	SCALE

DEPARTMENT OF SPACE AND CLIMATE PHYSICS
UNIVERSITY COLLEGE LONDON
MULLARD SPACE SCIENCE LABORATORY, HOLMBURY ST. MARY, DORKING, SURREY.

TITLE: DETECTOR INTERFACE ADAPTOR PLATE

DRAWING No. A3 5264 911



REVISIONS
LTR ZONE DESCRIPTION DWN CHK STRUCT MATL THRM CONT ENGR DSGN SUPV DATA MGT RELEASE DATE
A INITIAL RELEASE SEE TITLE BLOCK
X2 ADDED INSERTS TO BACK OF CHASIS, ADDED PINOUT LIST
8X R4
9,9
MDM-51PCBR-T
2X JPL ST11978-1
J08
J07
MDM-15PCBR-T
2X JPL ST11978-1
2X TR23081-101 INSERT
⌖ Ø0,35 A B C
J06
J05
2X 23,02
30,7
8X R3
MDM-515PCBR-T
2X JPL ST11978-1
MDM-15PCBR-T
2X JPL ST11978-1
2X 20 NS/FS
77 NS/FS
62 NS/FS
8X 90,3
2X 86,5
2X 63 NS/FS
4X TR23081-101 INSERT
⌖ Ø0,35 B A C
GENERAL VIEW
REFERENCE ONLY
SCALE: NONE
8X 4,3
MDM-25PCBR-T
2X JPL ST11978-1
J01
J02
SPIRE
10209750
JFET MODULE
JPL
J03
J04
4X Ø2,25
⌖ Ø0,2 Ⓜ A B C
A1 10209722
INTERFACE CONTROL DRAWING
QTY REQD ITEM NO REF DES CAGE NO PART OR IDENTIFYING NO NOMENCLATURE OR DESCRIPTION SPECIFICATION MATERIAL OR NOTE ZONE
PARTS LIST
3 ASSEMBLY NUMBER, NAME, TITLE, DASH NUMBER, AND REV LETTER TO APPEAR AS SHOWN IN THIS AREA.
2. THIS IS THE INTERFACE CONTROL DRAWING FOR THE JFET MODULE ASSEMBLY, JPL PART NUMBER 10209750, REFERENCE DESIGNATION TBD. JPL DRAWING NUMBER 10209750 SHALL CONTAIN THE FOLLOWING NOTE: THIS ASSEMBLY MEETS THE INTERFACE REQUIREMENTS OF JPL INTERFACE CONTROL DRAWING 10209722.
1. THIS TECHNICAL DATA IS EXPORT CONTROLLED UNDER U.S. LAW AND IS BEING TRANSFERRED BY JPL TO PPARC PURSUANT TO THE NASA / PPARC LETTER OF AGREEMENT WHICH ENTERED INTO FORCE ON DECEMBER 2, 1999. THIS TECHNICAL DATA IS TRANSFERRED TO PPARC FOR USE EXCLUSIVELY ON THE NASA/PPARC SPIRE ON FIRST COOPERATIVE PROJECT, MAY NOT BE USED FOR ANY OTHER PURPOSE, AND SHALL NOT BE RE-TRANSFERRED OR DISCLOSED TO ANY OTHER PARTY WITHOUT THE PRIOR WRITTEN APPROVAL OF NASA.
NOTES: UNLESS OTHERWISE SPECIFIED
MATERIAL
METRIC
THIRD ANGLE PROJECTION
NEXT ASSEMBLY USED ON
SPIRE
APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
LINEAR TOLERANCES:
0–6 ± 0.1
OVER 6–30 ± 0.2
OVER 30–120 ± 0.3
OVER 120–315 ± 0.5
OVER 315–1000 ± 0.8
OVER 1000 ± 1.2
ANGULAR TOLERANCES: ± 0.5°
MACHINE FINISH (MICROMETERS) 3.2
DO NOT SCALE DRAWING
INTERPRET DWG PER ANSI Y14.100M
CONTRACT NO 960939
APPD DATE
DWN D SNYDER 11/06/00
CHK
STRUCT
MATL
THRM CONT
ENGR
DSGN SUPV
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CA 91109
RELEASED THROUGH EDMG
JFET MODULE, INTERFACE CONTROL DRAWING
SIZE A1 CAGE NO 23835 10209722 REV X5
SCALE 2:1 UNCLASSIFIED SHEET 1 OF 2
REV 2/00
AutoCAD GENERATED

J01 JFET OUTPUT 1, SIGNALS 1-12

PIN #	PIN PURPOSE
1	SIGNAL 13A
2	SIGNAL 14A
3	SIGNAL 15A
4	SIGNAL 16A
5	SIGNAL 17A
6	SIGNAL 18A
7	SIGNAL 19A
8	SIGNAL 20A
9	SIGNAL 21A
10	SIGNAL 22A
11	SIGNAL 23A
12	SIGNAL 24A
13	FPU GND
14	SIGNAL 13B
15	SIGNAL 14B
16	SIGNAL 15B
17	SIGNAL 16B
18	SIGNAL 17B
19	SIGNAL 18B
20	SIGNAL 19B
21	SIGNAL 20B
22	SIGNAL 21B
23	SIGNAL 22B
24	SIGNAL 23B
25	SIGNAL 24B

J02 JFET OUTPUT 1, SIGNALS 13-14

PIN #	PIN PURPOSE
1	SIGNAL 1A
2	SIGNAL 2A
3	SIGNAL 3A
4	SIGNAL 4A
5	SIGNAL 5A
6	SIGNAL 6A
7	SIGNAL 7A
8	SIGNAL 8A
9	SIGNAL 9A
10	SIGNAL 10A
11	SIGNAL 11A
12	SIGNAL 12A
13	FPU GND
14	SIGNAL 1B
15	SIGNAL 2B
16	SIGNAL 3B
17	SIGNAL 4B
18	SIGNAL 5B
19	SIGNAL 6B
20	SIGNAL 7B
21	SIGNAL 8B
22	SIGNAL 9B
23	SIGNAL 10B
24	SIGNAL 11B
25	SIGNAL 12B

J03 JFET OUTPUT 2, SIGNALS 1-12

PIN #	PIN PURPOSE
1	SIGNAL 13A
2	SIGNAL 14A
3	SIGNAL 15A
4	SIGNAL 16A
5	SIGNAL 17A
6	SIGNAL 18A
7	SIGNAL 19A
8	SIGNAL 20A
9	SIGNAL 21A
10	SIGNAL 22A
11	SIGNAL 23A
12	SIGNAL 24A
13	FPU GND
14	SIGNAL 13B
15	SIGNAL 14B
16	SIGNAL 15B
17	SIGNAL 16B
18	SIGNAL 17B
19	SIGNAL 18B
20	SIGNAL 19B
21	SIGNAL 20B
22	SIGNAL 21B
23	SIGNAL 22B
24	SIGNAL 23B
25	SIGNAL 24B

J04 JFET OUTPUT 2, SIGNALS 13-14

PIN #	PIN PURPOSE
1	SIGNAL 1A
2	SIGNAL 2A
3	SIGNAL 3A
4	SIGNAL 4A
5	SIGNAL 5A
6	SIGNAL 6A
7	SIGNAL 7A
8	SIGNAL 8A
9	SIGNAL 9A
10	SIGNAL 10A
11	SIGNAL 11A
12	SIGNAL 12A
13	FPU GND
14	SIGNAL 1B
15	SIGNAL 2B
16	SIGNAL 3B
17	SIGNAL 4B
18	SIGNAL 5B
19	SIGNAL 6B
20	SIGNAL 7B
21	SIGNAL 8B
22	SIGNAL 9B
23	SIGNAL 10B
24	SIGNAL 11B
25	SIGNAL 12B

J05 JFET INPUT 1

PIN #	PIN PURPOSE
1	VOLTAGE +
2	VOLTAGE -
3	SIGNAL 24A
4	SIGNAL 24B
5	SIGNAL 21A
6	SIGNAL 21B
7	SIGNAL 18A
8	SIGNAL 18B
9	SIGNAL 15A
10	SIGNAL 15B
11	SIGNAL 12A
12	SIGNAL 12B
13	SIGNAL 6A
14	SIGNAL 6B
15	SIGNAL 3A
16	SIGNAL 3B
17	SIGNAL 2A
18	SIGNAL 2B
19	BIAS GND
20	SIGNAL 23A
21	SIGNAL 22A
22	SIGNAL 20A
23	SIGNAL 19A
24	SIGNAL 17A
25	SIGNAL 16A
26	SIGNAL 14A
27	SIGNAL 13A
28	SIGNAL 11A
29	SIGNAL 10A
30	SIGNAL 9A
31	SIGNAL 8A
32	SIGNAL 7A
33	SIGNAL 5A
34	SIGNAL 4A
35	SIGNAL 1A
36	SIGNAL 23B
37	SIGNAL 22B
38	SIGNAL 20B
39	SIGNAL 19B
40	SIGNAL 17B
41	SIGNAL 16B
42	SIGNAL 14B
43	SIGNAL 13B
44	SIGNAL 11B
45	SIGNAL 10B
46	SIGNAL 9B
47	SIGNAL 8B
48	SIGNAL 7B
49	SIGNAL 5B
50	SIGNAL 4B
51	SIGNAL 1B

J06 JFET SERVICE 1

PIN #	PIN PURPOSE
1	Vss
2	V+
3	H+
4	V-
5	V-
6	H+
7	V+
8	Vss
9	BIAS GND
10	Vdd
11	H-
12	
13	H-
14	Vdd
15	BIAS GND

J07 JFET SERVICE 2

PIN #	PIN PURPOSE
1	Vss
2	V+
3	H+
4	V-
5	V-
6	H+
7	V+
8	Vss
9	BIAS GND
10	Vdd
11	H-
12	
13	H-
14	Vdd
15	BIAS GND

J08 JFET INPUT 2

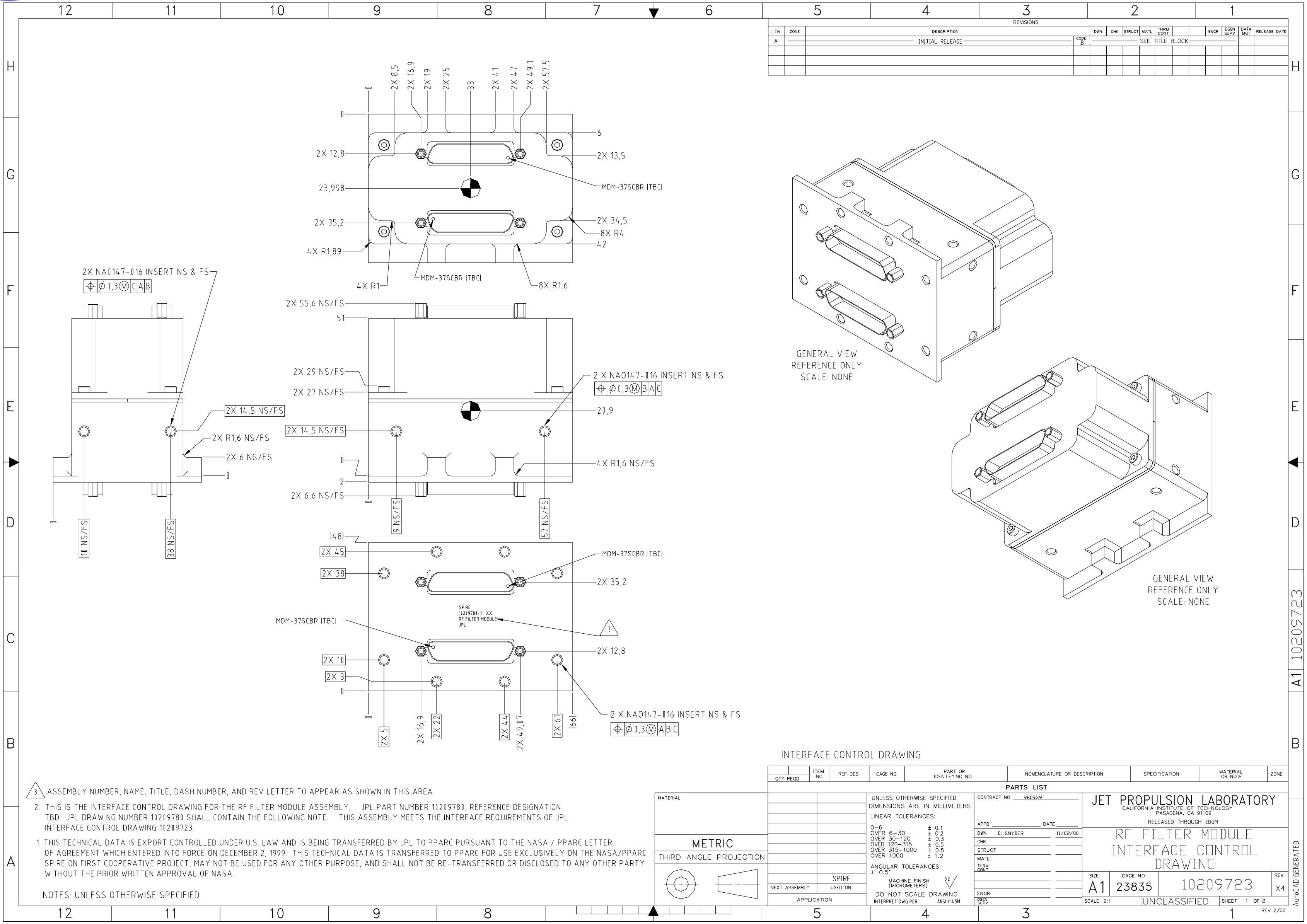
PIN #	PIN PURPOSE
1	VOLTAGE +
2	VOLTAGE -
3	SIGNAL 24A
4	SIGNAL 24B
5	SIGNAL 21A
6	SIGNAL 21B
7	SIGNAL 18A
8	SIGNAL 18B
9	SIGNAL 15A
10	SIGNAL 15B
11	SIGNAL 12A
12	SIGNAL 12B
13	SIGNAL 6A
14	SIGNAL 6B
15	SIGNAL 3A
16	SIGNAL 3B
17	SIGNAL 2A
18	SIGNAL 2B
19	BIAS GND
20	SIGNAL 23A
21	SIGNAL 22A
22	SIGNAL 20A
23	SIGNAL 19A
24	SIGNAL 17A
25	SIGNAL 16A
26	SIGNAL 14A
27	SIGNAL 13A
28	SIGNAL 11A
29	SIGNAL 10A
30	SIGNAL 9A
31	SIGNAL 8A
32	SIGNAL 7A
33	SIGNAL 5A
34	SIGNAL 4A
35	SIGNAL 1A
36	SIGNAL 23B
37	SIGNAL 22B
38	SIGNAL 20B
39	SIGNAL 19B
40	SIGNAL 17B
41	SIGNAL 16B
42	SIGNAL 14B
43	SIGNAL 13B
44	SIGNAL 11B
45	SIGNAL 10B
46	SIGNAL 9B
47	SIGNAL 8B
48	SIGNAL 7B
49	SIGNAL 5B
50	SIGNAL 4B
51	SIGNAL 1B

SIZE	CAGE NO		REV
A1	23835	10209722	X5
SCALE NONE		UNCLASSIFIED	SHEET 2 OF 2

A1 10209722

AutoCAD GENERATED

REV 2/00



MDM-37SCBR (TBC)
2X NA0147-016 INSERT NS & FS
GENERAL VIEW
REFERENCE ONLY
SCALE: NONE
INTERFACE CONTROL DRAWING
REVISIONS
INITIAL RELEASE
SEE TITLE BLOCK
PARTS LIST
SPIRE
10209780-1 XX
RF FILTER MODULE
JPL
3 ASSEMBLY NUMBER, NAME, TITLE, DASH NUMBER, AND REV LETTER TO APPEAR AS SHOWN IN THIS AREA.
2. THIS IS THE INTERFACE CONTROL DRAWING FOR THE RF FILTER MODULE ASSEMBLY, JPL PART NUMBER 10209780, REFERENCE DESIGNATION TBD. JPL DRAWING NUMBER 10209780 SHALL CONTAIN THE FOLLOWING NOTE: THIS ASSEMBLY MEETS THE INTERFACE REQUIREMENTS OF JPL INTERFACE CONTROL DRAWING 10209723.
1. THIS TECHNICAL DATA IS EXPORT CONTROLLED UNDER U.S. LAW AND IS BEING TRANSFERRED BY JPL TO PPARC PURSUANT TO THE NASA / PPARC LETTER OF AGREEMENT WHICH ENTERED INTO FORCE ON DECEMBER 2, 1999. THIS TECHNICAL DATA IS TRANSFERRED TO PPARC FOR USE EXCLUSIVELY ON THE NASA/PPARC SPIRE ON FIRST COOPERATIVE PROJECT, MAY NOT BE USED FOR ANY OTHER PURPOSE, AND SHALL NOT BE RE-TRANSFERRED OR DISCLOSED TO ANY OTHER PARTY WITHOUT THE PRIOR WRITTEN APPROVAL OF NASA.
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METRIC
THIRD ANGLE PROJECTION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
DO NOT SCALE DRAWING
CONTRACT NO 960939
DWN D. SNYDER 11/02/00
JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CA 91109
RF FILTER MODULE
INTERFACE CONTROL
DRAWING
A1 23835 10209723
SCALE 2:1 UNCLASSIFIED SHEET 1 OF 2

J01 RF OUTPUT 1

PIN #	PIN PURPOSE
1	OUTPUT 1
2	OUTPUT 2
3	OUTPUT 3
4	OUTPUT 4
5	OUTPUT 5
6	OUTPUT 6
7	OUTPUT 7
8	OUTPUT 8
9	OUTPUT 9
10	OUTPUT 10
11	OUTPUT 11
12	OUTPUT 12
13	OUTPUT 13
14	OUTPUT 14
15	OUTPUT 15
16	OUTPUT 16
17	OUTPUT 17
18	OUTPUT 18
19	OUTPUT 19
20	OUTPUT 20
21	OUTPUT 21
22	OUTPUT 22
23	OUTPUT 23
24	OUTPUT 24
25	OUTPUT 25
26	OUTPUT 26
27	OUTPUT 27
28	OUTPUT 28
29	OUTPUT 29
30	OUTPUT 30
31	OUTPUT 31
32	OUTPUT 32
33	OUTPUT 33
34	OUTPUT 34
35	OUTPUT 35
36	OUTPUT 36
37	OUTPUT 37

J02 RF OUTPUT 2

PIN #	PIN PURPOSE
1	OUTPUT 38
2	OUTPUT 39
3	OUTPUT 40
4	OUTPUT 41
5	OUTPUT 42
6	OUTPUT 43
7	OUTPUT 44
8	OUTPUT 45
9	OUTPUT 46
10	OUTPUT 47
11	OUTPUT 48
12	OUTPUT 49
13	OUTPUT 50
14	OUTPUT 51
15	OUTPUT 52
16	OUTPUT 53
17	OUTPUT 54
18	OUTPUT 55
19	OUTPUT 56
20	OUTPUT 57
21	OUTPUT 58
22	OUTPUT 59
23	OUTPUT 60
24	OUTPUT 61
25	OUTPUT 62
26	OUTPUT 63
27	OUTPUT 64
28	OUTPUT 65
29	OUTPUT 66
30	OUTPUT 67
31	OUTPUT 68
32	OUTPUT 69
33	OUTPUT 70
34	OUTPUT 71
35	OUTPUT 72
36	OUTPUT 73
37	OUTPUT 74

J05 RF INPUT 1

PIN #	PIN PURPOSE
1	INPUT 1
2	INPUT 2
3	INPUT 3
4	INPUT 4
5	INPUT 5
6	INPUT 6
7	INPUT 7
8	INPUT 8
9	INPUT 9
10	INPUT 10
11	INPUT 11
12	INPUT 12
13	INPUT 13
14	INPUT 14
15	INPUT 15
16	INPUT 16
17	INPUT 17
18	INPUT 18
19	INPUT 19
20	INPUT 20
21	INPUT 21
22	INPUT 22
23	INPUT 23
24	INPUT 24
25	INPUT 25
26	INPUT 26
27	INPUT 27
28	INPUT 28
29	INPUT 29
30	INPUT 30
31	INPUT 31
32	INPUT 32
33	INPUT 33
34	INPUT 34
35	INPUT 35
36	INPUT 36
37	INPUT 37

J05 RF INPUT 2

PIN #	PIN PURPOSE
1	INPUT 38
2	INPUT 39
3	INPUT 40
4	INPUT 41
5	INPUT 42
6	INPUT 43
7	INPUT 44
8	INPUT 45
9	INPUT 46
10	INPUT 47
11	INPUT 48
12	INPUT 49
13	INPUT 50
14	INPUT 51
15	INPUT 52
16	INPUT 53
17	INPUT 54
18	INPUT 55
19	INPUT 56
20	INPUT 57
21	INPUT 58
22	INPUT 59
23	INPUT 60
24	INPUT 61
25	INPUT 62
26	INPUT 63
27	INPUT 64
28	INPUT 65
29	INPUT 66
30	INPUT 67
31	INPUT 68
32	INPUT 69
33	INPUT 70
34	INPUT 71
35	INPUT 72
36	INPUT 73
37	INPUT 74

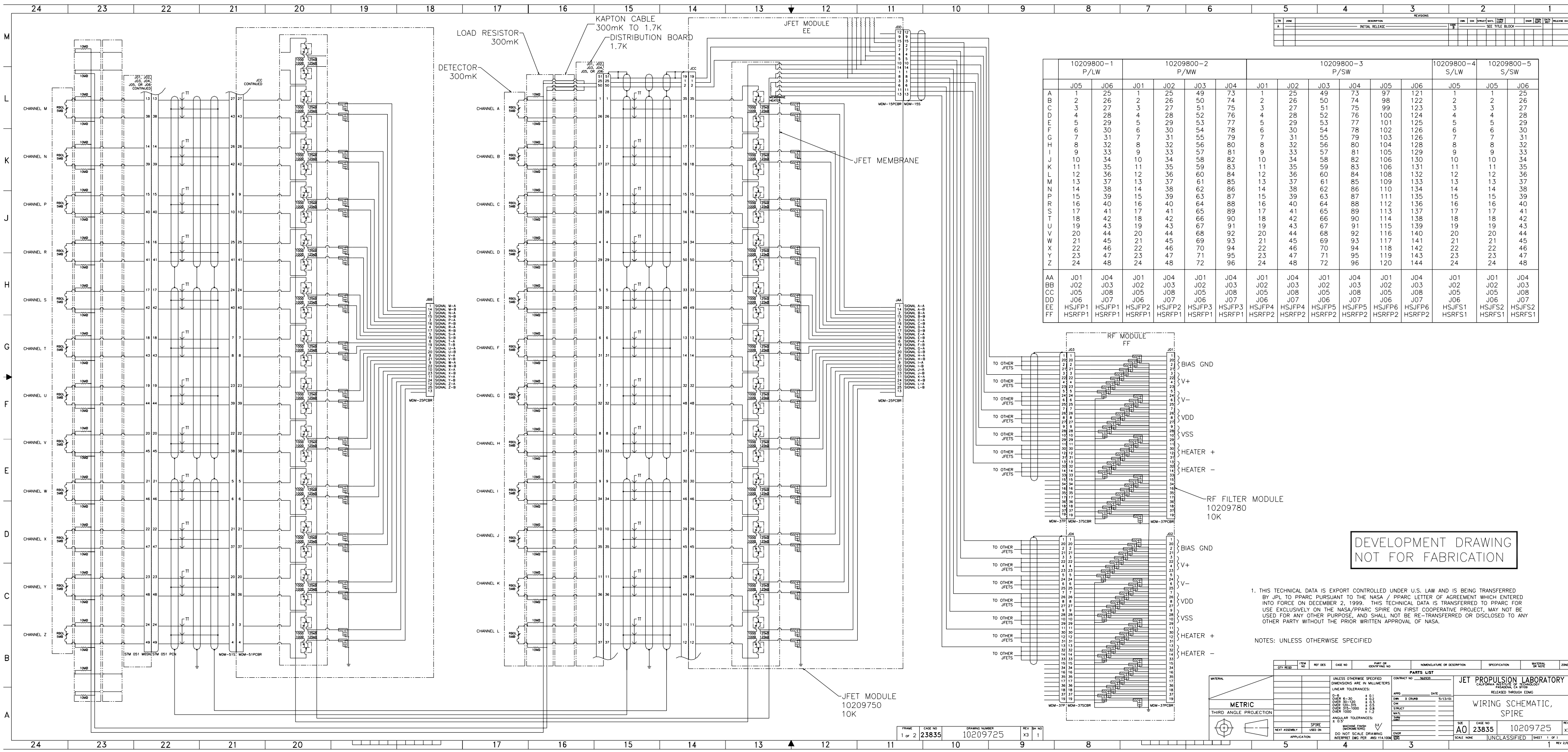
SIZE	CAGE NO		REV
A1	23835	10209723	X4
SCALE NONE	UNCLASSIFIED	SHEET 2 OF 2	

A1 10209723

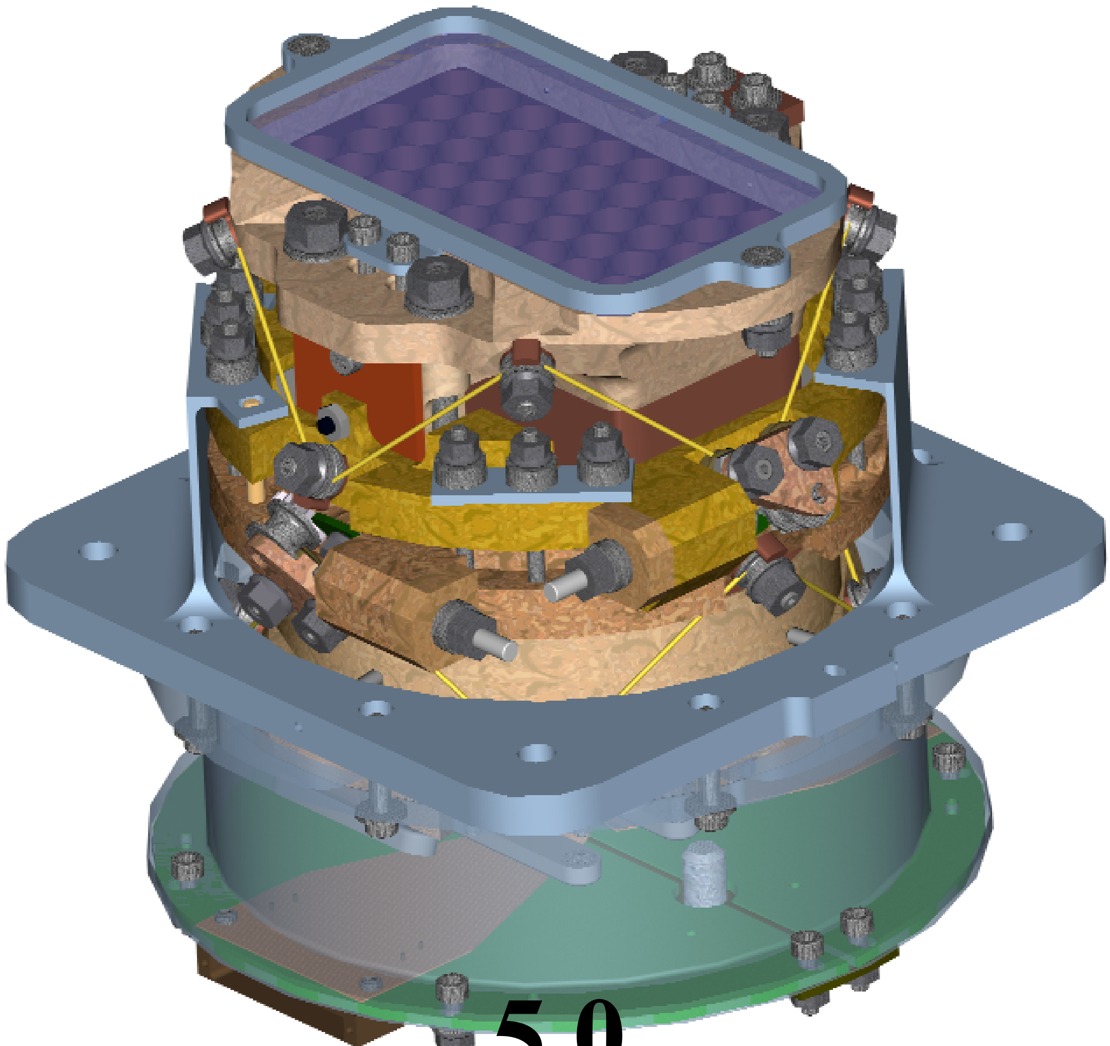
AutoCAD GENERATED

REV 2/00

Wiring Schematic



	10209800-1 P/LW		10209800-2 P/MW				10209800-3 P/SW						10209800-4 S/LW	10209800-5 S/SW	
	J05	J06	J01	J02	J03	J04	J01	J02	J03	J04	J05	J06	J05	J05	J06
A	1	25	1	25	49	73	1	25	49	73	97	121	1	1	25
B	2	26	2	26	50	74	2	26	50	74	98	122	2	2	26
C	3	27	3	27	51	75	3	27	51	75	99	123	3	3	27
D	4	28	4	28	52	76	4	28	52	76	100	124	4	4	28
E	5	29	5	29	53	77	5	29	53	77	101	125	5	5	29
F	6	30	6	30	54	78	6	30	54	78	102	126	6	6	30
G	7	31	7	31	55	79	7	31	55	79	103	126	7	7	31
H	8	32	8	32	56	80	8	32	56	80	104	128	8	8	32
I	9	33	9	33	57	81	9	33	57	81	105	129	9	9	33
J	10	34	10	34	58	82	10	34	58	82	106	130	10	10	34
K	11	35	11	35	59	83	11	35	59	83	106	131	11	11	35
L	12	36	12	36	60	84	12	36	60	84	108	132	12	12	36
M	13	37	13	37	61	85	13	37	61	85	109	133	13	13	37
N	14	38	14	38	62	86	14	38	62	86	110	134	14	14	38
P	15	39	15	39	63	87	15	39	63	87	111	135	15	15	39
R	16	40	16	40	64	88	16	40	64	88	112	136	16	16	40
S	17	41	17	41	65	89	17	41	65	89	113	137	17	17	41
T	18	42	18	42	66	90	18	42	66	90	114	138	18	18	42
U	19	43	19	43	67	91	19	43	67	91	115	139	19	19	43
V	20	44	20	44	68	92	20	44	68	92	116	140	20	20	44
W	21	45	21	45	69	93	21	45	69	93	117	141	21	21	45
X	22	46	22	46	70	94	22	46	70	94	118	142	22	22	46
Y	23	47	23	47	71	95	23	47	71	95	119	143	23	23	47
Z	24	48	24	48	72	96	24	48	72	96	120	144	24	24	48
AA	J01	J04	J01	J04	J01	J04	J01	J04	J01	J04	J01	J04	J01	J01	J04
BB	J02	J03	J02	J03	J02	J03	J02	J03	J02	J03	J02	J03	J02	J02	J03
CC	J05	J08	J05	J08	J05	J08	J05	J08	J05	J08	J05	J08	J05	J05	J08
DD	J06	J07	J06	J07	J06	J07	J06	J07	J06	J07	J06	J07	J06	J06	J07
EE	HSJFP1	HSJFP1	HSJFP2	HSJFP2	HSJFP3	HSJFP3	HSJFP4	HSJFP4	HSJFP5	HSJFP5	HSJFP6	HSJFP6	HSJFS1	HSJFS2	HSJFS2
FF	HSRFP1	HSRFP1	HSRFP1	HSRFP1	HSRFP1	HSRFP1	HSRFP2	HSRFP2	HSRFP2	HSRFP2	HSRFP2	HSRFP2	HSRFS1	HSRFS1	HSRFS1



5.0
Bolometer Detector Assembly (BDA)

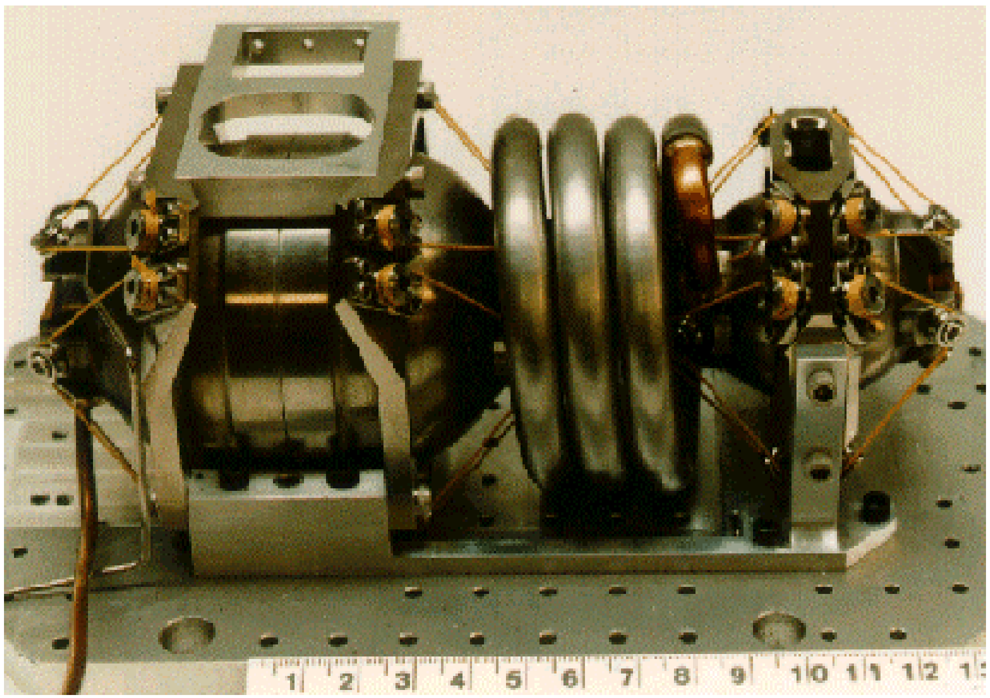
5.1
Mechanical Design

Dustin Crumb

Requirements

Specification ID	Description	Requirement Reference	Compliant
BDA-TEC-01	The BDA shall accommodate a defined mechanical interface to the 2 K structure.	IRD-DETS-R08 IRD-DETP-R14 IRD-STRP-R01	Yes
BDA-TEC-02	The BDA shall provide an attachment point and/or a thermal interconnect to a 300 mK thermal strap.	IRD-STRP-R01	Yes
BDA-TEC-03	The BDA mass will have a design value of 600 g (TBC) average over 5 detector arrays, including output connectors.	IRD-SUBS-03	Yes
BDA-TEC-04	The first resonant frequency of the BDA will be > 200 Hz (TBC), with a goal of > 250 Hz.	IRD-DETP-R15 IRD-DETS-R16	Yes
BDA-TEC-05	The mechanical envelope of the BDA will be described by the ICD.	IRD-DETP-R12 IRD-DETS-R13	Yes
BDA-TEC-06	The total power dissipated onto the 300 mK cooler will be < 15 μW (minimum performance); < 8 μW (design value). Assumes the focal plane mount is held at 1.7 K.	IRD-DETP-R13	Minimum Value not compliant. Design Value is compliant.

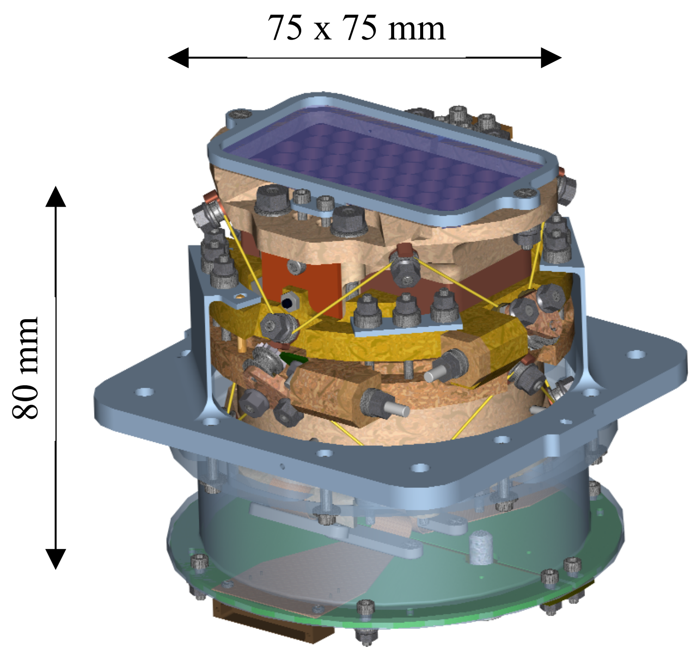
Array Design Mechanical Structure Heritage: Kevlar Supports



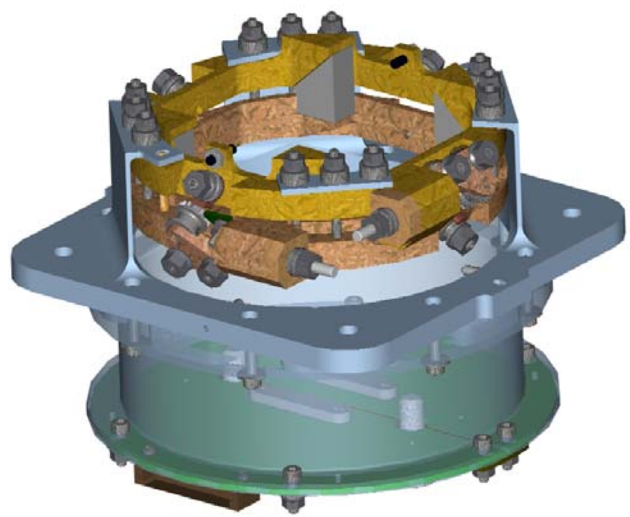
^{3}He Refrigerator for the Infrared Telescope in Space

- suspended mass =350 g
- lowest resonant frequency = 280 Hz
- single-strand/pully/kapston design
- tensioned maintained by thermal contraction
- < 1μW kevlar heat leak to 300mK
- successfully flown on IRTS

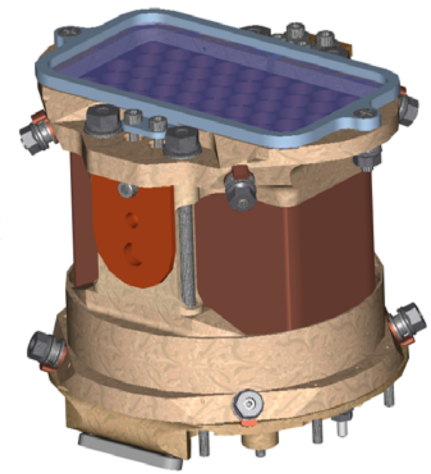
Array Design
Mechanical Structure



Focal Plane

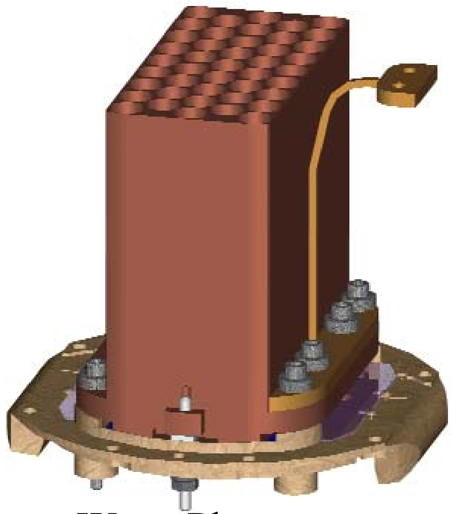


2K Structure

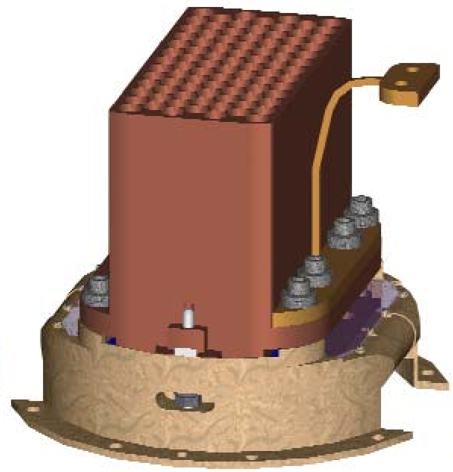


.3K Structure

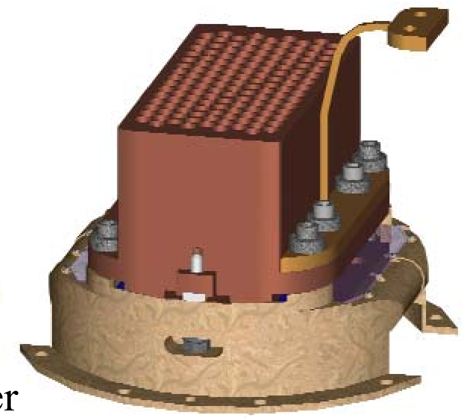
Detector Design/Detector Assembly



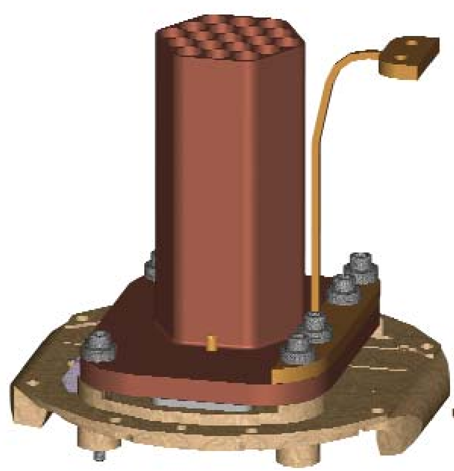
Long Wave Photometer



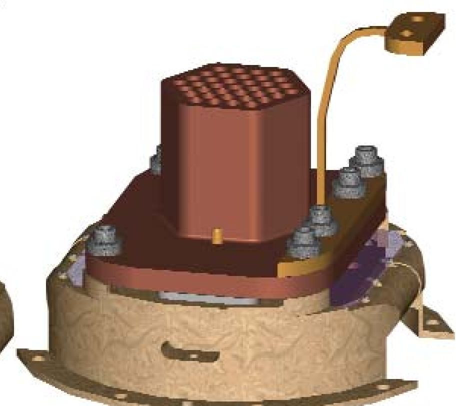
Medium Wave Photometer



Short Wave Photometer



Long Wave Spectrometer



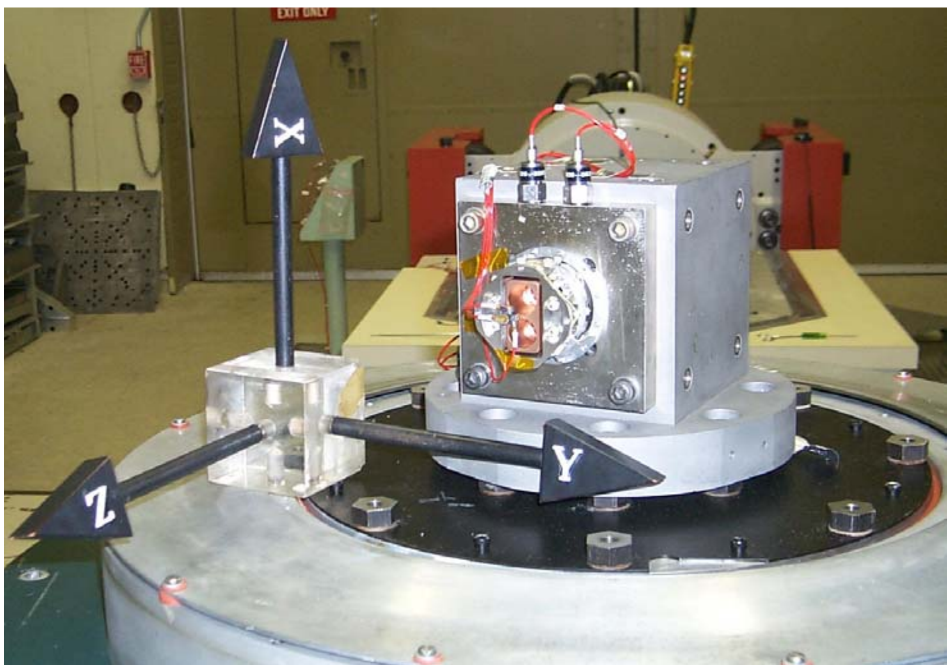
Short Wave Spectrometer

Array Design: Fabrication of Mechanical Prototype
Prototype finished January 2000

1st Natural Frequency is
208.6 Hz Experimental

Vibration test level:

5 - 30 Hz: 2.1 mm displacement amplitude
30 - 400 Hz: 7.5 G acceleration amplitude
400 - 2000 Hz: 15 G acceleration amplitude



SPIRE FPU under vibration test

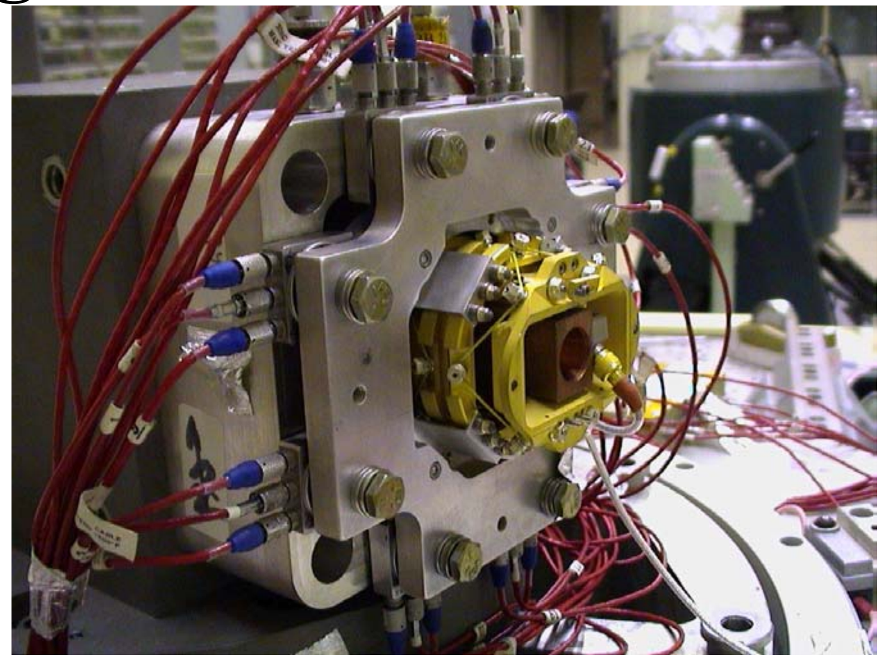
SPIRE Focal Plane Unit

Engineering Models

Three units Built

- Thermal Characterization Model
- Vibration Model
- Spare Unit

Engineering Models



Vibration Model

- •Metrology
- •Warm Shake
- •Metrology
- •Thermal Cycled to LN_2
- •Metrology
- •Warm Shake with force Transducers
- •Metrology
- •Cold Shake
- •Metrology

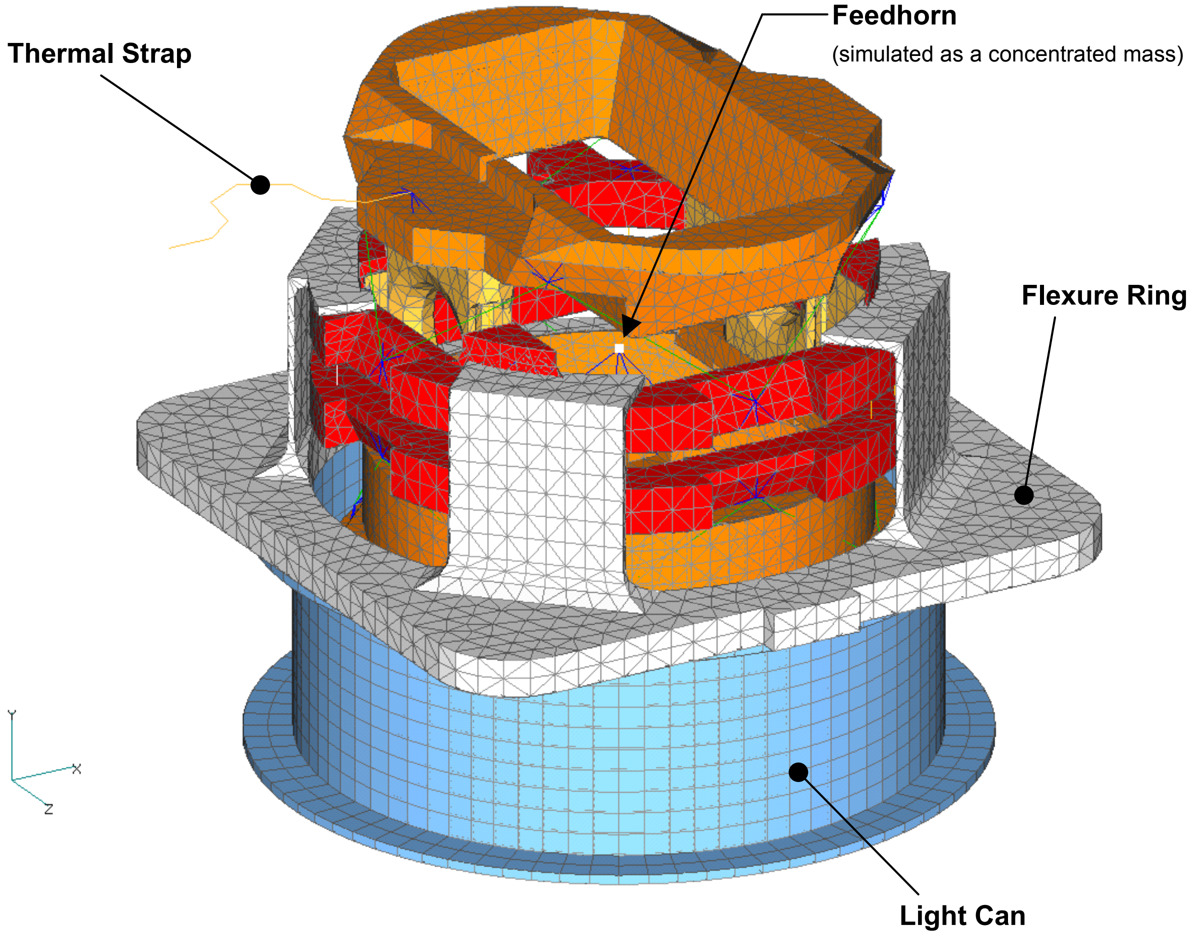
Need table of metrology results after each test

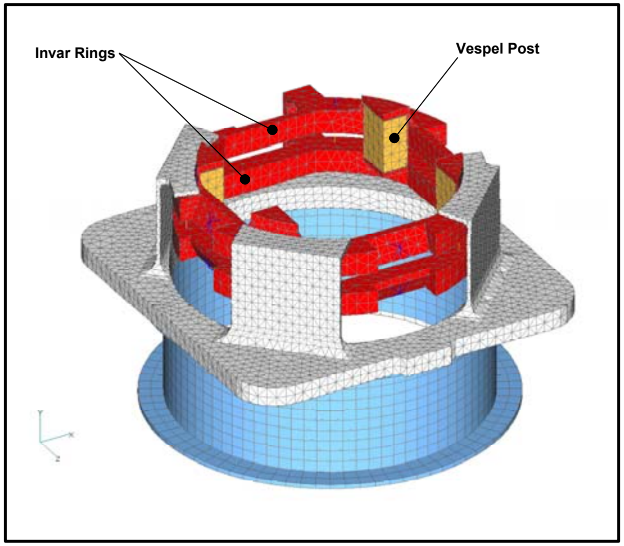
Mass Summary (grams)

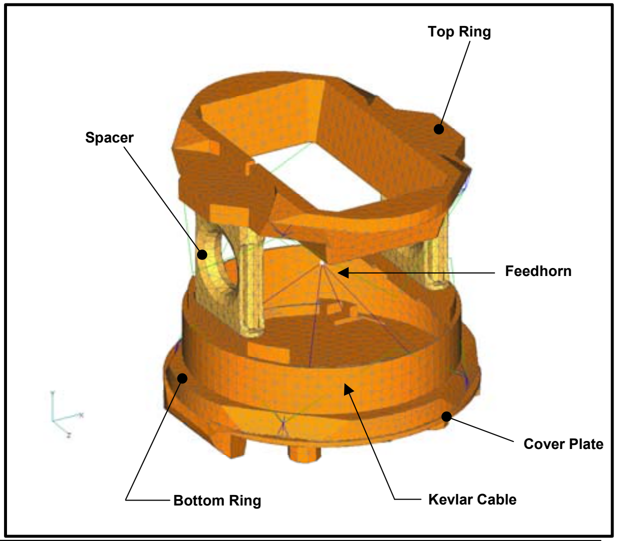
	Previous Mass	Current Mass	Change
P/LW Detector	639	672	4.8%
P/MW Detector	574	615	6.6%
P/SW Detector	520	564	7.8%
S/LW Detector	494	482	2.6%
S/SW Detector	445	466	4.6%
	Current Average	560	4.2%
	Allocated	600	
	Margin	6.7%	

Mass may still come down depending on how feedhorns are manufactured.

Structural Analysis - BDA







Mass (P/LW) = 612 grams Elements = 39155 Nodes = 17289

Structural Analysis - BDA

Materials				
Material - Temper	Alum 7075 - T7351	Invar 36	Kevlar 29	Vespel
Reference	MIL-HDBK-5H Table 3.7.4.0(b3)	Carpenter Technology Corp.	MatWeb	Dupont, Vespel Design Hdbk
Form	Plate	Cold Drawn Bar	3000 Denier	SP1 - M
Basis	A			
Ftu, ksi				
L	68	90	400	12.5
LT	69			
Fty, ksi				
L	57	70		
LT	57			
Fcy, ksi				
L	56			
LT	59			
Fsu, ksi	38	& 54		
Fbru, ksi				
(e/D = 1.5)	103	# 90		
(e/D = 2.0)	132			
Fbry, ksi				
(e/D = 1.5)	81	# 70		
(e/D = 2.0)	97			
E, 10^3 ksi	10.3	2.05	9.0	0.45
G, 10^3 ksi	3.9			
μ	0.33	0.3		0.41
ρ, lb/in^3	0.101	0.291	0.051	0.052
α*, in/in/°F	9.14E-06	1.25E-06	-1.11E-06	1.69E-05

* NASA Tech Brief, "Thermal Expansion Properties of Aerospace Materials", Brief 69-10055, March 1969

& Taken as 60% of Ftu

Fbru and Fbry are taken as Ftu and Fty respectively. This is conservative since bearing values are typically 1.5 times higher.

Structural Analysis - BDA

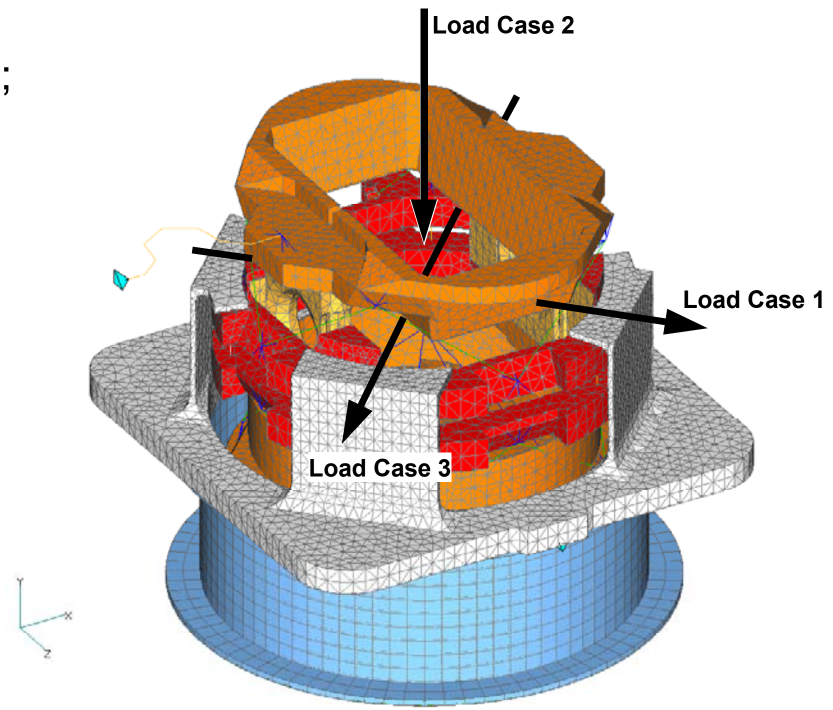
- Analysis Requirements Used to Verify Structural Integrity
  - Qualification Random Vibration Levels (IID - A)

Location	Axis	Freq Range	Density	RMS Value
Herschel Optical Bench	ALL	20 - 80 Hz 80 - 300 Hz 300 - 2000 Hz	+3 db/Oct .077 G^2/Hz -6 db/Hz	6.67 G

  - Factors of Safety (ERD D-19155)
    - FS_{yld} = 1.25
    - FS_{ult} = 1.4
    - Unconventional Material FS_{ult} = 2.0 (e.g. Kevlar cable)
  - Limit Loads (ERD D-19155)
    - 20 G Any Direction

Structural Analysis - BDA

- Load Cases (applied in three directions deemed most critical for stress)
  - Each load case consists of:
    - 82 G Quasi Static Equivalent Load
      - 1.5% damping (JPL Std.)
      - 3σ Value
      - Value above Limit Load requirement; wanted to assess capability
    - 50 lb. Kevlar cable preload
    - Thermal transition from 70°F to -460°F



- Constraints
  - Fixed at BDA-to-FPU Fastener Locations (4 Locations)
  - Appropriate DOFs constrained for guiding pins (2 pins)

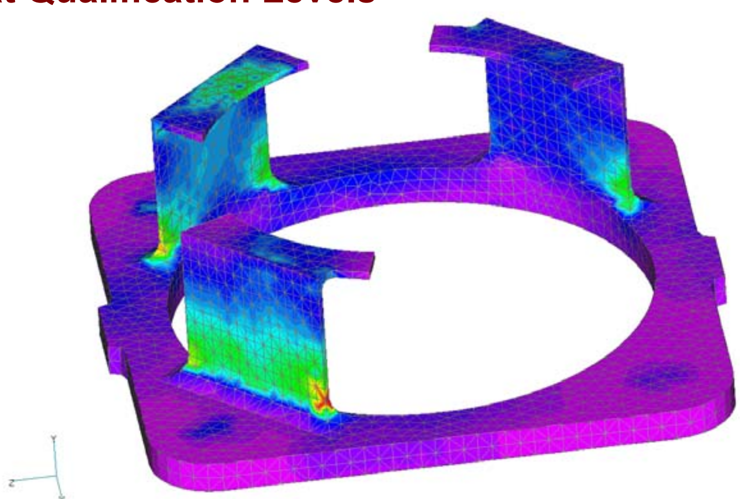
Structural Analysis - BDA

Margin of Safety Summary for Structural Elements at Qualification Levels

Part	Load Case	Stress	F.S. (Yield)	F.S. (Ult.)	F_{yld}	F_{ult}	Failure Mode	MS (Yield)	MS (Ult.)
Flexure Ring	82G(.707, 0., .707),P,T	27,871 psi	1.25	1.4	57,000 psi	68,000 psi	Von Mises	0.64	0.74
Top Ring	82G(.707, 0., .707),P,T	25,082 psi	1.25	1.4	70,000 psi	90,000 psi	Von Mises	1.23	1.56
Invar Rings	82G(-.707, 0., .707),P,T	21,878 psi	1.25	1.4	70,000 psi	90,000 psi	Von Mises	1.56	1.94
Light Can	82G(.707, 0., .707),P,T	3,990 psi	1.25	1.4	36,000 psi	42,000 psi	Von Mises	6.22	6.52
Spacers	82G(-.707, 0., .707),P,T	10,155 psi	1.25	1.4	70,000 psi	90,000 psi	Von Mises	4.51	5.33
Cover Plate (P/LW & S/LW)	82G(-.707, 0., .707),P,T	11,986 psi	1.25	1.4	70,000 psi	90,000 psi	Von Mises	3.67	4.36
Bottom Ring	82G (0., -1., 0.),P,T	38,396 psi	1.25	1.4	70,000 psi	90,000 psi	Von Mises	0.46	0.67
Kevlar Cable	82G(-.707, 0., .707),P,T	199,199 psi	N/A	2.0	N/A	400,000 psi	Tension	N/A	0.00

N/A = Not Applicable

Margin of Safety Summary for Fasteners at Qualification Levels



Location	Load Case	FSult	Failure Mode	M.S. (ult)
Circuit Board to Light Can	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	2.24
Light Can to Flexure Ring	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	1.83
Flexures to Invar Ring	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	1.55
Bottom Ring to Cover Plate	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	1.92
Spacer to Top Ring & Bottom Ring	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	1.41
Spacer to Top Ring (Horiz)	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	2.41
BDA to Detector	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	1.54
Spacer to Bottom Ring Pins	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	3.77
Flexure to Invar Ring Pins	82G RSS, P, T	1.4	Bolt Tension-Shear Interaction	3.68
Pulley Fastener (Bot Ring - 2.0 mm dia)	82G (0, -1., 0.), P, T	1.4	Bolt Tension-Shear Interaction	1.64

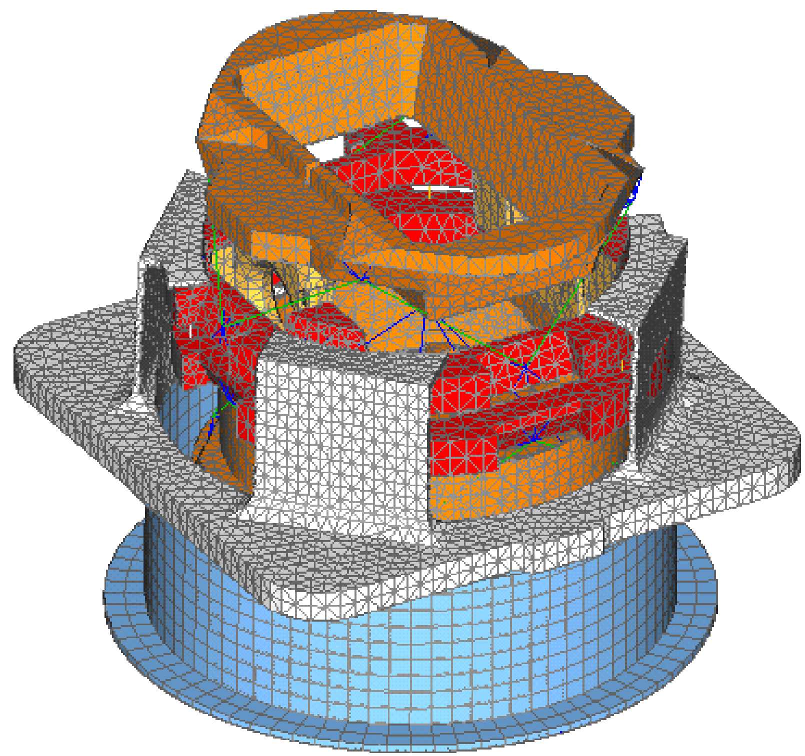
RSS = Root-Sum-Square

Structural Analysis - BDA

- Computer Model Validation - Comparison to Test Data
  - Modal Frequencies
    - Tests were conducted with S/LW variant of detector

Mode #	Computer Model (S/LW)	Warm Test	Cold Test
	(Hz)	(Hz)	(Hz)
1	265	253	TBD
2	328	386	TBD
3	399	486	TBD

Table of damping values



Mode 1: 265 Hz

Structural Analysis - BDA

- Where Are We Now?
  - Input Spectrum at BDA interface as proposed by MSSL
    - Quasi Static Equivalent (3σ Value) = 278 G

Location	Axis	Freq Range	Density	RMS Value
Herschel Optical Bench	ALL	20 - 100 Hz 100 - 600 Hz 600 - 2000 Hz	+6 db/Oct .8 G^2/Hz -6 db/Hz	27.9 G

VS.

  - Survivable Spectrum for Current Design (Machined Parts Only)
    - Quasi Static Equivalent (3σ Value) = 102 G

Location	Axis	Freq Range	Density	RMS Value
Herschel Optical Bench	ALL	20 - 100 Hz 100 - 600 Hz 600 - 2000 Hz	+6 db/Oct .17 G^2/Hz -6 db/Hz	12.74 G

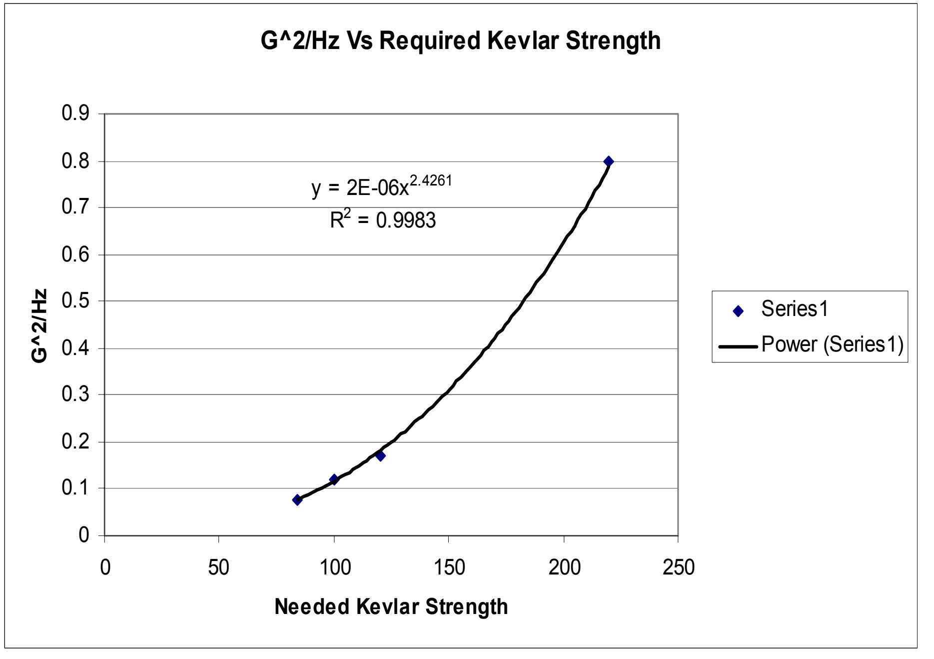
Kevlar Testing

- Pulley diameter is not strongly tied to breaking strength for yarn.
- Clamping kevlar reduces ultimate strength by approximately 10%.
- Original EM capstan design provided under 30% of rated strength for yarn
- New larger capstan design now baseline for CQM provides better then 95% of rated strength for braided

Kevlar Preload

G^2/Hz	Dynamic +/-	Recommended Preload	Max Dynamic Load	Needed Strength
0.077	16	26	42	84
0.170	25	35	60	120
0.800	50	60	110	220
~0.12*	20	30	50	100

- 100lbs is Max load demonstrated so far
- Value estimated from curve fit of a power series
- Assumes 1.5% damping



Time Dependent Properties of Kevlar

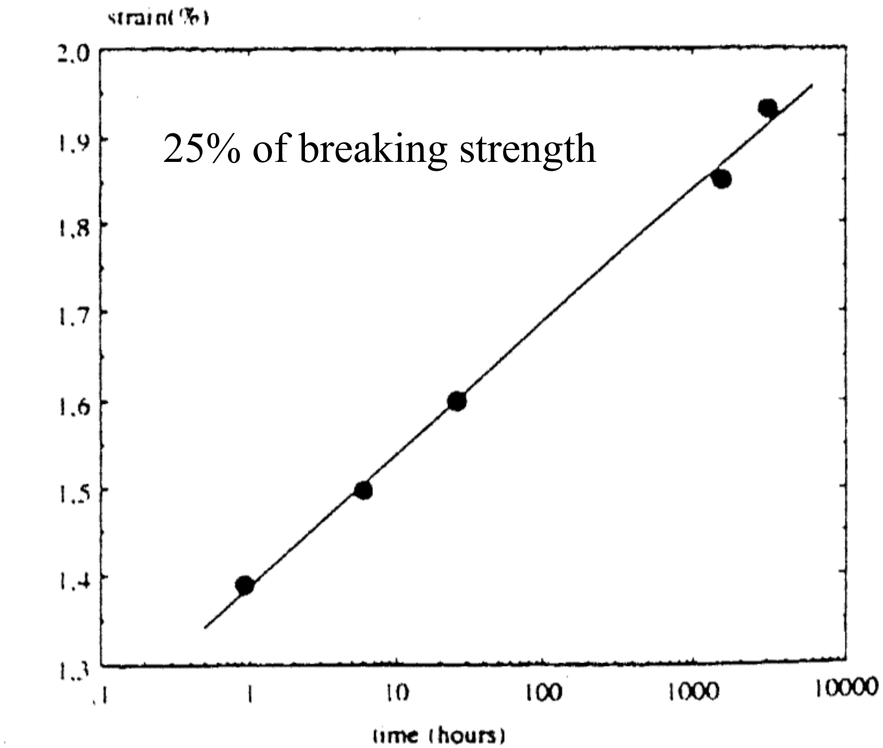
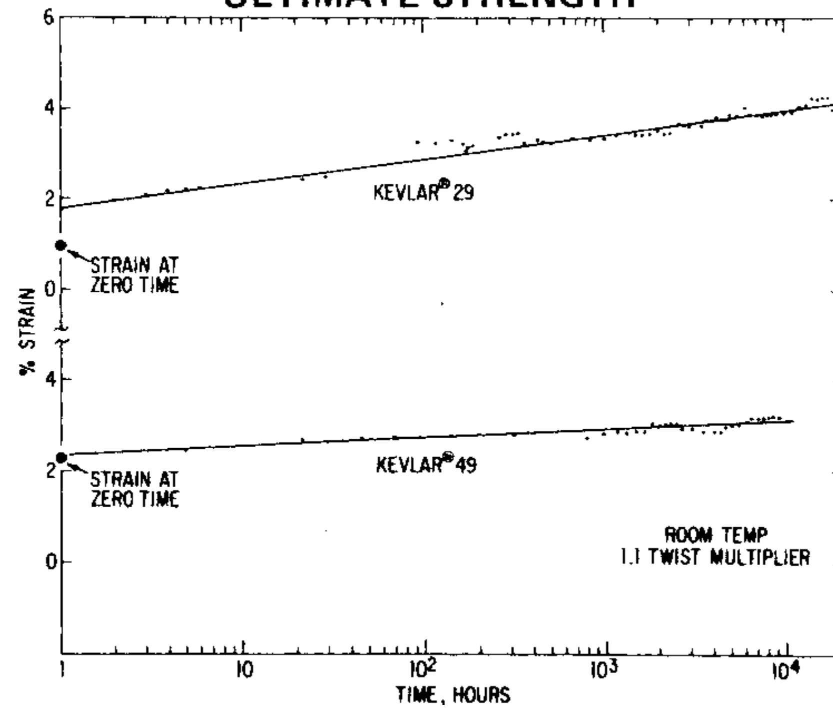


Figure 4 Measured creep of Kevlar 29 braided cords

Graph from **L. Duband, L. Hui and A. Lange.** Thermal Isolation of large loads at low temperature using Kevlar rope *Cryogenics* (1993) 33 643-647

FIGURE 5
CREEP OF YARNS OF KEVLAR® 29 AND KEVLAR® 49 ARAMID AT 50% OF ULTIMATE STRENGTH



Graph from Characteristics and Uses of Kevlar 29 Aramid, company memo, Dupont, Wilmington, Deleware, USA.

Kevlar Issues

Yarn - Highest Strength, difficult to work with, hard to do it same way every time

Braided - Easiest to work with, fraction of strength of Yarn

Twisted - Need more information on

List of Materials in BDA

- AL 6061-T6
- AL 7075
- A 286 CRES
- INVAR 36
- 303 CRES
- Kapton
- Vespel
- Kevlar 29
- 2216 Epoxy
- HDPE

- Silicon Nitride
- Gold
- Miller Stevens 903 Epoxy
- CDA 172
- Copper 99.999%
- Constantin
- Indium
- NTD Germanium
- Buried Oxide Silicon Wafers
- Nickel
- Titanium
- Ablestik 84-3 Epoxy (TBC)

Process List

• General Cleaning	JPL FS505146
• Gold Plate	MIL-G-45204, Type 3, Class 3
• Bonding	D-8208, Section 3.18
• Bonding	BS515871
• Torque	ES504255
• Solder Joint	D-8208, Section 3.14.
• Passivation	JPL FS505146
• Connector Installation	D-8208, Section 3.12.

Materials and Processes Review

- M&P review to ensure functional, reliability, and safety requirements.
- Materials evaluated for:
  – Stress Corrosion Cracking Resistance
  – Outgassing
- Data obtained from:
  – MSFC-HDBK-527/JSC-09604
  – MSFC-SPEC-522

Materials and Processes Review

(Continued)

- Materials Identification and Usage List (MIUL) completed.
  - All materials and processes used identified
  - Each material and process assigned a rating of 1 through 4
    - 1 or 2 rating acceptable for flight
    - 3 or 4 require Material Usage Agreement (MUA)
- All materials and processes have been rated 1 or 2 and are acceptable for flight

Materials Identification and Usage List (MIUL)

Materials Identification and Usage List - Metallic Materials

em o.	Material Description/ Condition	Application	Material Specifications	Stress Corrosion Cracking Rating	JPL Rating[1]	Comments
1	Invar 36	Structural Elements	ASTM B753-T36 or AMS-I-23011 Class 7			
2	Al 7075 T73	Structural Elements	SAE-AMS-QQ-A-225/9			
3	Al 6061 T651	Structural Elements	SAE-AMS-QQ-A-250/11			
4	A286	Fasteners				
5	303 CRES	Fasteners	AMS 5738			
6	Copper, 99.999% pure	Thermal Strap				
7	CDA 172	Clamps	B194			

Materials Identification and Usage List (MIUL)

Materials Identification and Usage List - Non-Metallic Materials

tem o.	Material Description/ Brand Name Supplier	Application	Material Specifications	Thermal Vacuum Stability (%)	JPL Rating[1]	Comments
1	Vespel, Dupont SP1	Structural Support		TML = VCM= WVR=		
2	Kevlar 29 3000 Denier Yarn, Dupont	Tension Member		TML = VCM= WVR=		
3	Miller Stevens 903	Adhesive		TML = VCM= WVR=		

Materials Usage and Identification List (MIUL)

Materials Identification and Usage List - Processes

ITEM NO.	PROCESS	SPECIFICATION	MATERIALS PROCESSED	APPLICATION	JPL EVALUATION	
					APPROVE/ DISAPPROVE[1]	COMMENTS
	Gold Plating	MIL-G-45204, Class 3, Type 3	Invar 36	Corrosion Protection, Thermal Conduction		
	Gold Plating	MIL-G-45204, Class 3, Type 3	Copper	Thermal Conduction		
	Passivation	FS 505146	303 CRES	Passivation		
	Bonding	D-8208, Section 3.18, FP513414	Solithane 113/C113-300 Filled Polyurethane	Spot Bonding of Component Parts		
	Bonding	BS515871	Scotch Weld 2216 B/A with Filler	Spot Bonding of Component Parts		
	Workmanship	FS504040		Workmanship Standards for Mechanical Parts and Material		
	Torque	ES504255		Torque Requirements, Threaded Fasteners, Spacecraft Structural and Electronic Equipment		
	Solder Joint	D-8208, Section 3.14, Fp513414		Solder Joint		
	Installation	D-8208, Section 3.12, FP513414		Connector Installation – Rectangular Miniature		

Drawing Status

This slide to be provided at CDR

Conclusions on BDA Detailed Design

- **The design will survive the current ERD loads.**
- **We have made all the practical design changes to the BDA to increase our load capacity.**
- **Ready to fabricate mechanical hardware if the present kevlar design does not change**
- **In order to bring our survivable launch loads higher than 0.12 g^2/Hz, we need to do more investigation on Kevlar.**

5.2 Feedhorn Design & Test

Working Group

Jason Glenn, CU	Design & Testing
Brooks Rownd, CU	Testing
Martin Caldwell, RAL	Optical Simulations
Anthony Murphy, Maynooth	Horn Field Calculations
Hien Nguyen, JPL	Testing
Goutam Chattopadhyay, JPL	Cavity Simulations
Bruce Swinyard, RAL	Instrument Scientist

Overview

•Requirements
•Design Strategy & Tradeoffs
•Simulations
•Testing Strategy
•Risk Analysis

Status

•Designs complete
•Modeling nearly complete
•P/SW & S/LW prototypes manufactured
•Preliminary P/SW tests

Presented by Jason Glenn

Feedhorn Requirements and Interfaces

- $\eta_{optical,,design}$ (Phot, Spec) = 0.85, $\eta_{optical,\ minimum}$(Phot) = 0.45
- Ω_{Phot} = single-mode
- Ω_{Spec} = multi-mode
- Bandpass → waveguide aperture
- *Redundancy in case of bad pixels constrains apertures*
- Photometer bandwidths driven by science, $\lambda/\Delta\lambda = 3$
  - P/SW $\lambda_C = 250\ \mu m$,
  - P/MW $\lambda_C = 350\ \mu m$
  - P/LW $\lambda_C = 500\ \mu m$
- Spectrometer bandwidths driven by science, photon backgrounds
  - S/SW $200\ \mu m < \lambda < \lambda_{crossover}$ TBD
  - S/LW $\lambda_{crossover}$ TBD $< \lambda < 609\ \mu m$
- *Feedhorn lengths constrained by mechanical envelopes*
- Optimization for point source sensitivity → single mode

General design strategy: design horns and cavities at chosen wavelength, calculate performance at other wavelengths within the band, modify design.

Feedhorn Array Formats

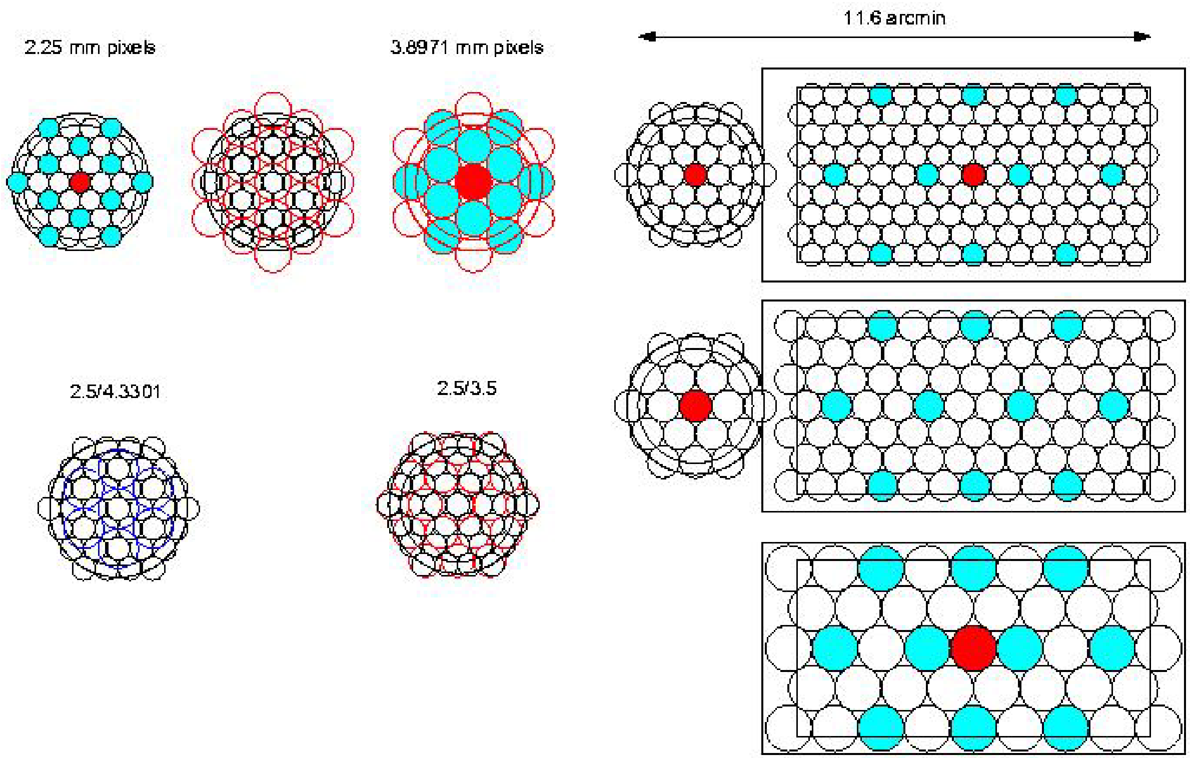
Viewed from "above" the horns looking at their apertures

S/SW
37 horns

S/LW
19 horns

New configuration:
max overlap,
smaller apertures

Old configuration:
less overlap



P/SW
139
horns

P/MW
88
horns

P/LW
43
horns

Feedhorn Design Tradeoffs

•Lengths: $\eta_{aperture}$ & manufacturing difficulty increase with L, constrained by BDA envelopes

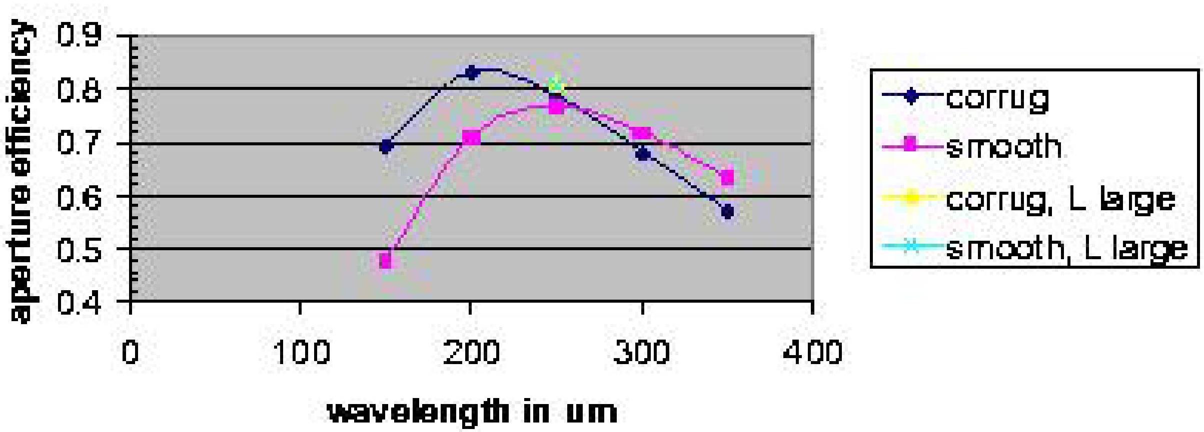
	P/MW	
L = 7.5 mm	T_E(dB) = -6	$\eta_{aperture}$ = 40% (46% refocus)
L = 31.75 mm	*T_E(dB) = -9*	*$\eta_{aperture}$ = 76%*
L = ∞	T_E(dB) = -9	$\eta_{aperture}$ = 80%

•Apertures: 2fλ apertures for max $\eta_{aperture}$

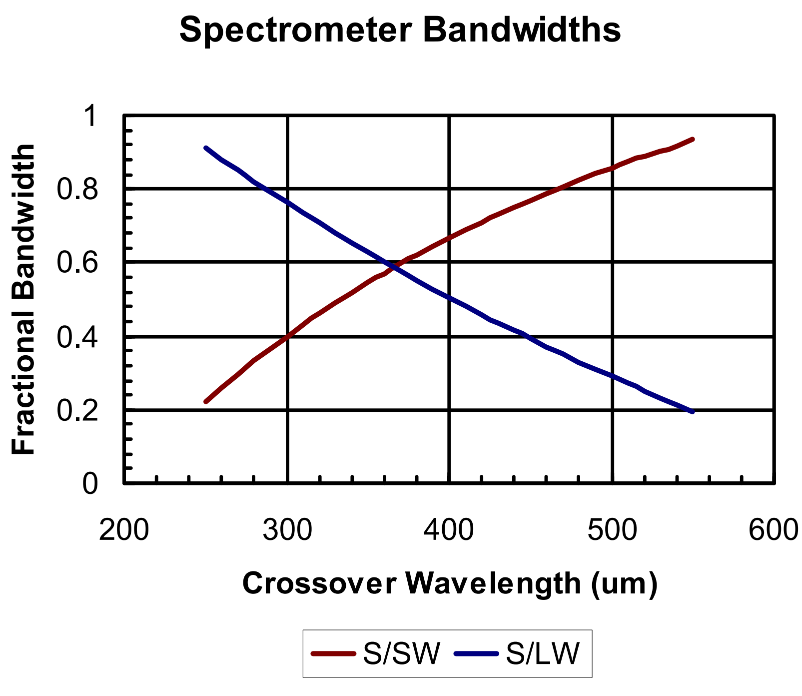
•Profiles: Long, aperture-limited horns do not require profiling

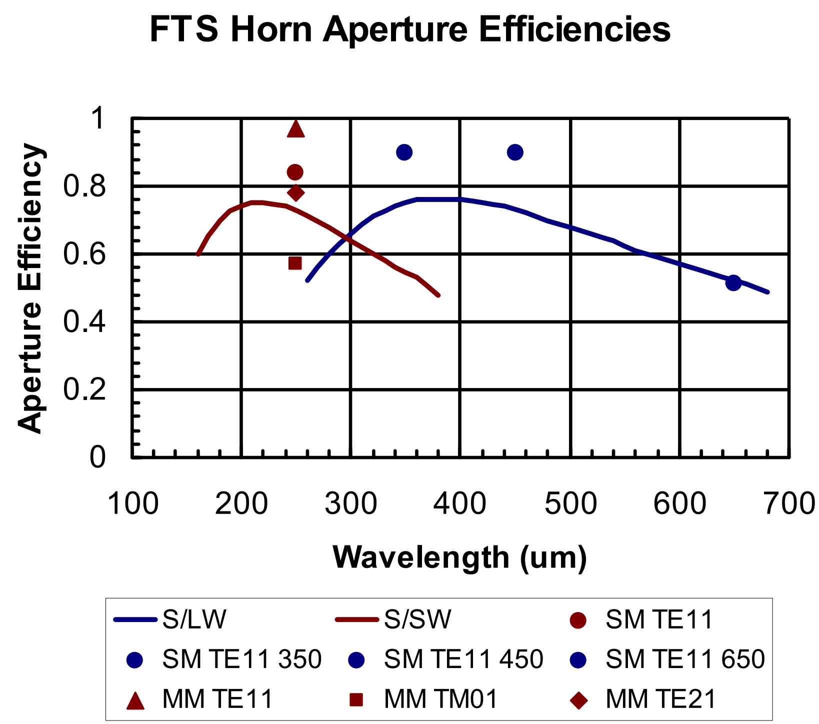
→Straight-walled, conical

•Corrugations: cost ↑x2, steeply tapered edges not required with cold stops



Spectrometer Crossover Wavelength





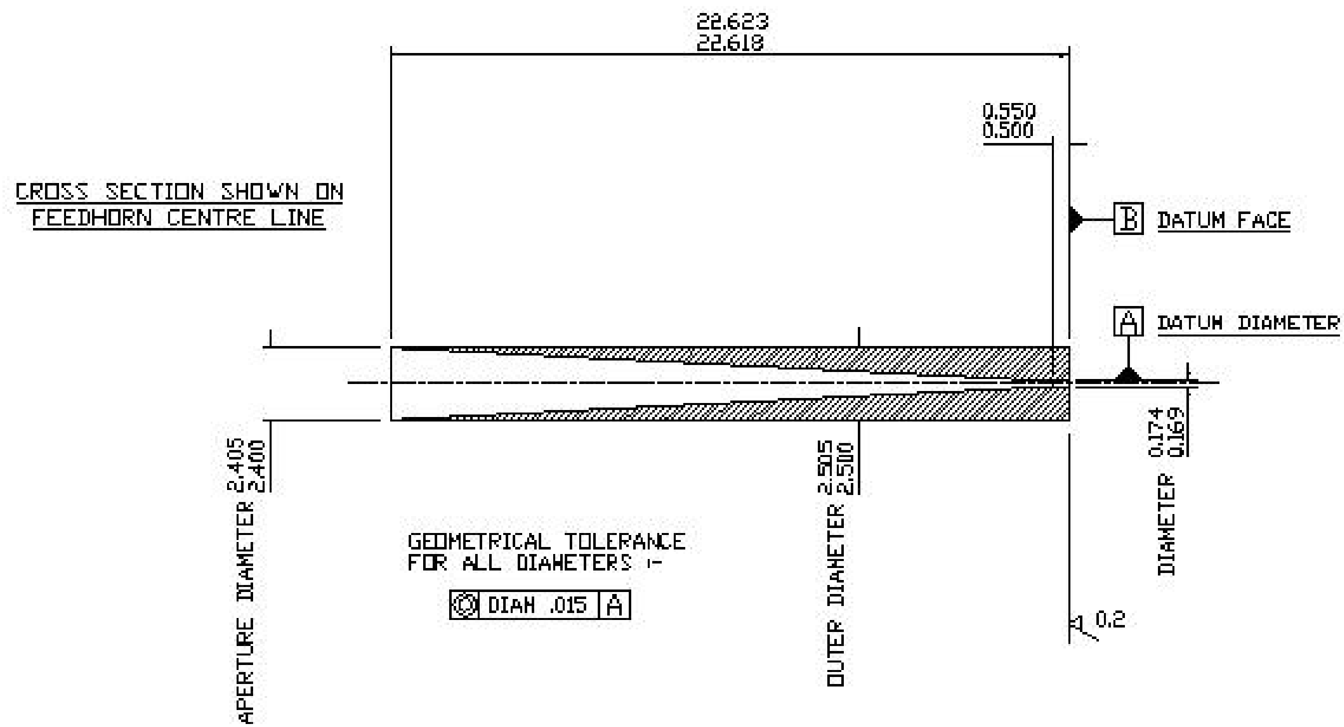
Background photon power equal for $\lambda_{crossover} = 300\ \mu m$

$\Rightarrow \lambda_{crossover} = 300$ to $310\ \mu m$

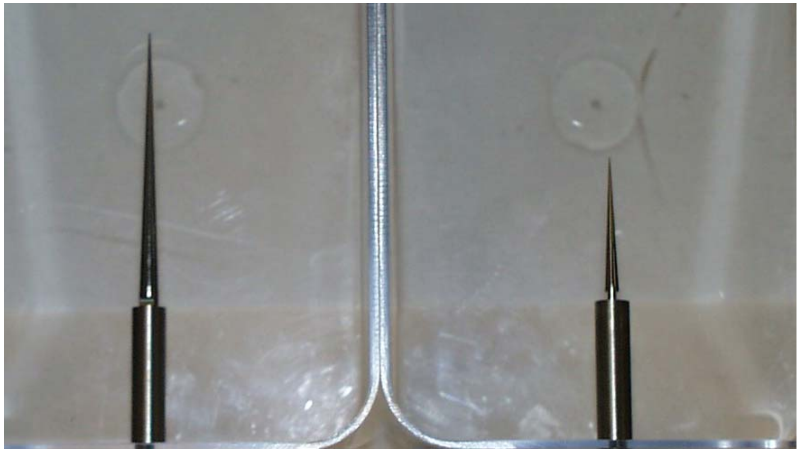
Feedhorn Parameters

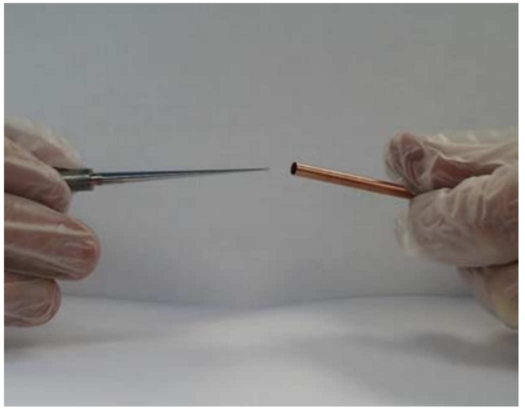
Array	λc (μm)	Band (μm)	Length (mm)	Aperture (mm)	Wave. Dia. (μm)	Wave. Len. (μm)	Defocus (mm)
P/SW	250	209-291	23.68	2.40	171	500	1.6
P/MW	350	292-408	32.75	3.40	239	700	2.5
P/LW	500	418-583	46.36	4.90	342	1000	4.0
S/SW	265	200-310	23.68	2.15	208	550	0.0
S/LW	450	300-*670*	46.36	3,80	393	900	0.0

P/SW Schematic (drawing courtesy RAL)



Prototype Feedhorn Manufacturing @ RAL

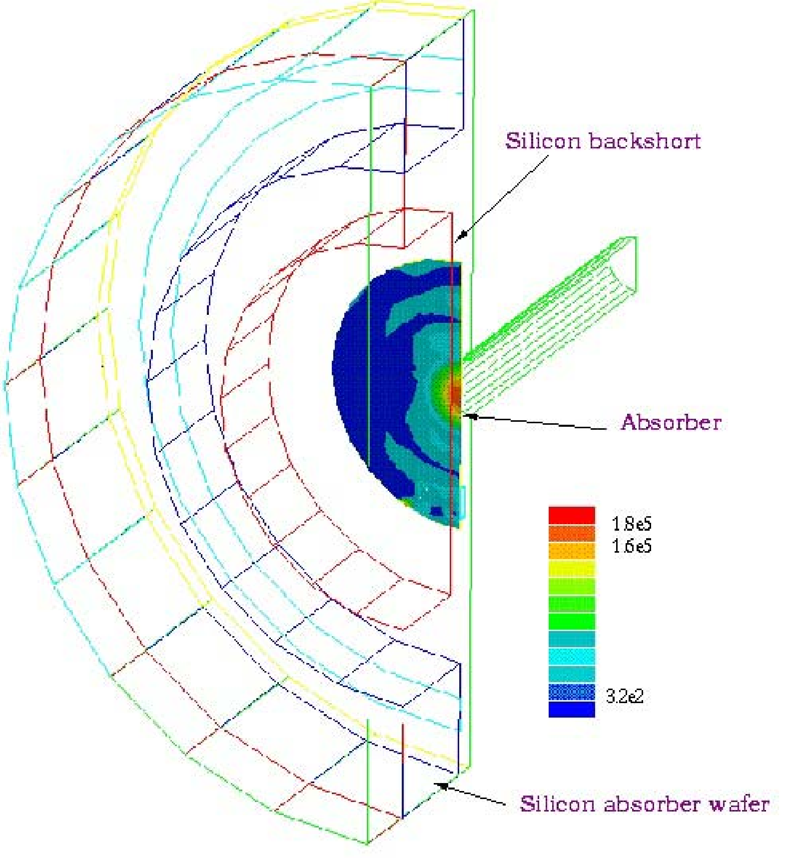




Photos courtesy RAL

Feedhorn Simulations & Preliminary Results

- E-fields calculated for each horn configuration
- Fields summed and propagated through optics to form beams on the sky and calculation efficiencies
- Mode coupling to absorbers simulated with HFSS



Preliminary results: P/SW, 3 channels, $\eta_{optical} = 0.6$

Feedhorn Risk Analysis

•Primary risk: feedhorn tolerances cannot be met. S/SW and P/SW at greatest risk.

→*Reduced $A\Omega$ and/or $\Delta\lambda$*

→*Beams are not likely to be affected because we have cold stops.*

•Secondary risk: supplier cannot meet schedule or cost.

→ Mitigated by a 3-stage manufacturing approach:

-Prototypes (P/SW-tightest tolerances)

-CQM (2 substages: P/LW, S/LW)

-Flight units and spares

•Bad feedhorns within an array cannot be replaced (optical pretesting prior to assembly under review)

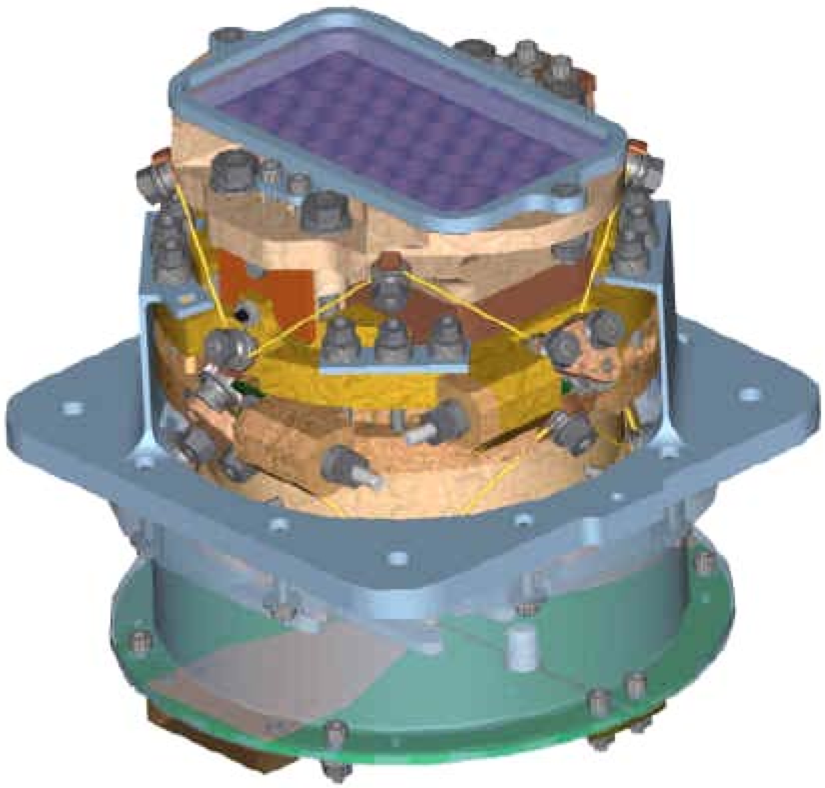
Future Work & Schedule

- Modeling
  - -Complete set of efficiencies and beam profiles on the sky as f(λ)
  - -P/SW efficiency at λ = 265 μm
  - -Tolerances on frontshorts
  - -Coupling of S/LW higher order modes
- CQM P/LW horns delivered to JPL 10/2001
- CQM S/LW horns delivered to JPL 12/2001
- Ongoing beam & optical efficiency testing of witness horns @ CU
- Flight & flight-spare horns delivered to JPL 11/2002

5.3
BDA Thermal Model and Test Results

Terry Cafferty

BDA thermal design goals



Heat load into 3He fridge

8 uW for all 5 BDAs
min performance 15 uW

bolometer-3He fridge gradient

10 mK based on 290 mK fridge
and 300 mK bolometers

Bolometer assembly thermal time constant

100 s min based on assumed fridge
stability of 0.1 mK/hr and detector
stability of 10 uK/Hz$^{0.5}$ from 0.1 - 10 Hz
(should eliminate need for active
thermal control of detector
we have 2 uW budgeted if needed)

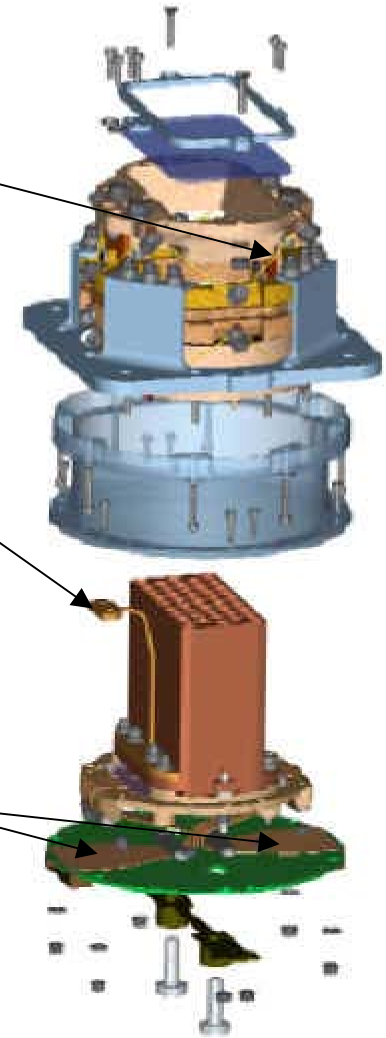
BDA thermal features

0.3 K to 1.7 K suspension system
Pretensioned 3000 denier kevlar,
0.3 mm^2 cross-sectional area.
16 legs each 25 mm long

thermal strap to 0.3 K 3He fridge
Pure copper machined in one piece, annealed, bent once at installation. Bottom flange 4 screws to feedhorn block, which is bolted directly to invar bolometer mount plate.
Top flange mates with SPIRE 0.3 K thermal bus

1.7 K to 0.3 K cables
Etched 5 um thick constantan foil conductors sandwiched between Kapton covers. Line and space widths 100 um. Kapton 125um thick. Acylic glue 50 um thick. Each BDA uniquely cabled to minimize heat leak. Thermal length between clamps 35 mm.

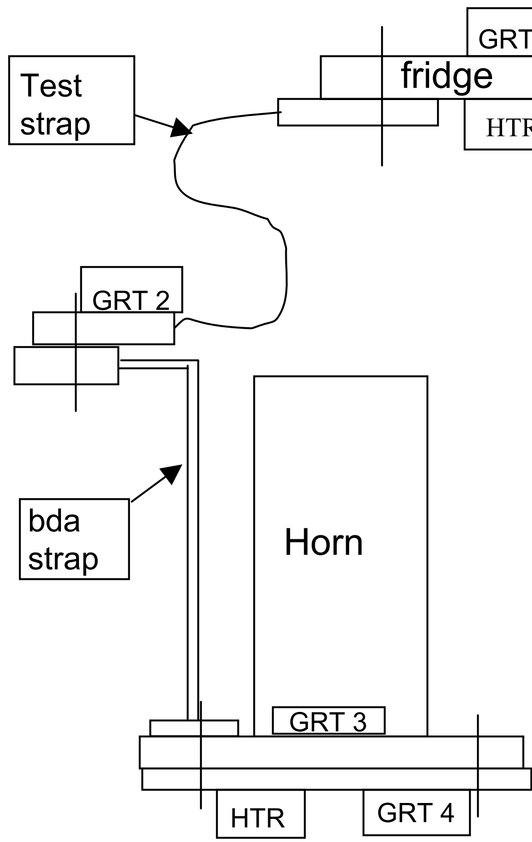
'soft' Kevlar failure features
cage of Vespel and A286 parts limit conducted heat load to a maximum of ~10 uW per BDA if Kevlar breaks



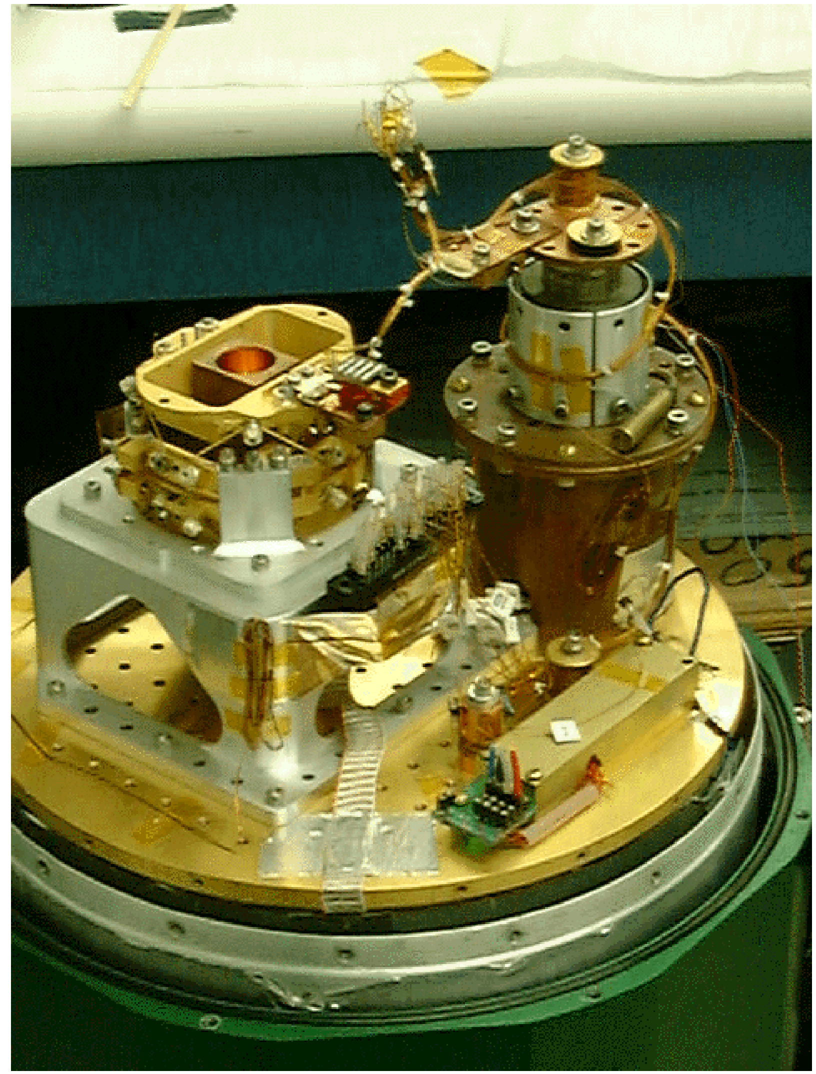
BDA predicted thermal performance

- total heat load (1.7 K He bath)
  - 8.3 uW (1.66 uW/BDA average)
    - 3.4 uW kevlar
    - 2.2 uW kapton portion of cables
    - 2.7 uW constantan portion of cables
- predicted temperature drop
  - ~16 mK bol plate to strap attach point (average)
  - dominated by interface thermal resistance
- predicted time constant
  - ~160 s average

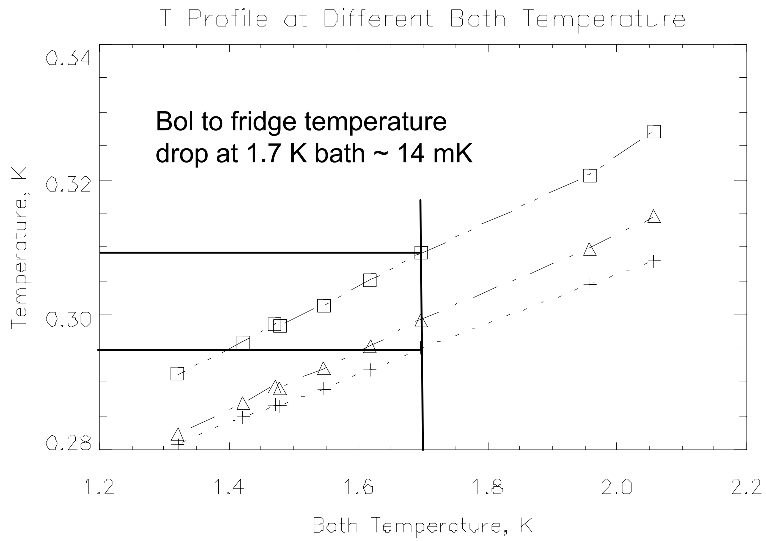
BDA thermal characterization test

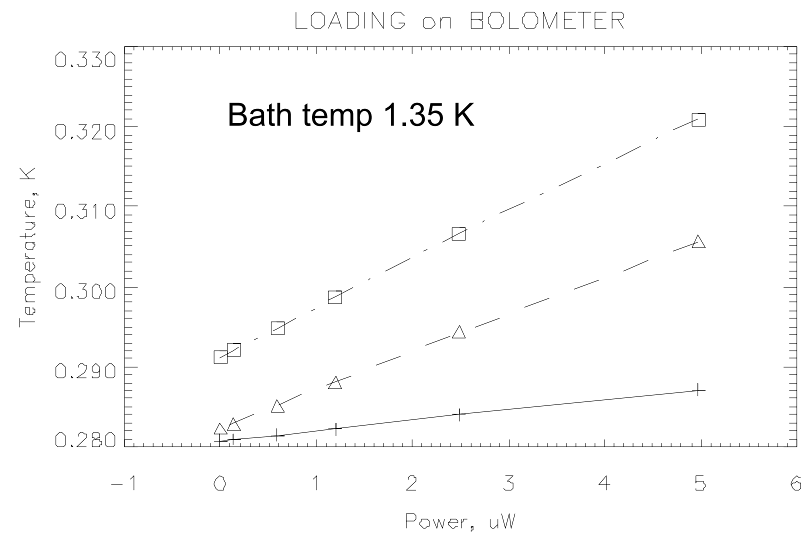


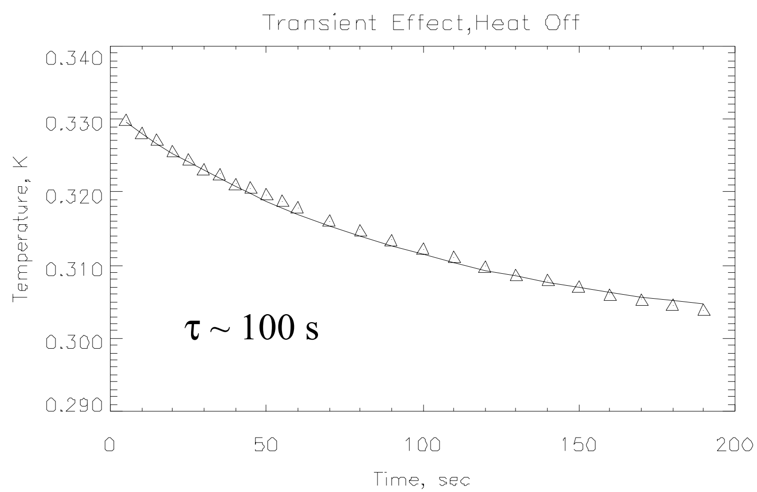
GRT1	Fridge
GRT2	Strap Junction
GRT3	Horn
GRT4	Bol plate
GRT5	Helium Bath



BDA thermal characterization test results







Summary of test results

Time constant ~ 100 s (meets goal)

Bol-fridge ΔT ~ 14 mK (goal <10)

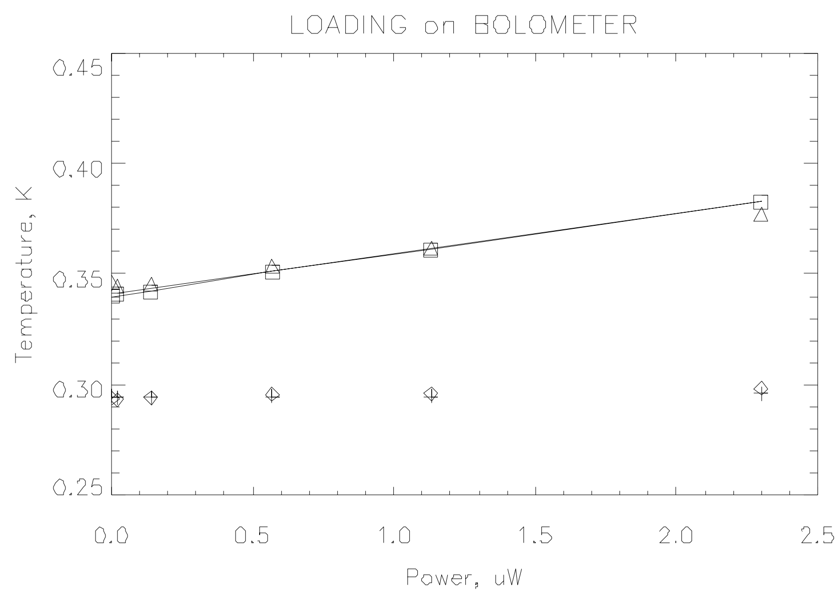
Derived heat load ~1.4 uW @ 1.7K bath

(goal average 1.6 uW)

BDA thermal conclusions

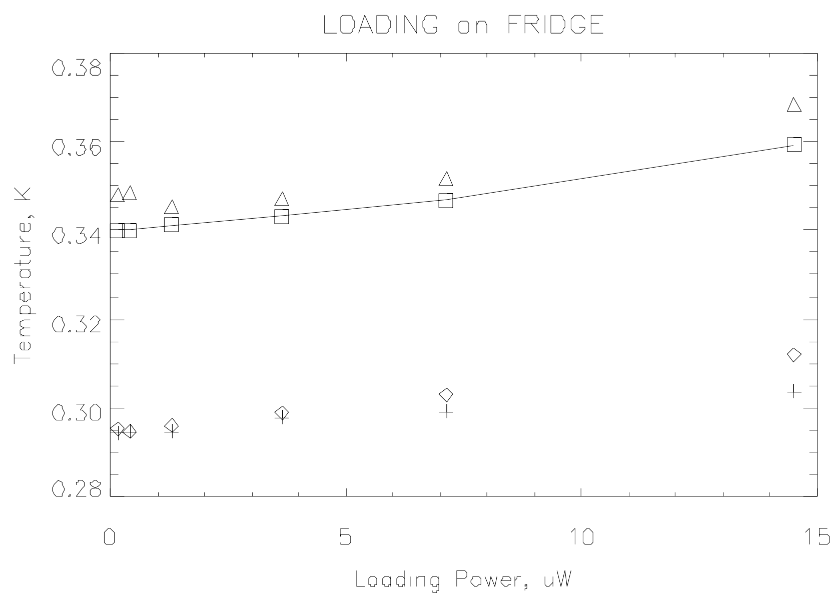
- measured 0.3 K heat load meets goal when observed systematic parasitic heat load is subtracted
- measured bulk 0.3K assembly thermal time constant of ~ 100 s meets design goal
- measured temperature drop from fridge to bolometers 14 mK, goal 10 mK
- maximum additional heat load due to 'soft' caging system for failed Kevlar is ~10 uW/BDA
- BDA is good to go from thermal point of view

BDA Temperature Profile: Heat Load on Bolometer



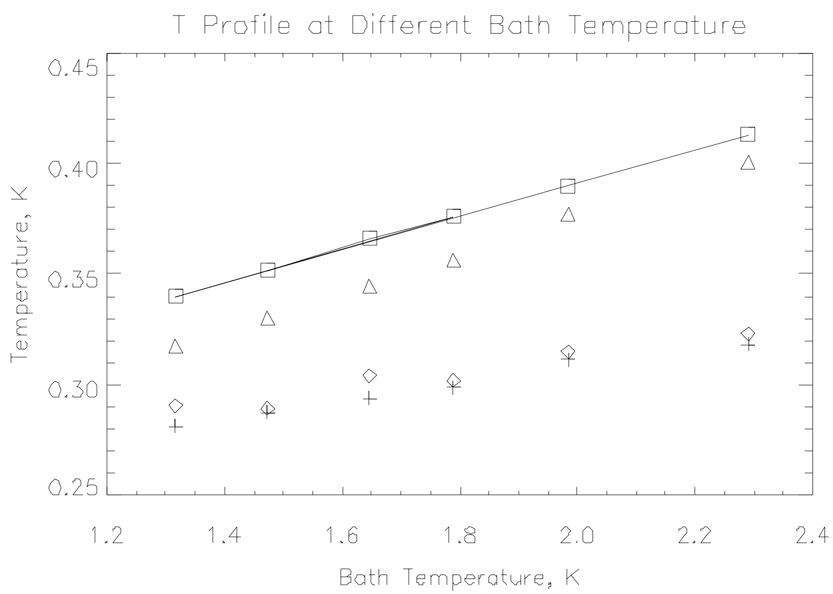
Bath Temperature 1.35 K

TEMPERATURE PROFILE ON BDA DUE TO HEAT ON FRIDGE

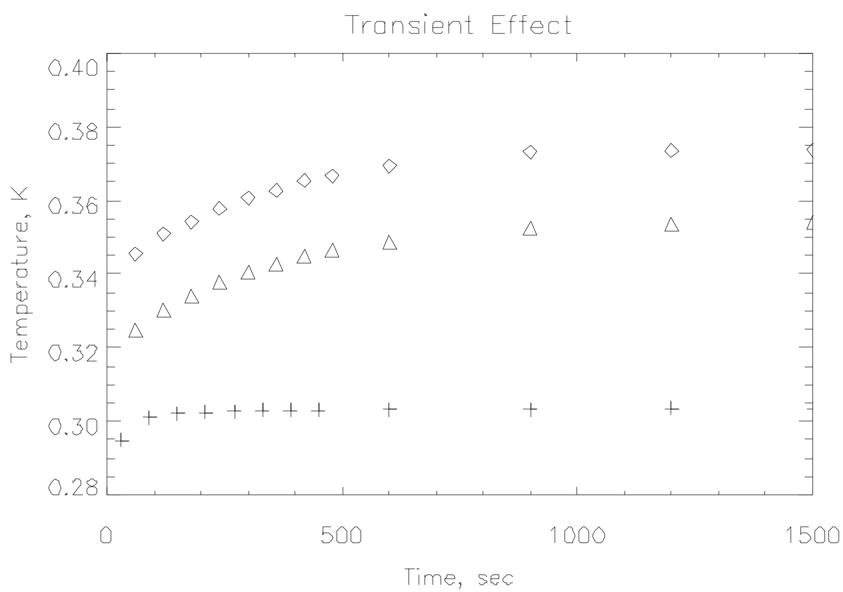


Temperature Reading Uncertainty ~ 4 mK

Temperature Gradient in BDA

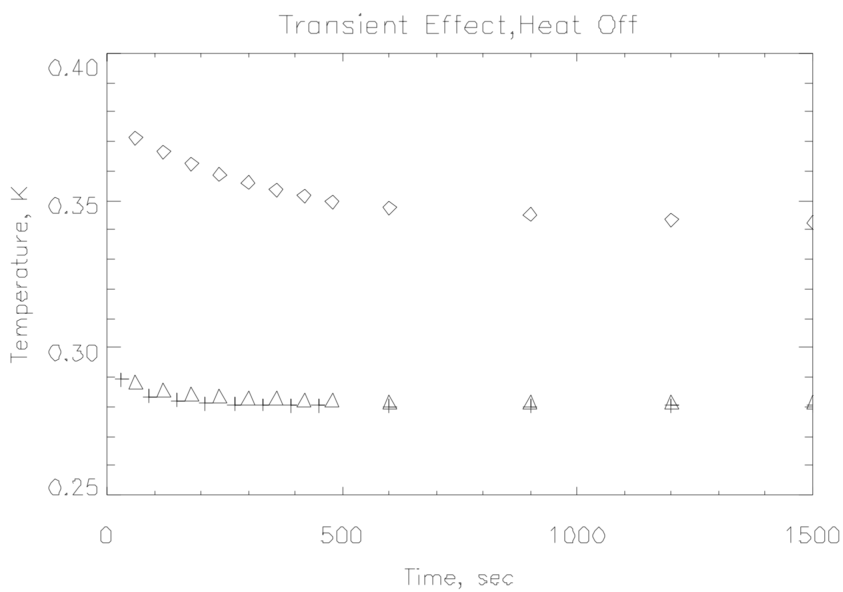


Transient Measurement: Heat On Fridge



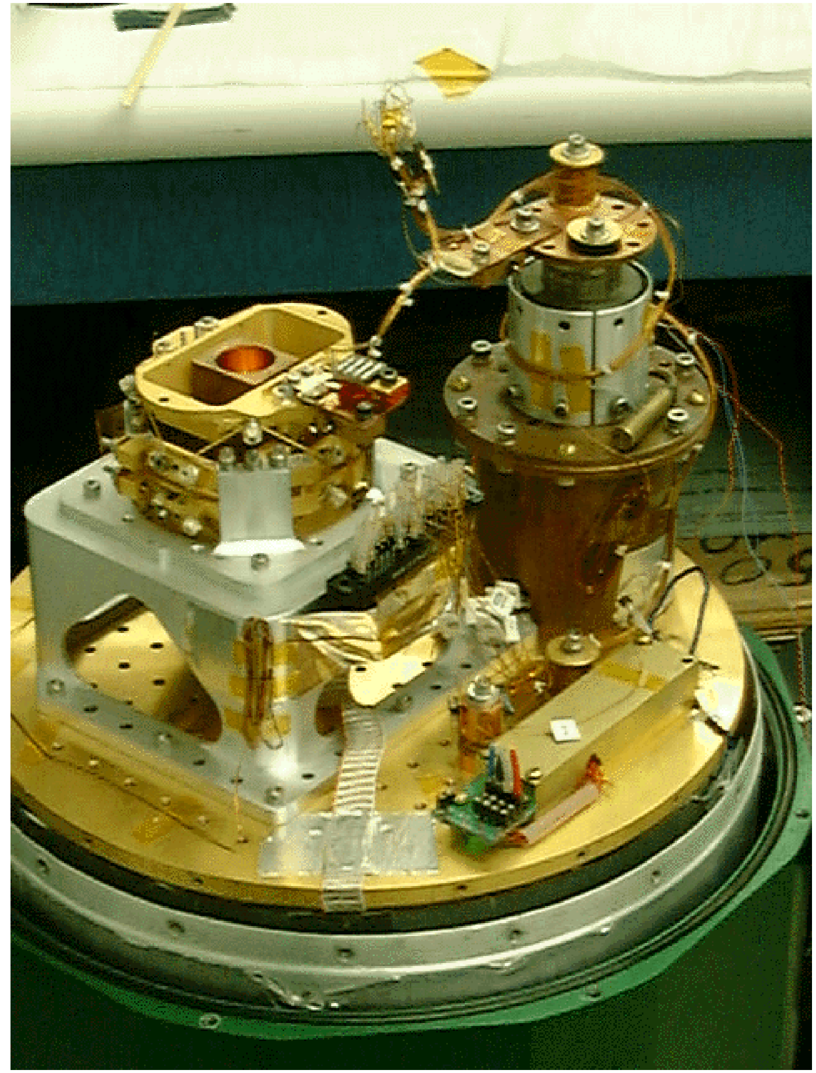
Input 150 mV or ~30 uW into Fridge

Transient Measurement: Heat Off Fridge

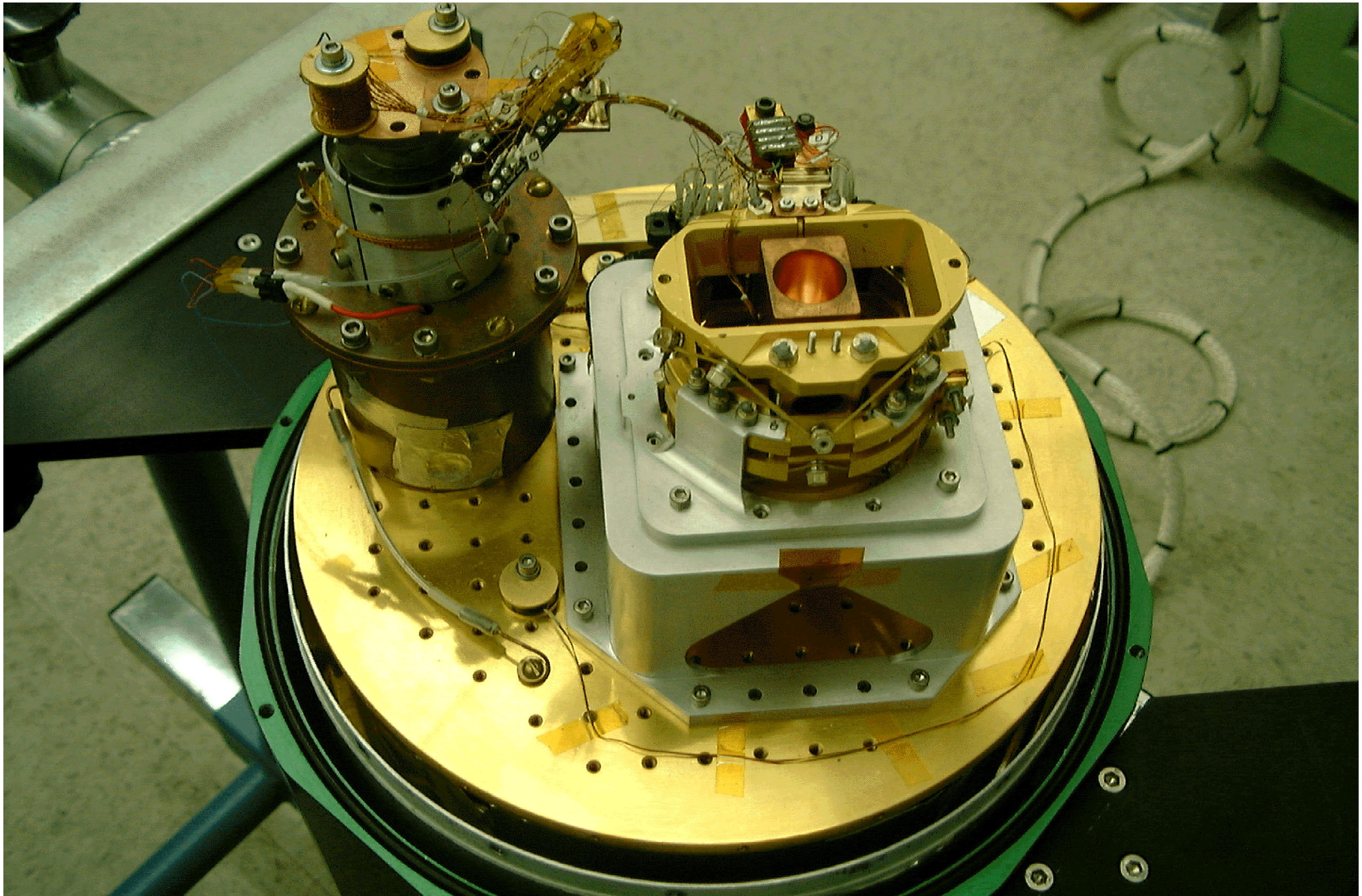


Some Changes

1. Tape up the hole in the shields (~4-40 tapped thru holes)
2. Add charcoal getter
3. Tightening up the four screws on the thermal strap
4. Tightening up the screws between the bottom cover plate and the structure



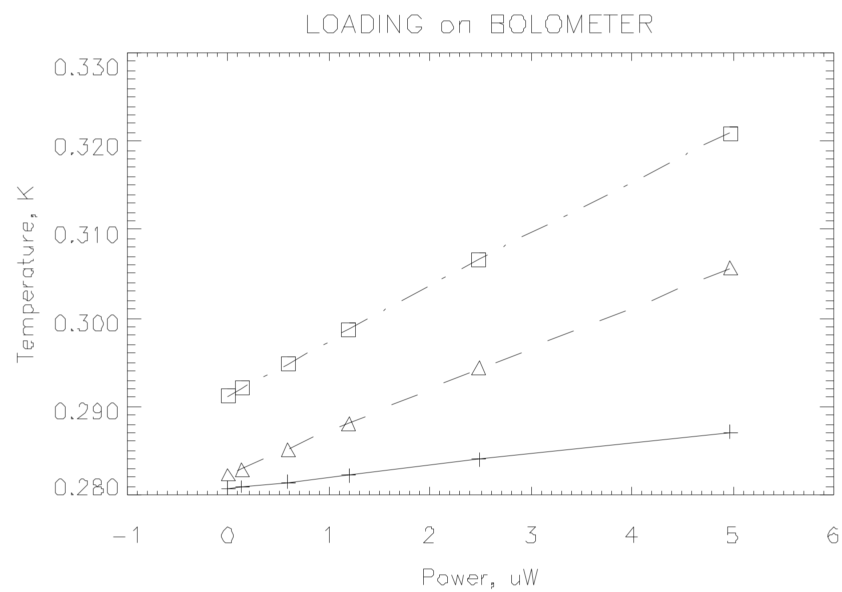
BDA for Thermal Characterization



New Measurements after Tightening Screws

What was being done?

I applied some electrical power to rhe heater at the bolometer site, and recorded all the temperatures.

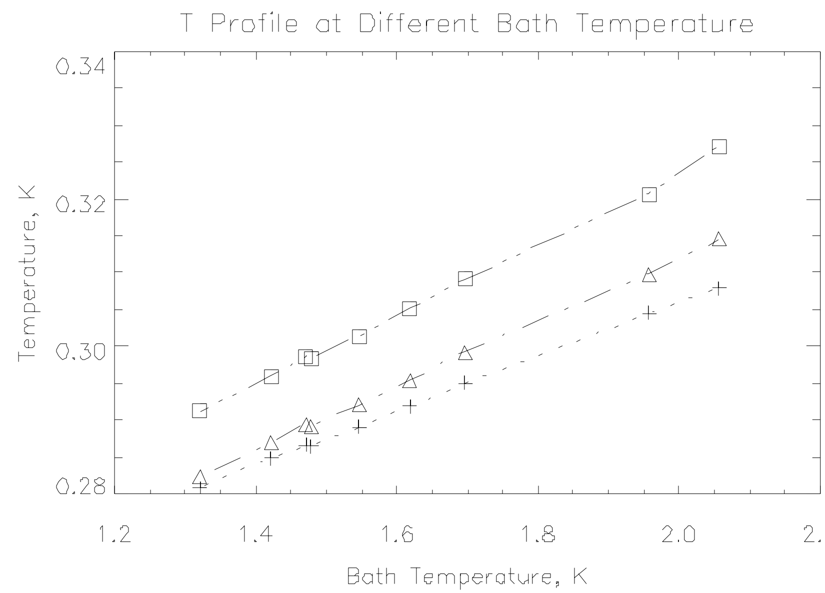


Varying Bath Temperature

What was being done:

Varying the bath temperature (by changing the speed of the pump) and recording all the temperatures (the temperature of the bottom of the thermal strap is missing because the wires were touching)

At 1.7 K the difference between T_bol and T_fridge is ~ 14 mK.

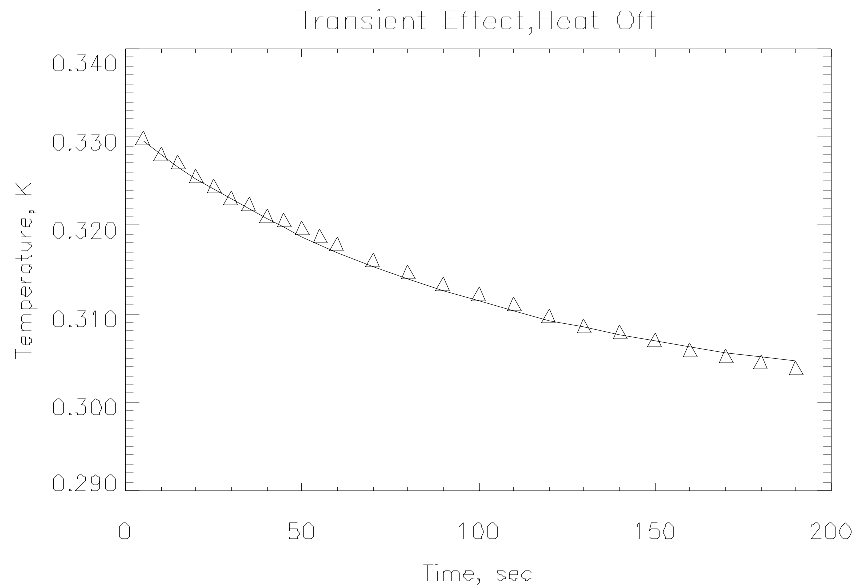


Transient Measurement

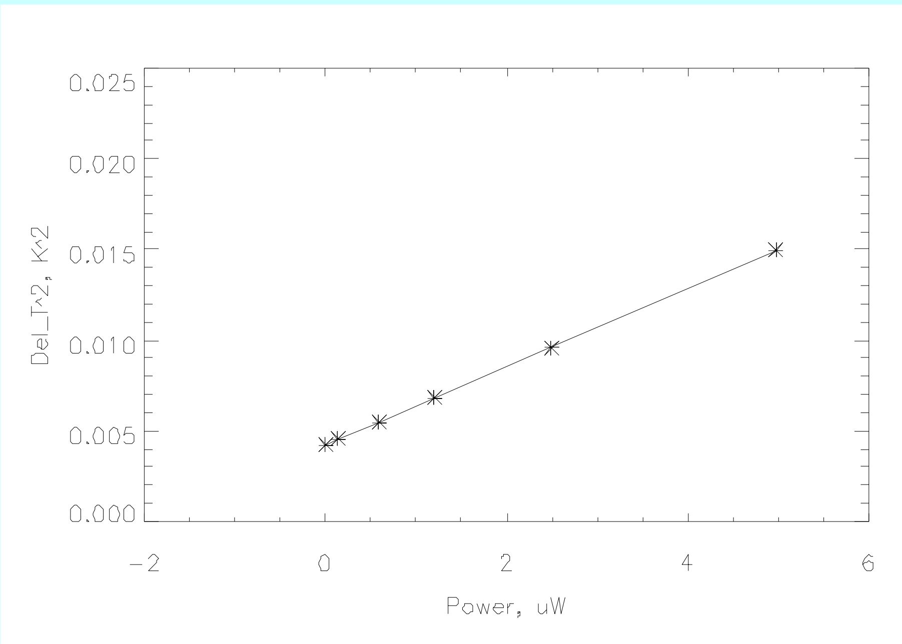
What did I do?

Turned on the power of the heater on the fridge let it come to the equilibrium, then turned it off. The data in the left figure were recorded during the cooling off phase (temperature is on bolometer site)

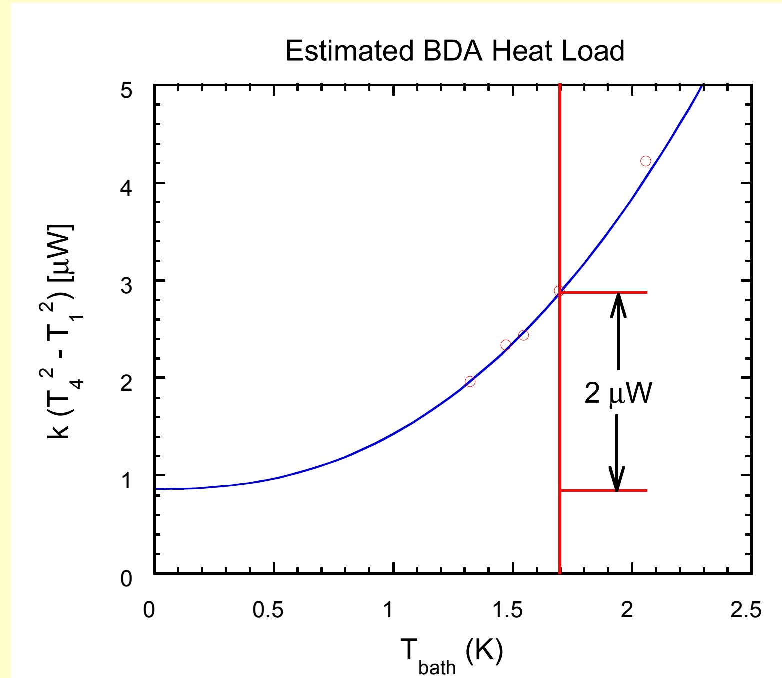
Triangle is data
Line is eye-balled fit of with 100 sec time constant



Estimate of BDA Heat Load



- Estimate loading from T_{bol} and T_{fridge} (T_{strap} not functioning)
- Extrapolate to $(T_{bol}^2 – T_{fridge}^2) = 0$



- Fit estimate power to
  $$P0 + k(T_{bath}^{2.4} – 0.3^{2.4})$$
- BDA measured load at 1.7 K is 2.0 µW
- Reasonable agreement with the theoretical load of 1.4 µW
- Recommend measurements on kapton cable

Summary

- Testing program confirmed thermal model accuracy
- Some uncertainty in total heat load
  - Should measure conductance of kapton cables at a future date
- Assembly procedures and tightening of fixtures was demonstrated to be important

5.4
SPIRE Array Fabrication

Judith Podosek, Minhee Yun, and Anthony Turner

Jet Propulsion Laboratory, Pasadena, CA 91109

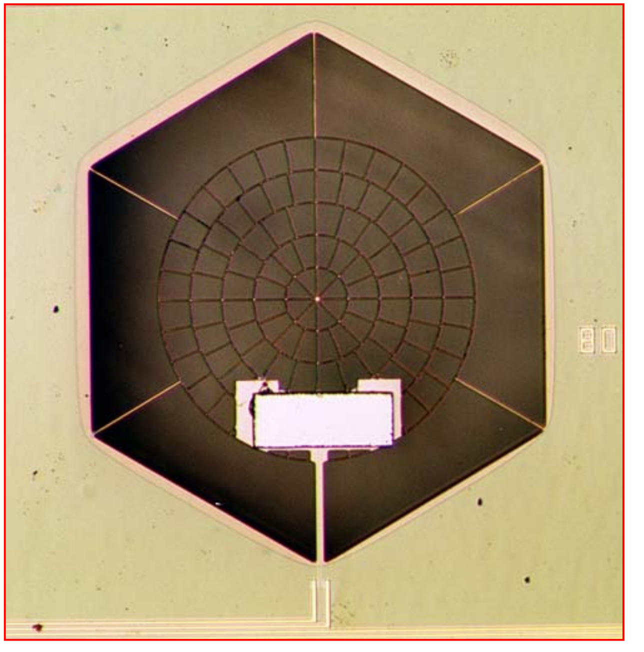
Introduction

- **Advantages & Requirements**
- **Fabrication Processes**
- **Risks**
- **Present Status**
- **Future Work**

Advantages

Spider-web architecture provides

- low absorber heat capacity
- minimal suspended mass
- low-cosmic ray cross-section
- low thermal conductivity = high sensitivity



Design Values

	Wavelength (μm)	NEP x 10^{-17} (W $Hz^{-1/2}$)	Tau (ms)	Dark pixels	# of detectors	Dimension (arcmin)	Thermi-stors	Requirement Reference	5 MΩ Resistors
Photometer	250	8.9	9	2	139	4x8	2	IRD-PHOT-R02	1
	350	6.7	11	2	88	4x8	2	IRD-PHOT-R02	1
	500	4.9	14	2	43	4x8	2	IRD-PHOT-R02	1
Spectrometer	250 TBC	12.0	3.4	2	37	2.1	2	IRD-SPEC-R04	1
	400 TBC	11.9	4.9	2	19	2.1	2	IRD-SPEC-R04	1

Design Values, cont.

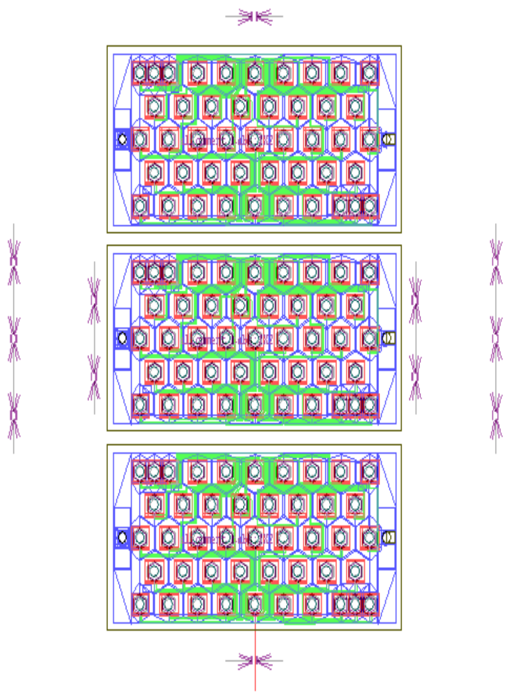
Table 3-1-1(SSSD) Summary of Detector Design Values

Quantity	Units	P/LW	P/MW	P/SW	S/LW	S/SW
Q	pW	3	4	5	12.5	9.8
NEP_{tot}	e-17 W/√Hz	6.0	7.9	10.0	14.0	13.4
G_0	pW/K	50	64	80	140	210
V_{bol}	mV_{rms}	3.7	4.2	4.7	7.6	6.3
S_{dc}	e8 V/W	4.3	3.7	3.3	2.1	2.1

Table 3-1-2(SSSD) Summary of Common Detector Design Values

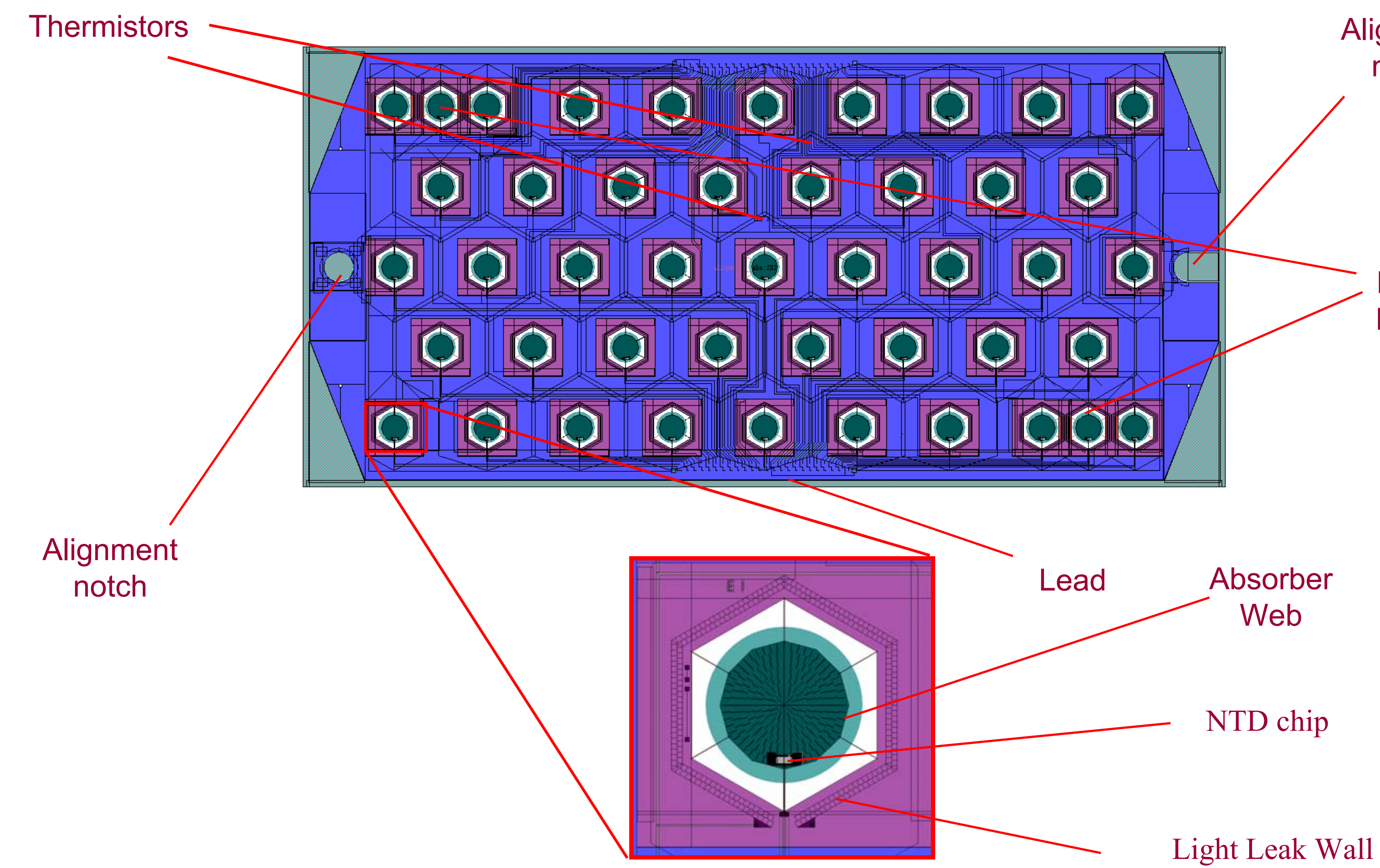
Quantity	Value	Unit
R_0	180	W
D	41.8	K
T_{bol}	0.39	K
R_{bol}	5.8	MW
Z/R	0.4	

Composite of P/LW Array Mask set

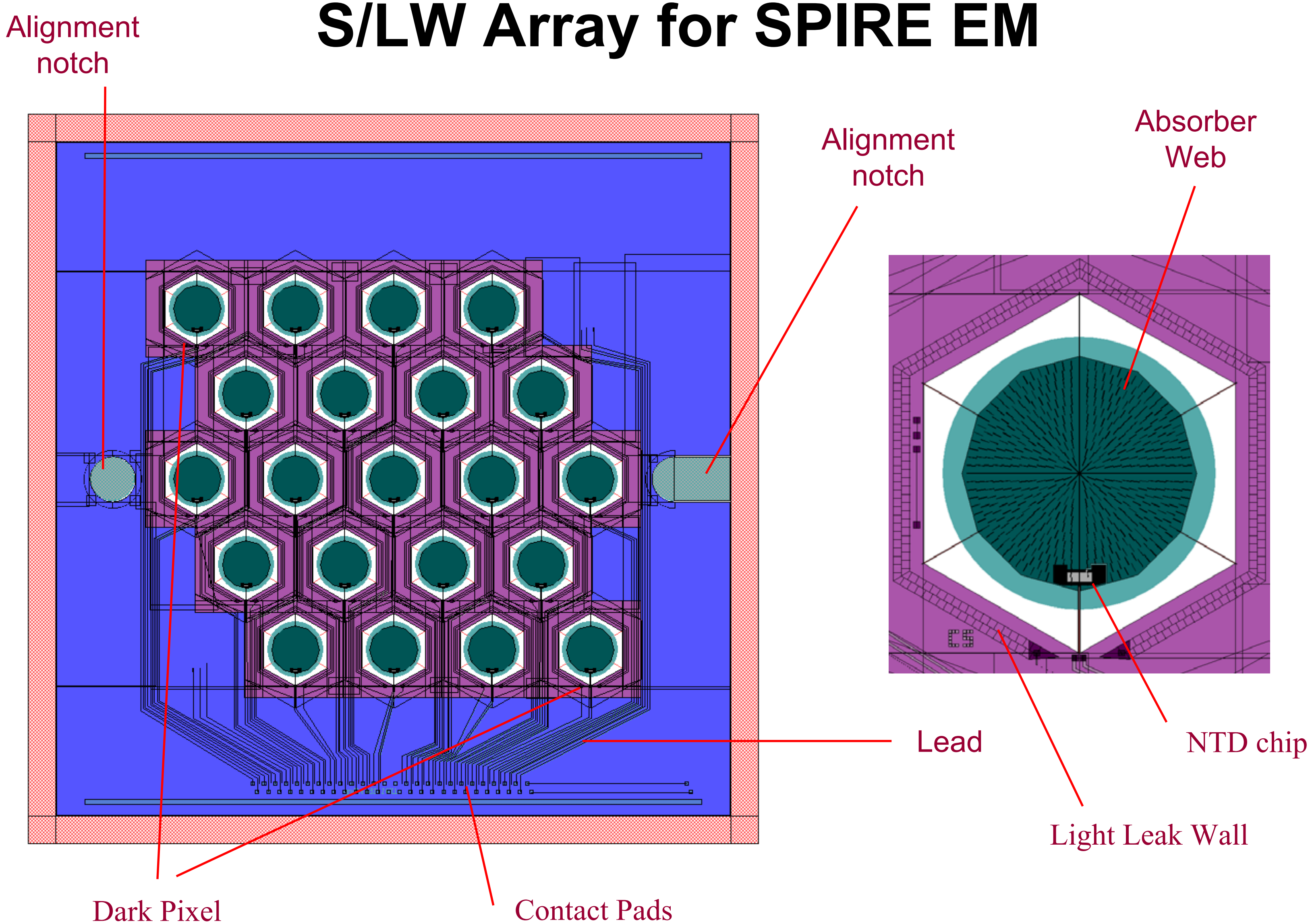


- Stack of 7 masks used in the fabrication of the bolometers.
- These are the final design of the masks that will be used in the fabrication of the P/LW CQM
- They are not yet under configuration control

P/LW Array for SPIRE CQM



S/LW Array for SPIRE EM



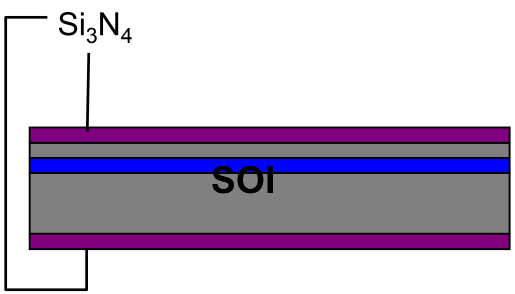
MDL (MicroDevices Laboratory) Fabrication Process Description

- MDL is a DNP organization that has adopted facility and process improvements to accommodate a flight program
  - Facilities Monitoring
    - ✓ Particle Detector PMS
      - Wafer Particle Detector
    - ✓ Electrostatic Discharge (ESD) Control
      - Ionizing blowers
      - Simco, Aerostat, Ionizer, Semtronic
      - NRD Ionizer cartridges for N2 guns and Nuclespot Static Eliminators
    - ✓ Thermocouple Temperature Readouts

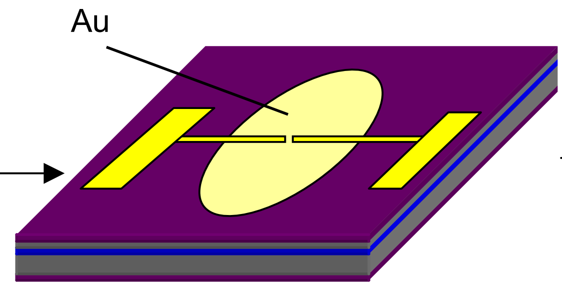
MDL Fabrication Process Description, continued

- Designated locked flight cabinets
- All materials used in this program will have certifications and are used exclusively for the flight project
- Travelers, AIDS, Procedures, Traceability to manufacture to the lots, etc have been implemented
- All personnel working on project have taken the flight hardware classes
- Facilities certified, ESD
- Cleanliness certifications in place

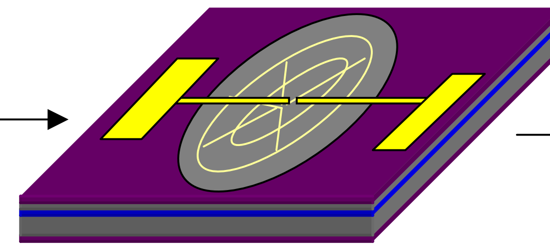
Fabrication of Detector Arrays



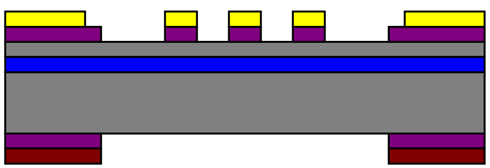
Deposit low stress Si_3N_4 onto SOI wafers



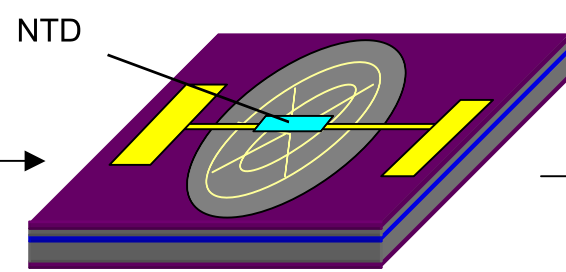
Metalize top $Si_3 N_4$ with absorber, leads and contacts by liftoff



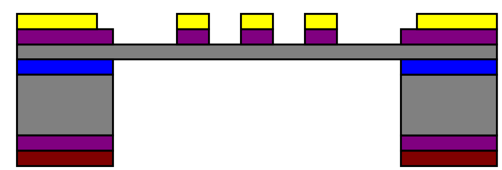
- **Pattern absorber onto metalization and nitride with photoresist**
- **Dry etch absorber pattern into metalization and nitride**



Pattern backside with photoresist and dry etch backside Si_3N_4

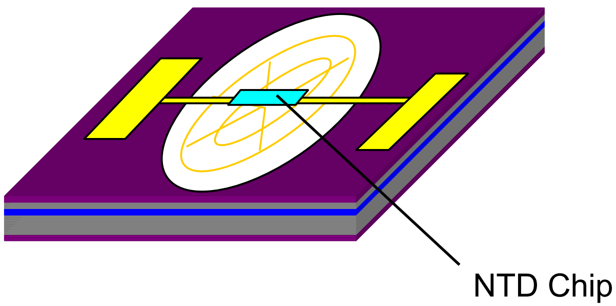


Metalize In bumps by liftoff and bump bond NTD Ge thermistor to sample

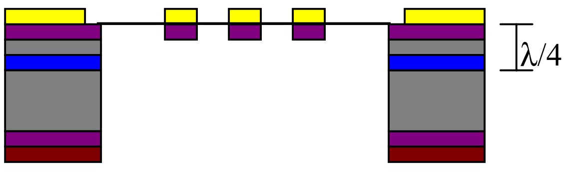


Dry etch Si through backside of SOI wafer with deep trench Si etcher to buried oxide layer. Strip buried oxide layer with wet etch.

Fabrication of Detector Arrays (cont.)



Wet etch top Si from backside and release web

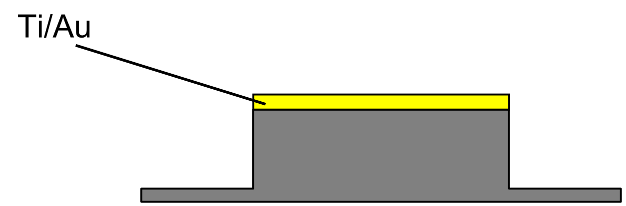


Cross-sectional view of the Arrays

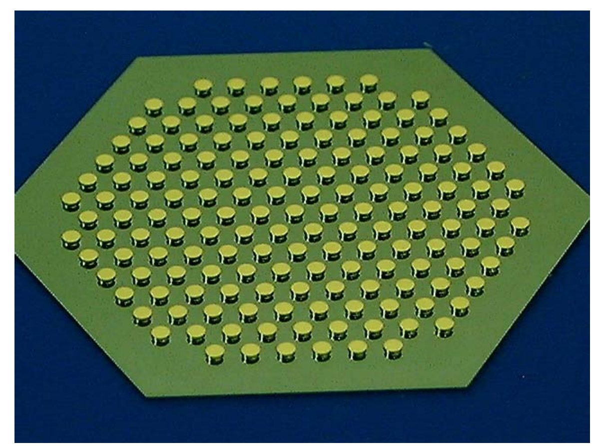
Fabrication of Array Backshort

Form backshort post to required depth with STS Deep RIE of cleaned Silicon wafer

→

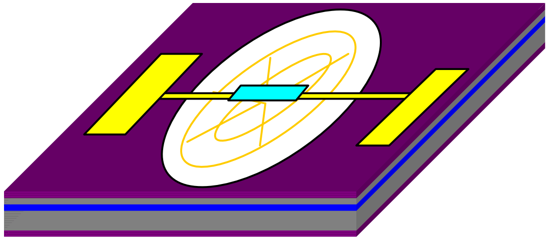


Ti/Au deposition,
Cross-sectional view of the Backshort



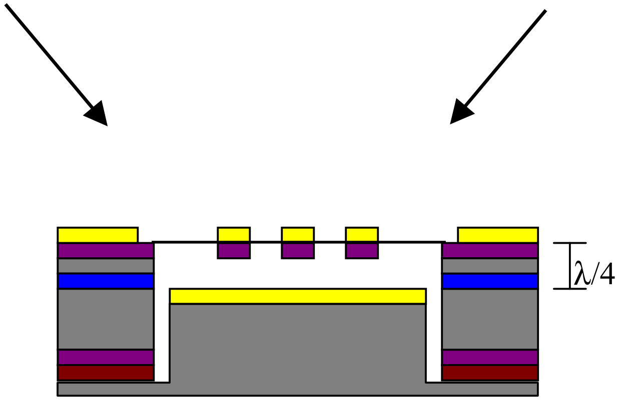
Top view of a Backshort

Array Assembly



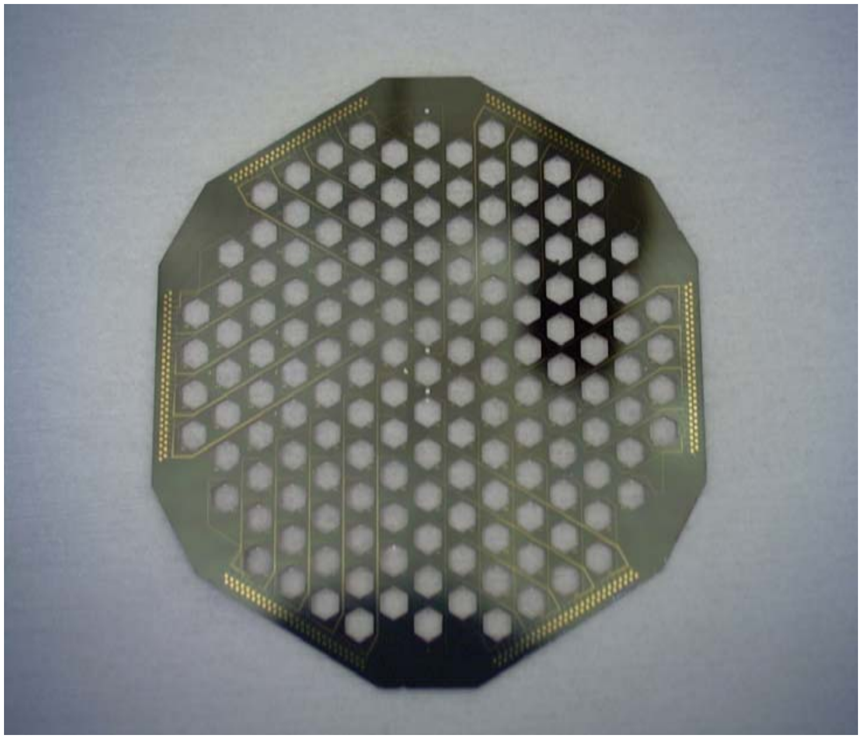
Detector Array

Backshort Device



Assemble of Detector and Backshort

Example of Technology Heritage, Bolocam



- **Bolocam ; 151 Detectors**
  - **Web Failure : 18**
  - **Chip Failure : 10**
  - **Lithographic Error : 2**
- **Yield = 80.2 % (121/151)**

We have successfully delivered the 151 detector array Bolocam with a better than 80% yield. The lessons we learned during the fabrication of this array enables us to expect even better yield on the HSO detector arrays.

Risks

Devices	Risks	Mitigation
Detector Arrays	Lithographic error	Most critical lithography steps now use non-contact aligners (stepper, e-beam)
	In bump	Establish the highest temperature to which the detector can be subject to and remain viable
	Tight schedule	Have added processing engineers and inserted slack
Backshort	Uniformity across surface	Ultra clean process & Deep RIE development

Array Status

	Device	Deliver to	Current Status
EM	P/SW (7 elements, 250µm)	Univ. of Colorado, Feedhorn test	Completed/Delivered
	S/LW (7 elements, 400µm)	Univ. of Colorado, Feedhorn test	Final test before delivery
	S/LW (21 elements, 400µm)	JPL, Cryo./Noise test	Ready for release
CQM	P/LW (43 elements, 500µm)	JPL, Cryo./Noise test	Oct., 2001
	S/SW (37 elements, 250µm)		Feb., 2002
	S/LW (21 elements, 400µm)		
FM	S/LW (21 elements, 400µm)	JPL, Cryo./Noise test	2002 – 2003
	P/LW (43 elements, 500µm)		
	P/MW (88 elements, 350µm)		
	P/SW (140 elements,250µm)		
Spare	SSW (37 elements, 250µm)	JPL, Cryo./Noise test	2002 – 2003
	PMW (88 elements, 350µm)		
	PSW (140 elements, 250µm)		

Document Status

Document Title	Document #	Statue
AIDS for Wafer level fabrication of CQM P/LW Array	221731	Signed off
Procedure for Wafer level fabrication of CQM P/LW Array	JPL D# EP518503 Version A	Signed off
Traveler for Wafer level fabrication of CQM P/LW Array	N/A	Signed off
Map of Wafer level CQM P/LW Array	N/A	Signed off
Array Data sheet for Wafer level fabrication of CQM P/LW	N/A	Signed off
AIDS for Device level fabrication of CQM P/LW Array	221732	Signed off
Procedure for Device level fabrication of CQM P/LW Array	JPL D# EP518504 Version A	Signed off
Traveler for Device level fabrication of CQM P/LW Array	N/A	Signed off
Map of CQM P/LW Array Device	N/A	Signed off
Data sheet for Device level fabrication of CQM P/LW Array	N/A	Signed off

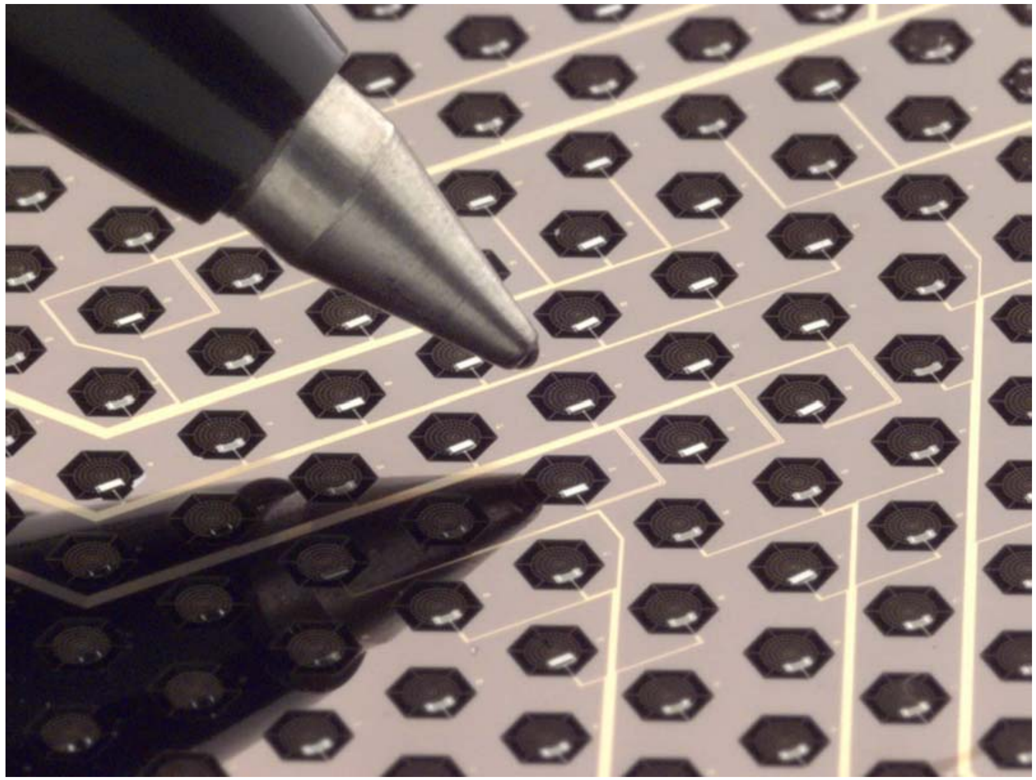
Summary and Future Work

- Process techniques have been developed, resulting in an increase the viability of the applicable device fabrication. (ex. ; NTD chip bonding, stepper lithography)
- Final devices will have 90% or better yield with array performance to specification.
- We are on schedule with the EM delivery.
- We have completed Bolocam fabrication and delivered to Caltech.
- Future work as stated in Array Status.

5.5
SPIRE DETECTOR DEVELOPMENT

Hien Nguyen

SPIDER WEB BOLOMETER ARRAY

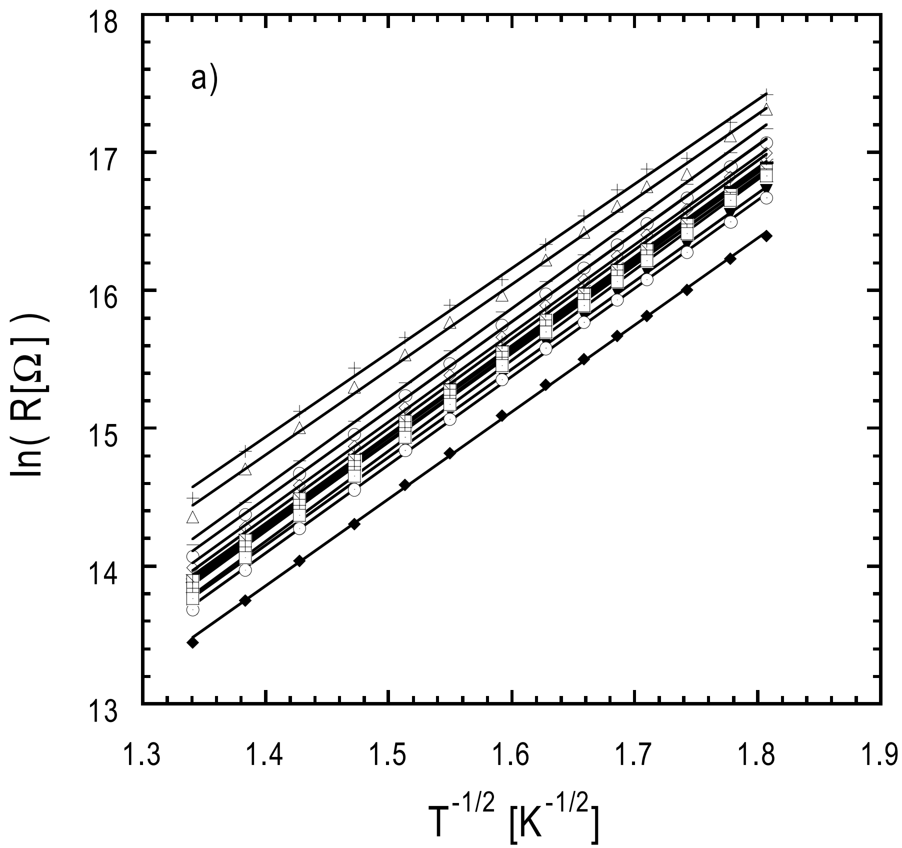


The array of micromesh bolometers designed for photometry at λ = 350 μm. Each device has a 725 μm diameter absorber with a grid spacing of 72.5 μm and a filling factor of 0.077. The absorber is suspended by five 5 μm wide, 240 μm long support legs. The thermistors are placed to one side of the absorber and read out with two leads deposited on a single, 18 μm wide support member. The pixel spacing is 1.75 mm in order to allow the array to be tested with 1fλ or 2fλ f/5 feeds, although only the 2fλ feeds were eventually tested in a 19-element format.

Bolometer Description

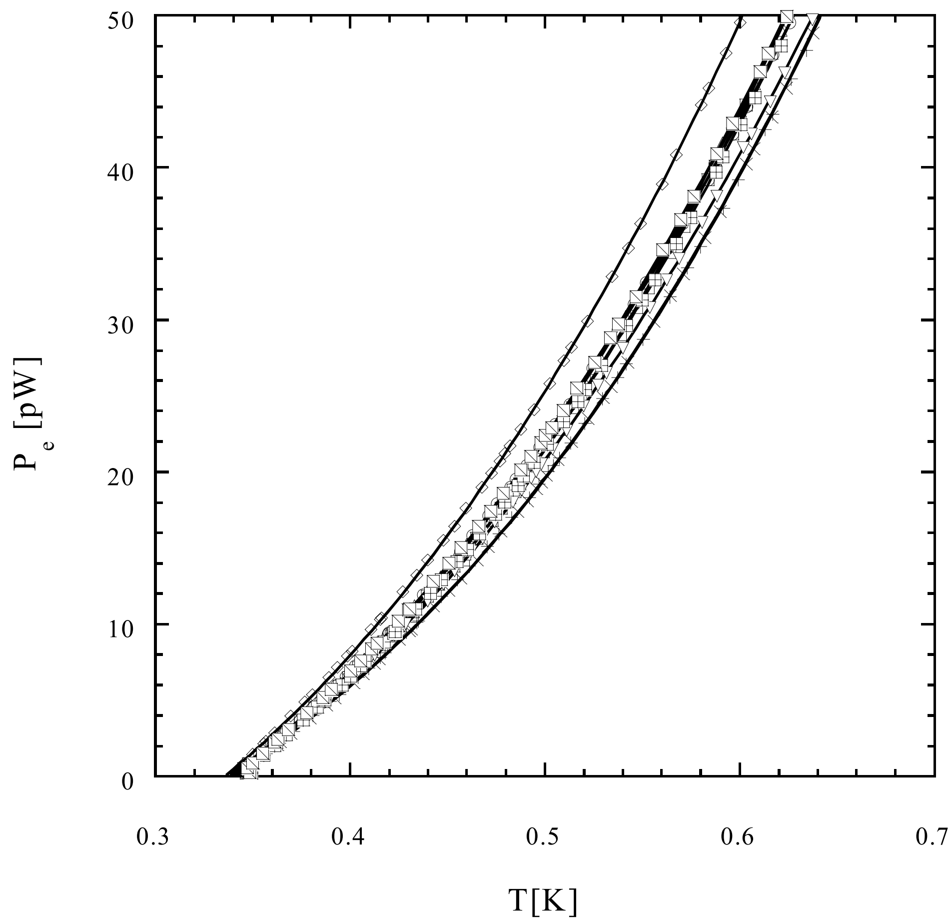
- Demonstration array to meet requirements of 350 micron wavelength photometer
  - Used in technology downselection
- Detector demonstrates performance near specification
  - Array was placed through flight-like performance test program

Resistance vs. Temperature



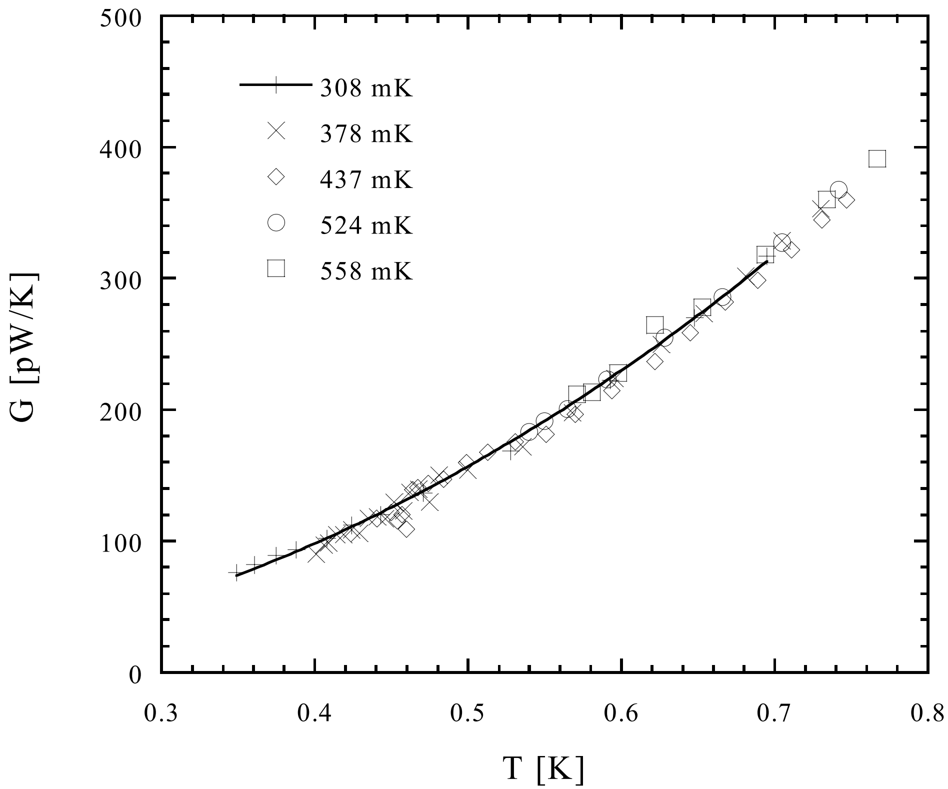
Hopping conduction in NTD Ge: $R = R_0\, e^{\sqrt{\Delta/T}}$

Thermal Conductance



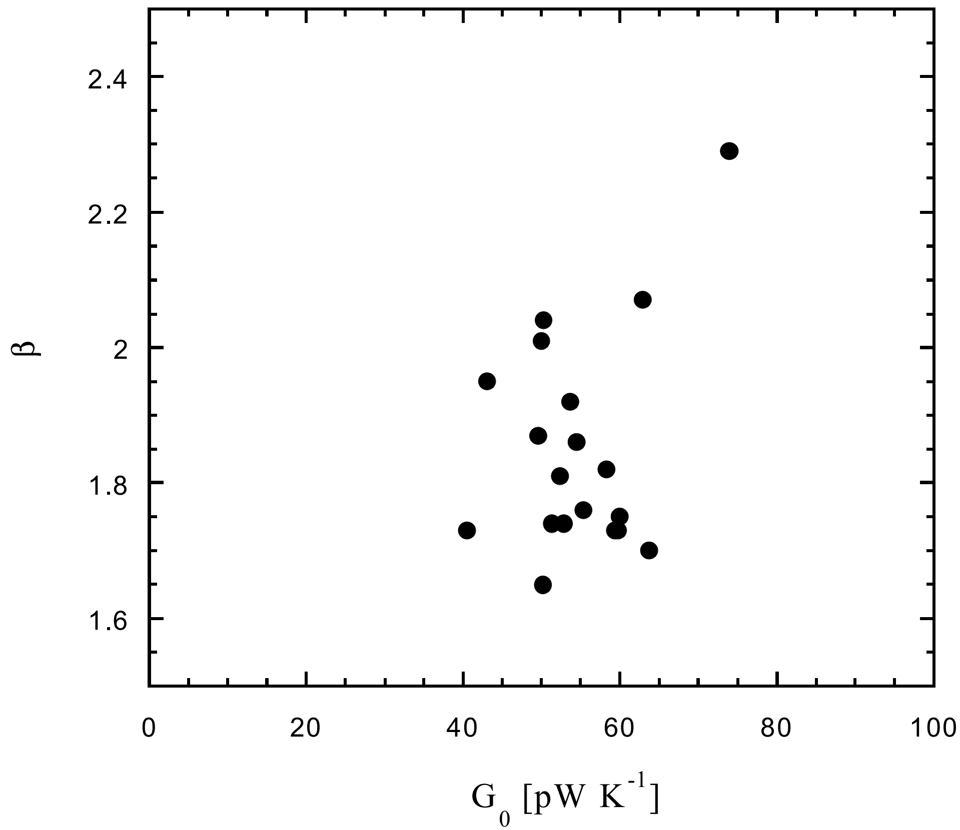
Measurement of thermal conductance from dark load curves

G vs. T



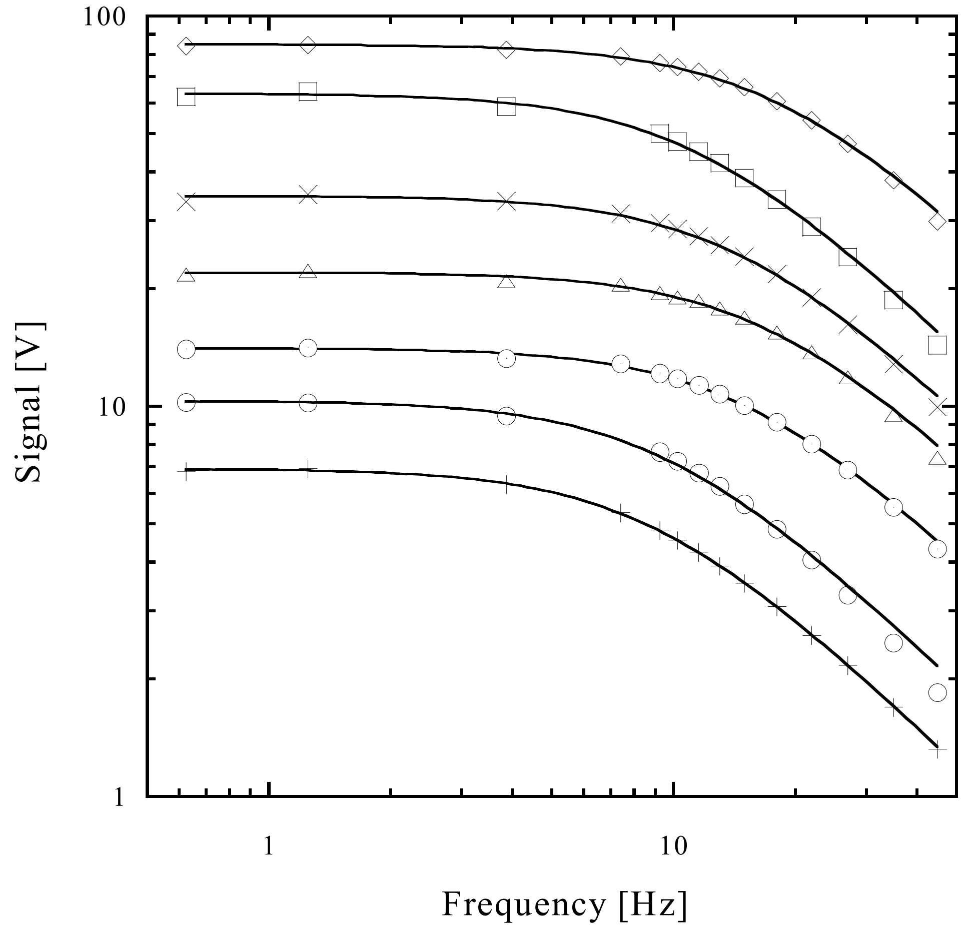
- Comparison of thermal conductivity derived from dark load curves over a range of temperatures
- Good agreement indicates electrical non-linearities small

Scatter in Thermal Conductance



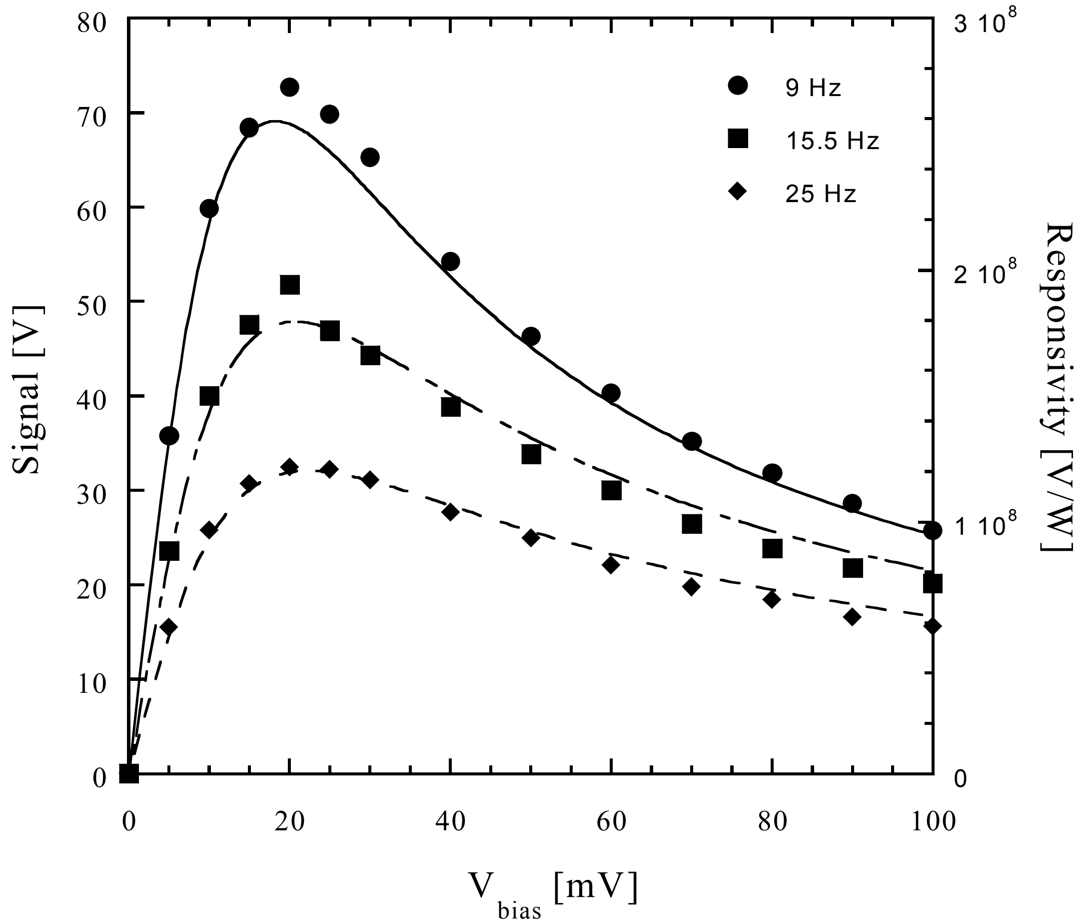
~15 % scatter in the thermal conductivity over the array

Time Constant



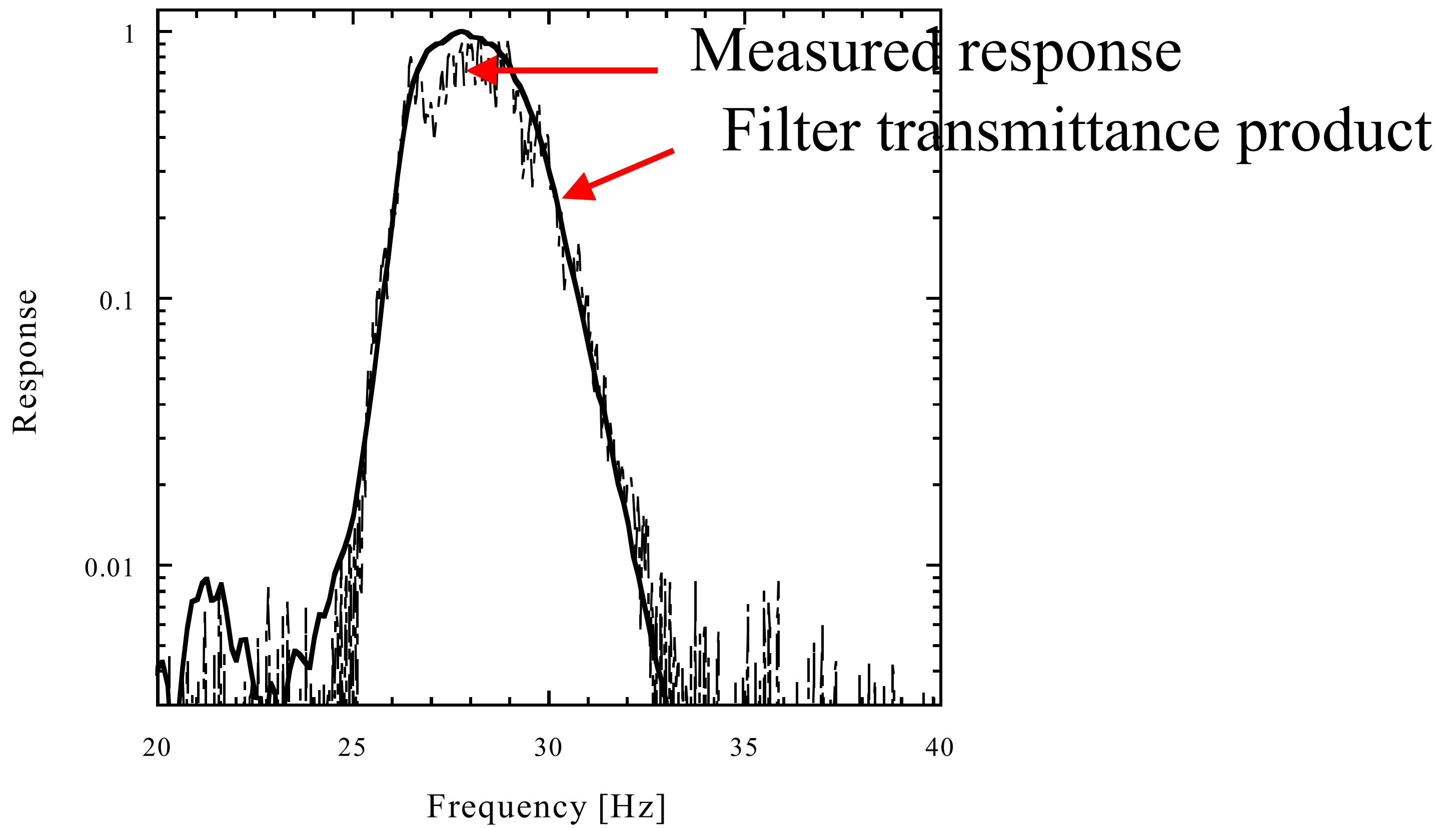
Response described by a single-pole filter

Responsivity



Good agreement between electrical model and optical data

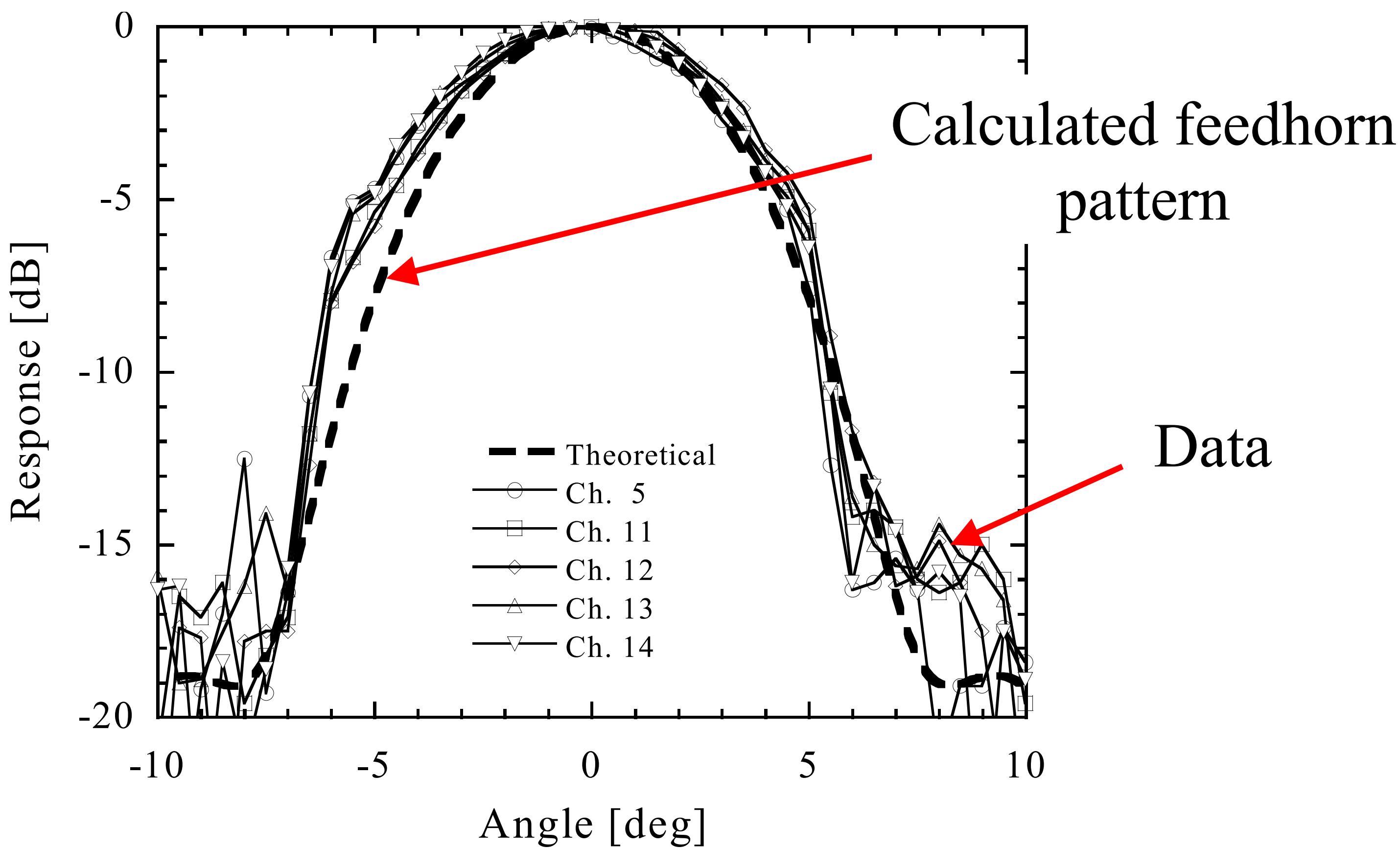
Spectroscopy



Reasonable agreement with expected profile

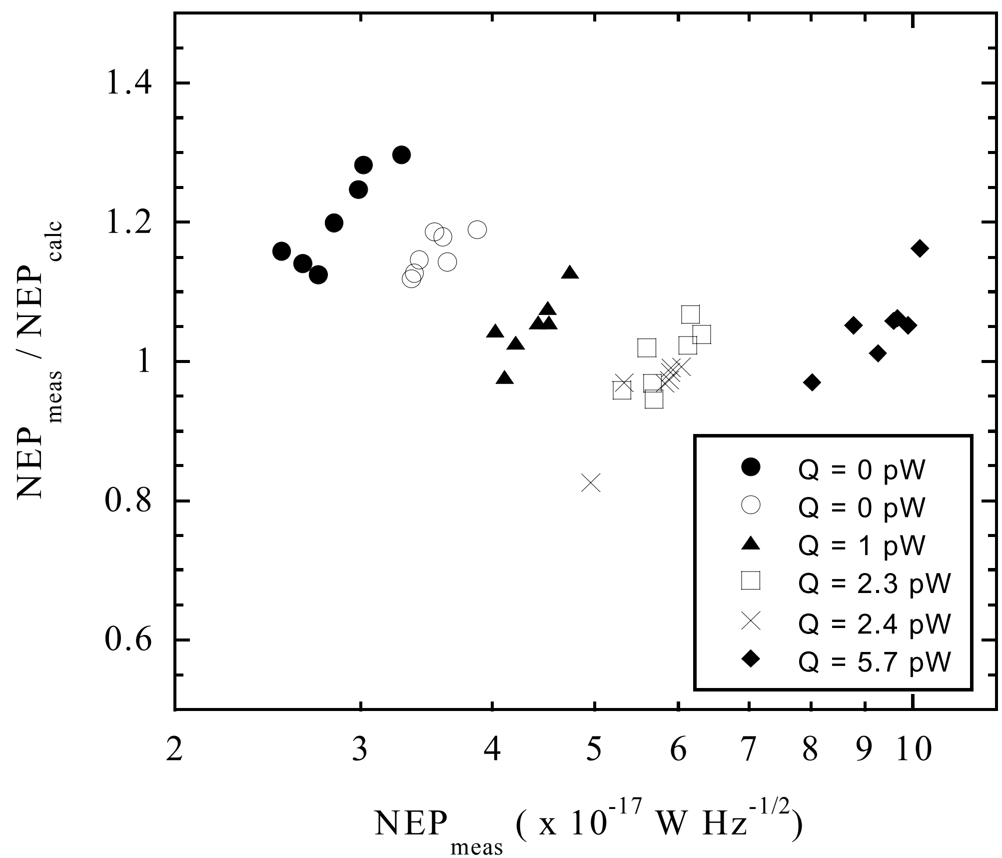
Some dips in passband – may be from feedhorn

Beam Map



Some deviations from model – may be from Lyot stop

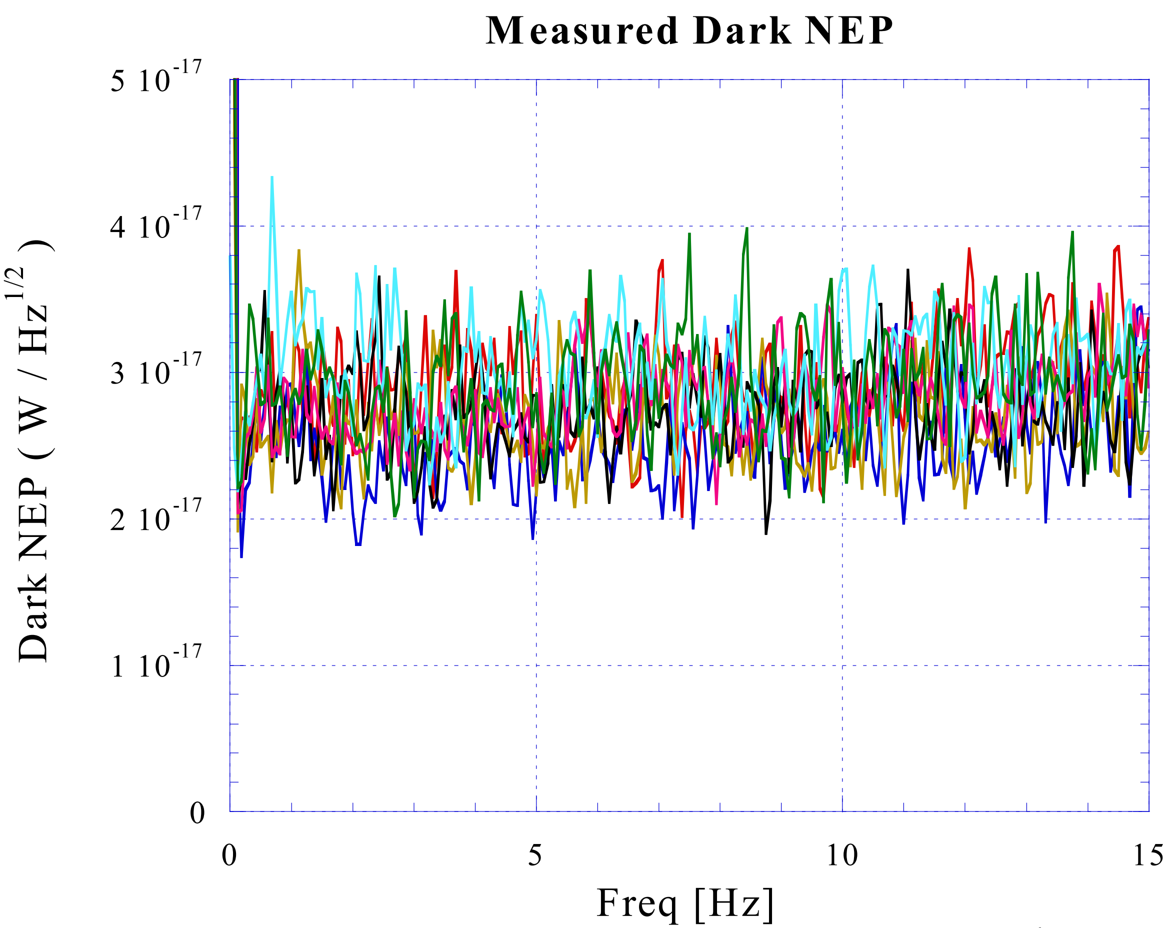
Background-limited performance ratio



Near-background limited performance

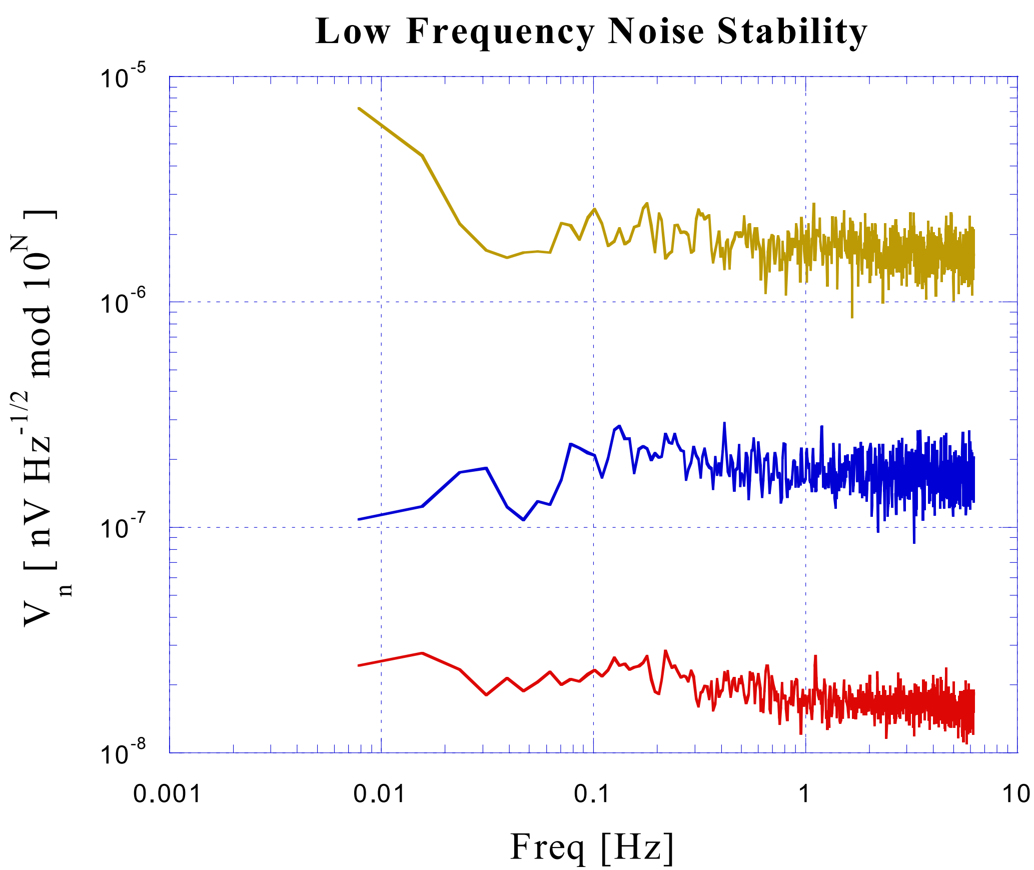
Photon loading calculated from optical load curve

Dark Noise Measurements



Close agreement with Mather noise model

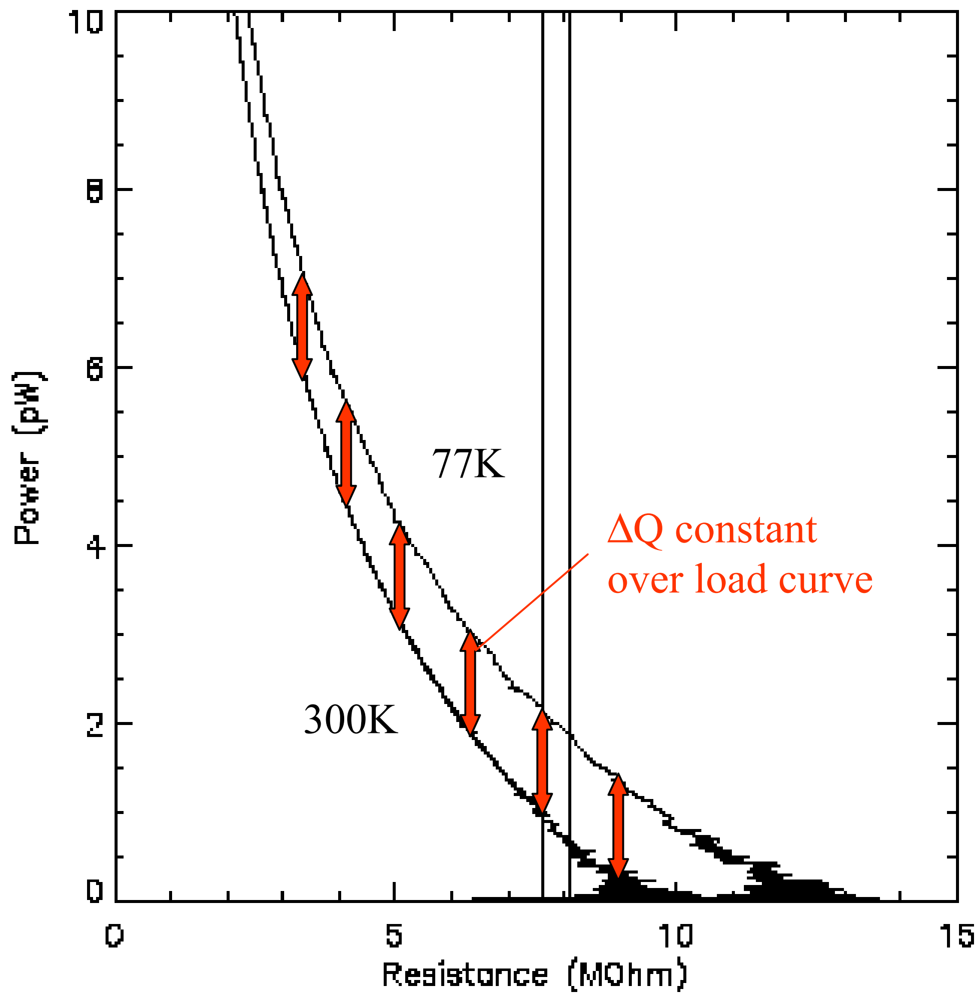
Low Frequency Noise Stability



Measurement of Optical Efficiency

TECHNIQUE

- Take IV Curves for each optical loading
- Compute Resistance as a function of electrical power (bias Voltage)
- Optical power inferred from difference in electrical power $\Delta Q = \Delta P_{electrical}$



Measurement of System Cross-talk

1. Optical Cross-talk
- Focus light into one pixel and measure the response
- 10 Hz chop, DC bias at QMW

  ave = 5.5 % for adjacent pixels

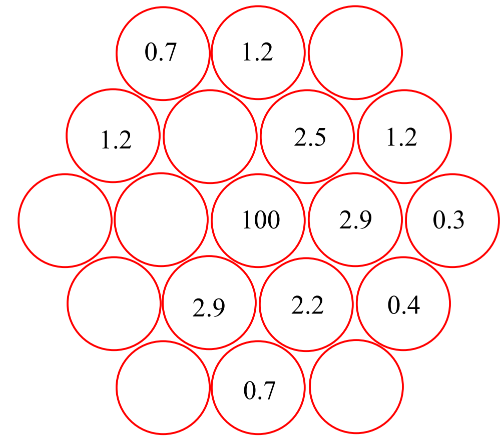
  < 0.4 % Other pixels

•Adjacent pixel coupling was 2.7 % at JPL with different external optics

•Cross-talk may arise from bacus optics, feedhorns, or electrical coupling*, but appears due to defocus of external optics*

•N-N cross-talk < 1 % based on symmetry of focal plane maps

2. Electrical Cross-talk
- Measure the response with AC-bias at 200 Hz and demodulate
- <u>no increase</u> above optical cross talk.
- Crosstalk in 5 MW load resistor < 0.05%



A Optical Cross-talk Map

Summary

Measured Array Specifications

Quantity	Measured Value	Spec (Target)	Units
Dark <NEP_{bol}>	2.7×10^{-17}	(2.5×10^{-17})	[W/√Hz]
Dark <S_e>	5.88×10^{8} (± 6 %)		[V/W]
Yield	0.9	0.9	
<G_0>	54.8 ± 7.6	120 (60)	[pW/K]
<C_0>	0.96 ± 0.24	(1.0)	[pJ/K]
τ	11.7 ± 0.8	8 / 30	[ms]
η_{bol}	0.46 – 0.64	0.8	
1/f knee	~30	100	[mHz]
NEP_{bol}/NEP_{blip}	1.10 (+0.05, –0.15)	1.15	
DQE	0.38 - 0.53	0.60	

- **Good optical efficiency**
  but below expected value
  with $\eta_{bol} = 0.8$, DQE = 0.66
- **G_0 and C_0 equal to target quantities**
- **High uniformity in NEP and responsivity**
  high yield
  background limited for Q > 1.5 pW
- **Detectors show theoretical noise and responsivity**
  close agreement with Mather bolometer model
  no excess noise or non-linearity
- **Stable noise performance for drift-scanned observations**

Design Changes from Downselect Array

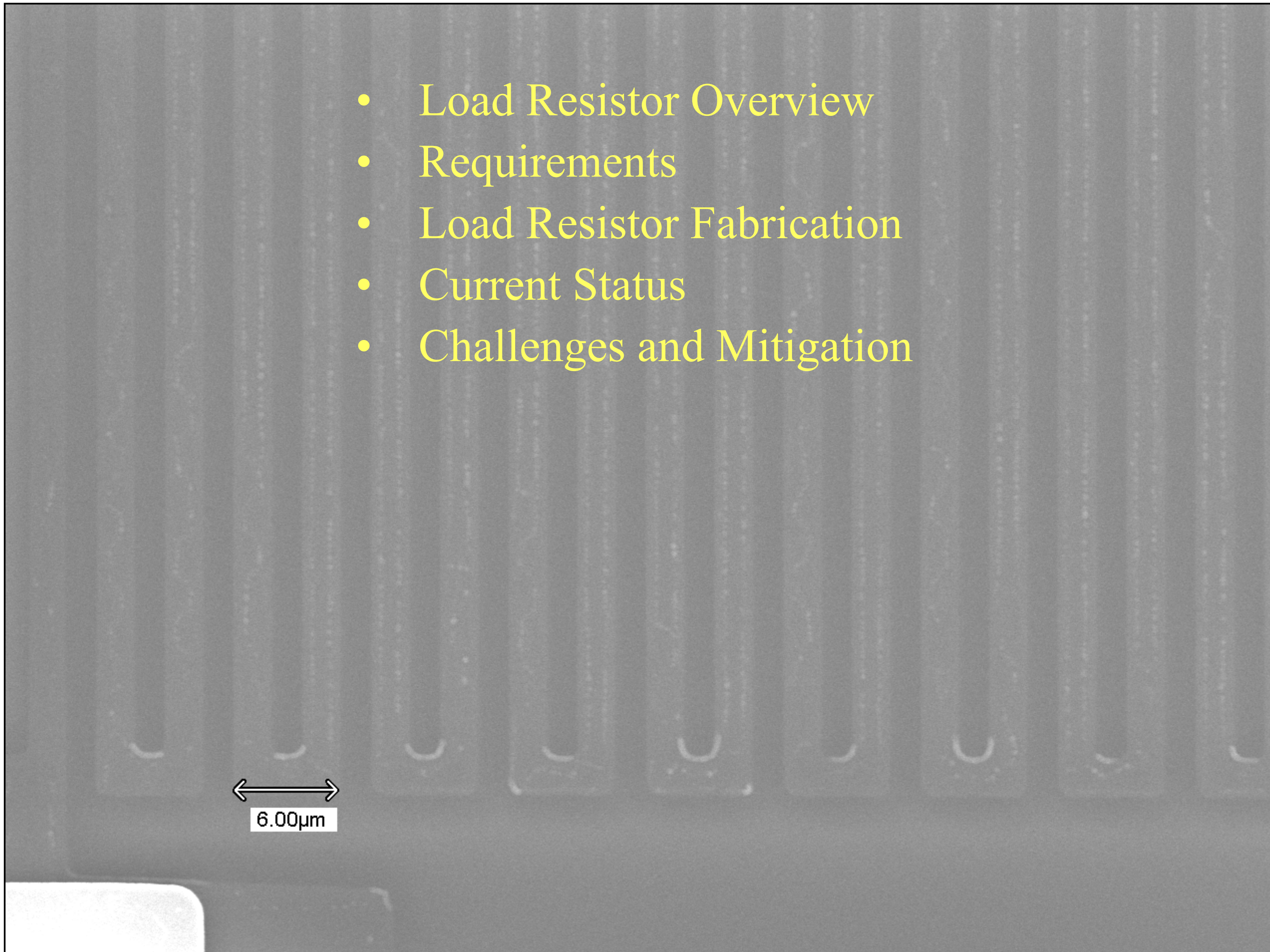
- Low optical efficiency is primary issue to be resolved
  - High efficiency demonstrated in millimeter-wave instruments
  - High beta (1.85) indicates significant contribution from silicon nitride
  - No significant change after modifying feedhorns waveguides
  - Cavity dimensions confrimed by measurement
  - Bolocam array wafer with same process also showed low efficiency compared with earlier array
- Loss may be due to thermal inefficiency
  - Decrease nitride thickness from 1.8 µm to 0.8 µm
  - Increase support beams from 250 µm to 500 µm
  - Increase absorber metal thickness from 10 to 12.5 nm

5.6
Load Resistor Fabrication

Anthony Turner, Eric Jones

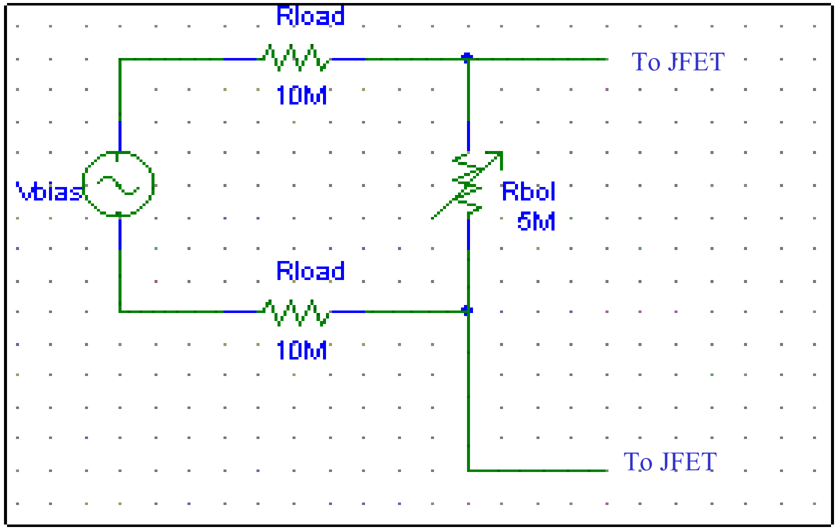
Overview

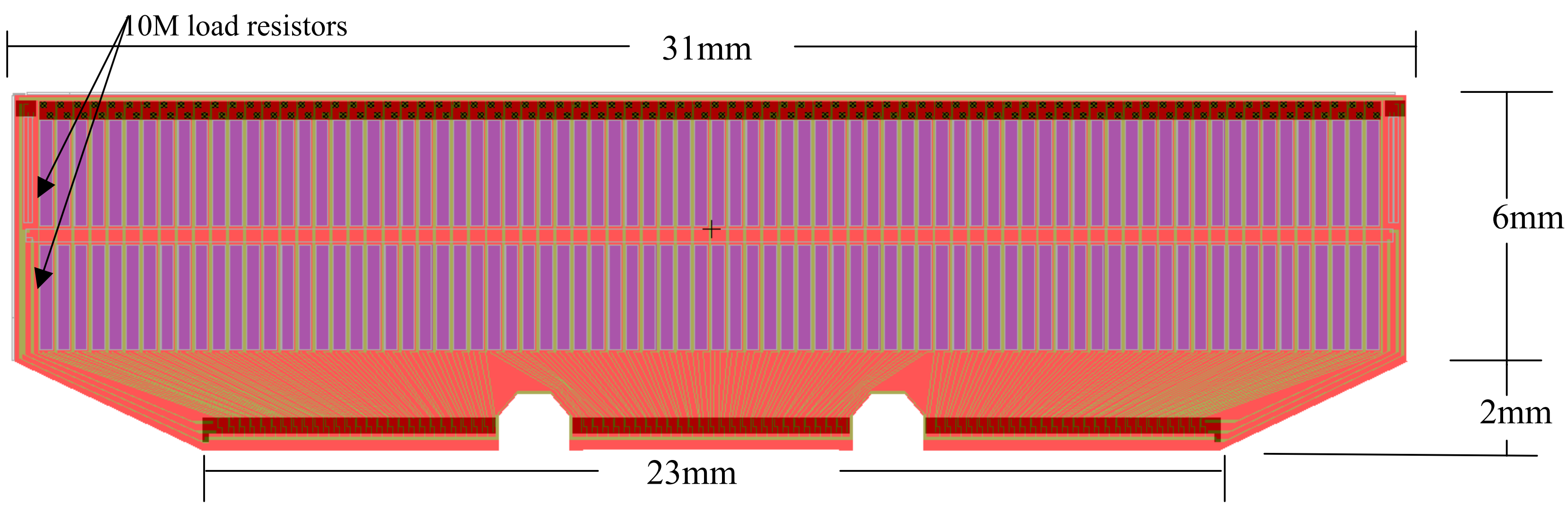
- Load Resistor Overview
- Requirements
- Load Resistor Fabrication
- Current Status
- Challenges and Mitigation



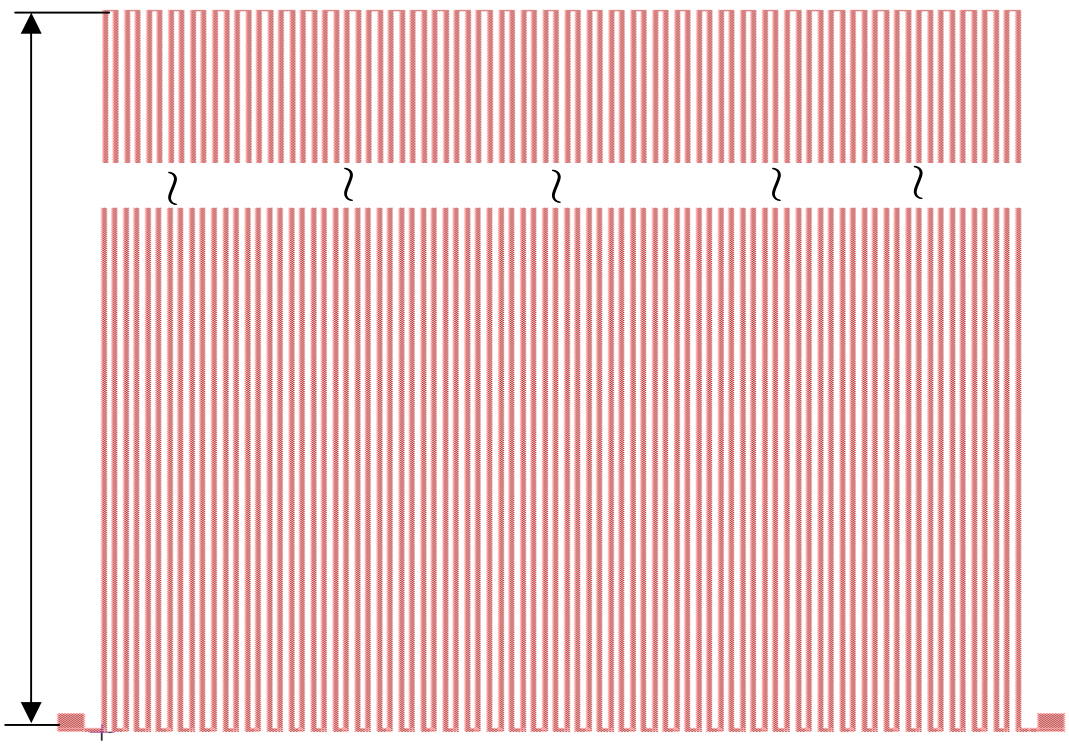
Load Resistor Module Overview

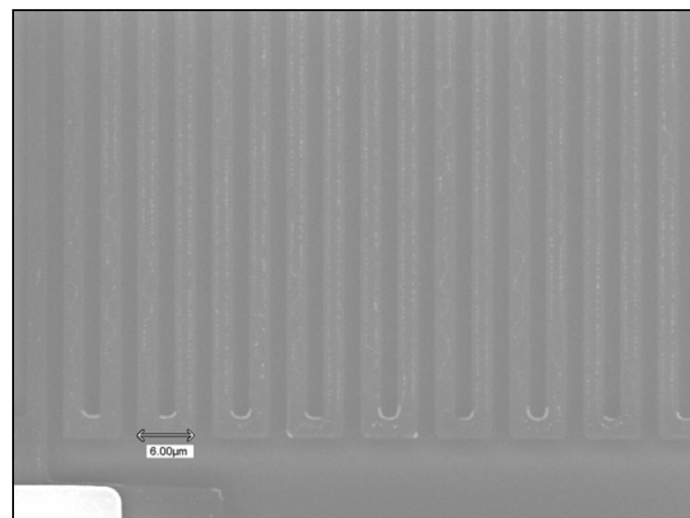
- Provide AC bias circuitry for bolometer arrays
- 78 channels per load resistor
  - 1 redundant channel per 25 channels
  - Allows jumpers via wirebonds
  - Channels needed per LR is72 for the PSW array (>92% yield)
- *2 high and low bias lines for redundancy*
- 10Meg load resistors (NiCr based thin film)
- Ease of fabrication
  - Two metalizations, one passivation layer, one etch to define perimeter of device





10 Meg NiCr Load Resistors Overview





Load Resistor design:
2um lines/4um centers
NiCr metalization:
100k□ assuming 100Ω/ □

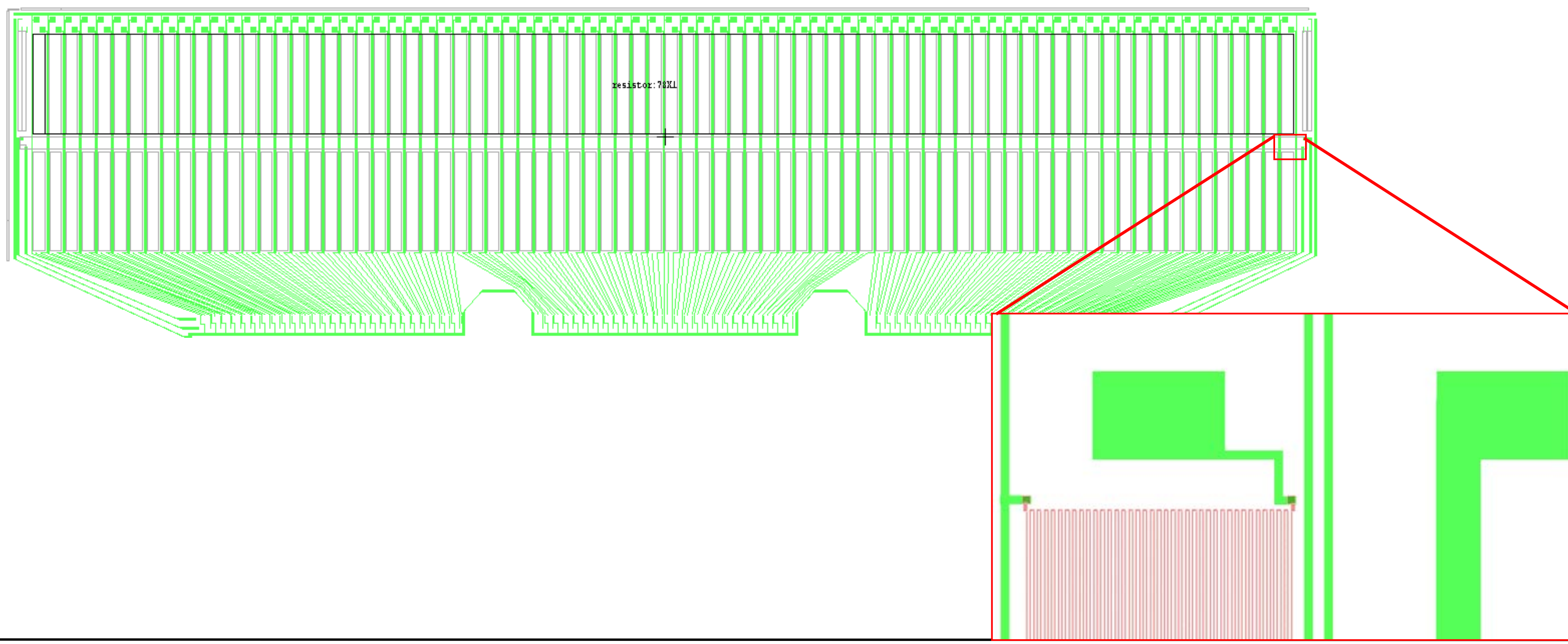
Load Resistor Requirements

Device Type	Channels	#Load R needed	Channel Yield Left 26 channels	Channel Yield Center 26 channels	Channel Yield Right 26 channels
PLW	48	2 per array 4 total		>95%	
PMW	93	2 per array 4 total	>85%	>85%	>85%
PSW	144	2 per array 4 total	>95%	>95%	>95%
SLW	24	1 per array 2 total		>80%	
SSW	42	2 per array 4 total		>90%	
Total		18 devices plus spares			

•Note: 14 load resistor fabricated per wafer. Channel yield and channel location will determine which array they can be coupled to.

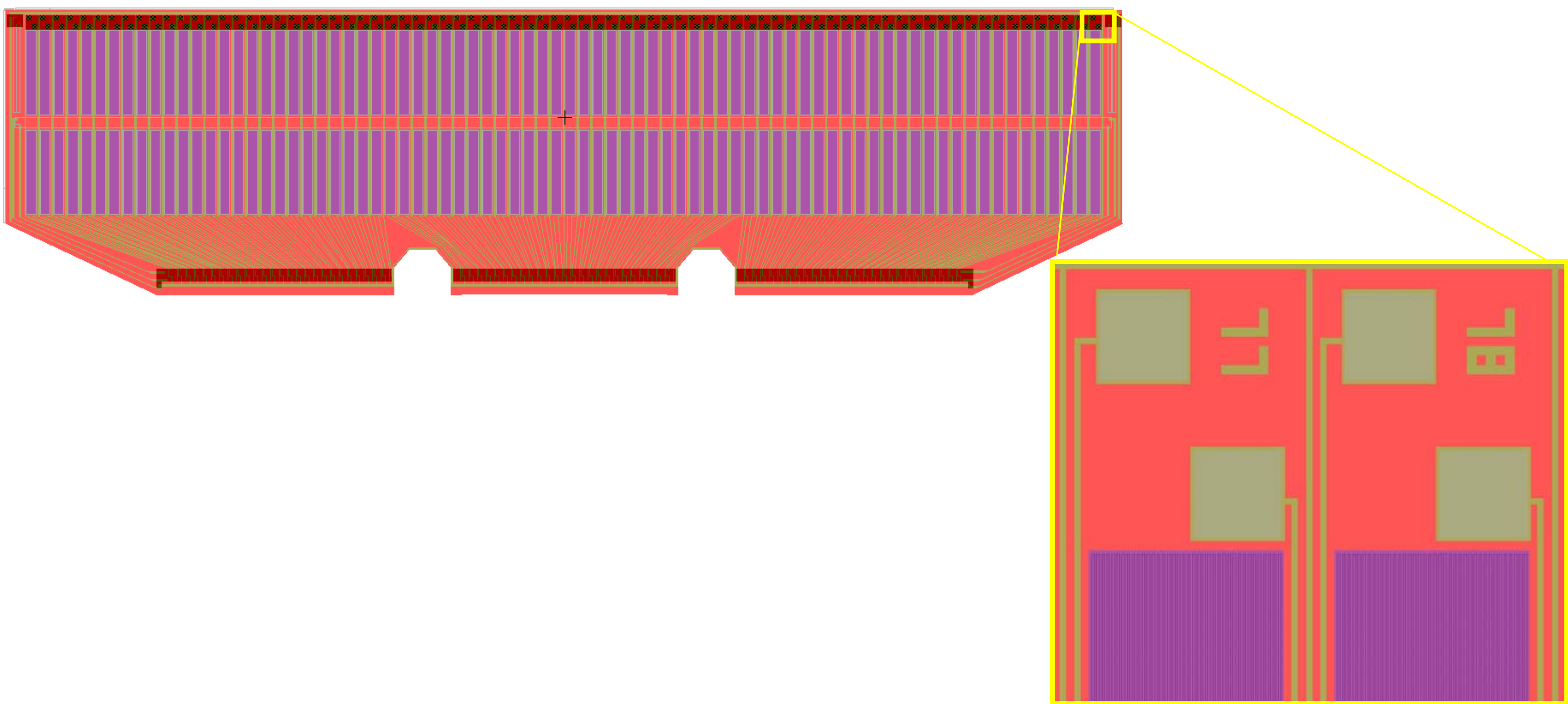
Load Resistor Fabrication

- Start with a 4in DSP Si Wafer with a 1um low stress SiN (provided by Stanford University)
- Deposit NiCr/Au over entire wafer
  - NiCr will be used for the high impedeance load resistors (~10-20 M)
- E-Beam pattern load resistor meanders and Au interconnects
- Utilize Ion Mill to etchback NiCr/Au to form meanders and interconnects
- Au wet etched over NiCr meanders to obtain low conductance thru NiCr (100Ω/□)



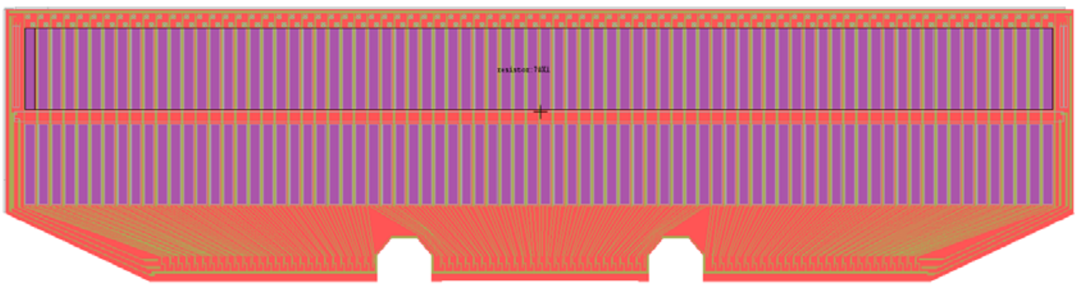
Load Resistor Fabrication (Cont)

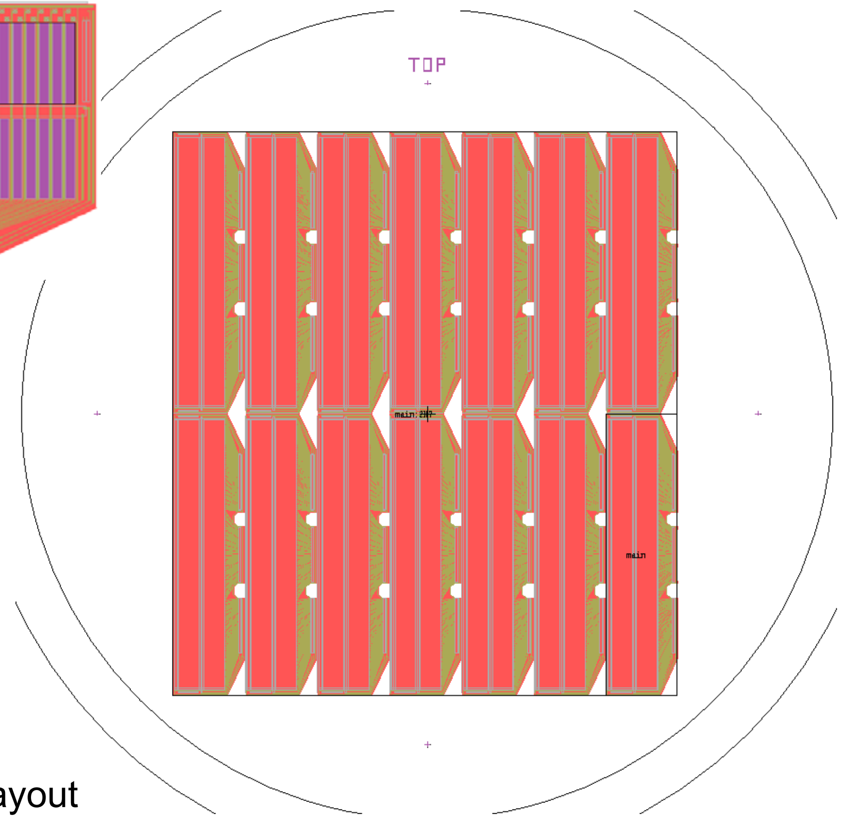
- Deposit PECVD oxide over entire wafer surface for passivation
- Pattern contact pad openings
- Wet etch PECVD oxide from these openings
- Deposit Cr/Au at these contact pads for wirebonding



Load Resistor Fabrication (cont)

- Pattern parameter of device for STS DRIE Si etch
- Strip off SiN in patterned area and STS etch Si
- Clean and deliver to testing

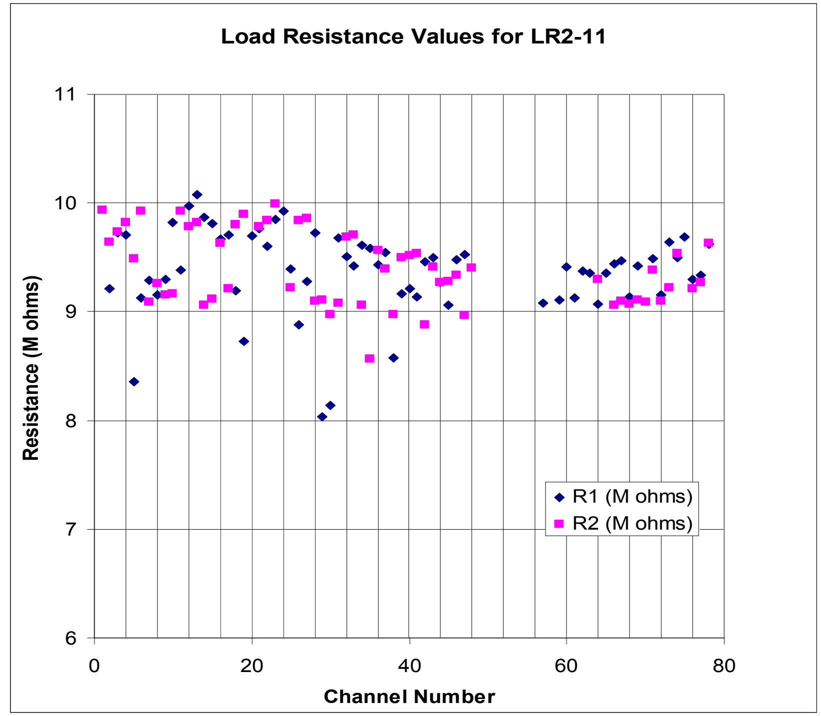




Wafer layout

Load Resistor Current Status

- EM Load Resistor have been completed and are awaiting cyrogenic tests
- Yield to this date has not been determined.
- Preliminary measurements indicate:
  – resistor yield of 85-95%
  – channel yield of 70-90%
  – Majority of failures due to a defect in the Si wafer (scratches in wafer)
- Preliminary tests conducted:
  – Conductivity measurements
  – N_2 Dip thermal shock test
    - No failures in passivation layer
  – Conductivity measurements after thermal shock
    - No failures in resistors
    - No failures in leads



Load Resistor Open Issues

- Open Issues
  - Process sheets are 90% complete
  - Noise data has yet to be conducted
  - Small line widths make photolithography process very challenging but within achievable constraints

- Mitigations
  - Multiple wafer runs should provide all devices needed for flight detectors

5.7
Kapton Cables for SPIRE Bolometer Arrays

By

Anthony Turner

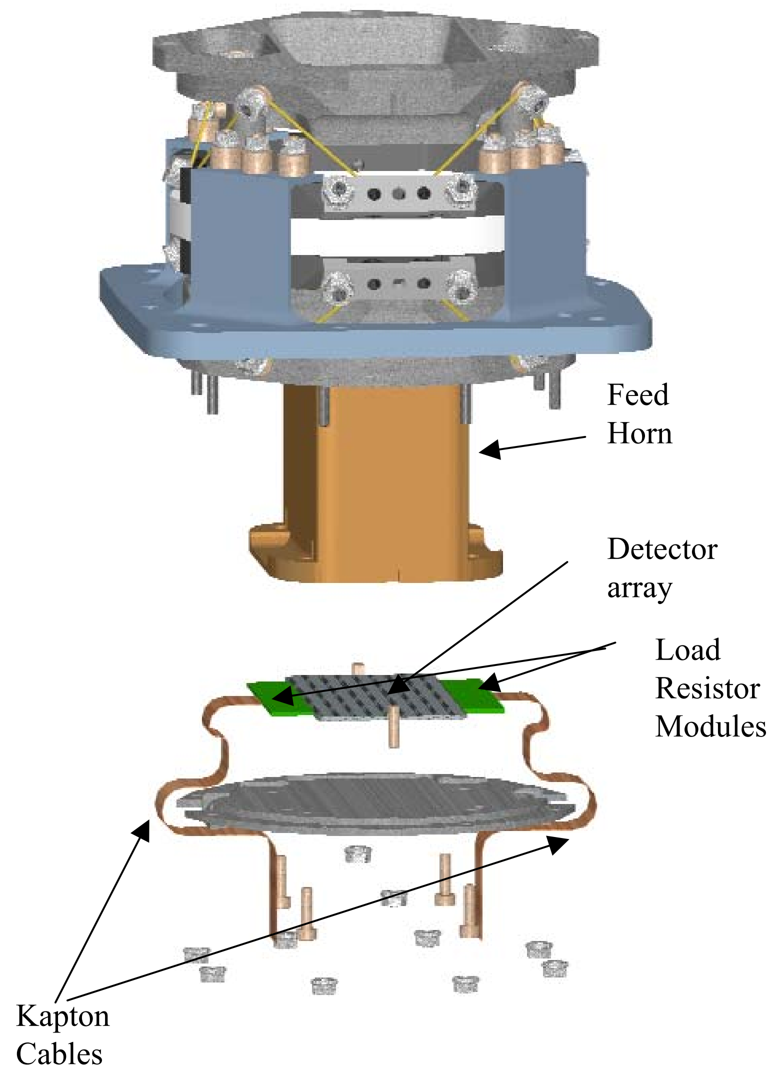
July 20, 2001

Overview

- Kapton Cable Overview and Status
- Cable Fabrication
- Challenges and Mitigations

Kapton Cable Overview

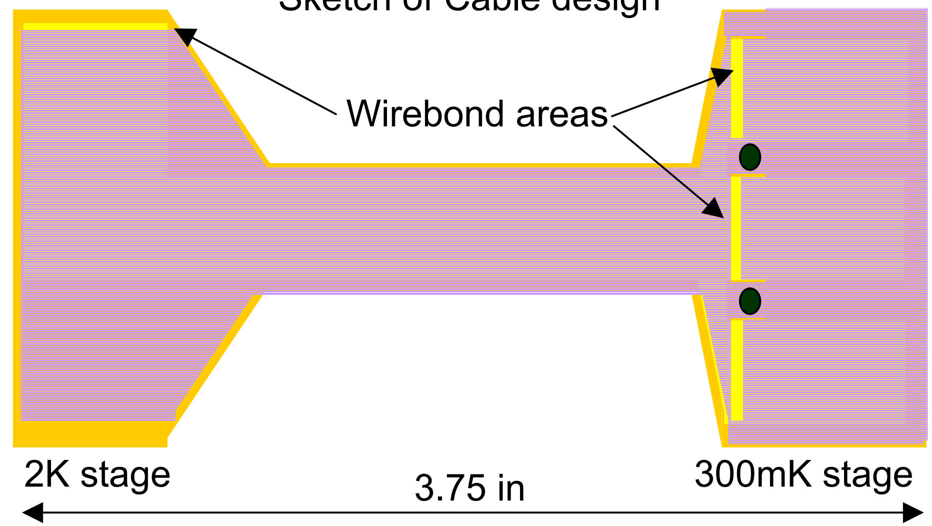
- Kapton Flex Cables will provide a low thermal conductance from the 2K Temperature Stage to the detectors and load resistors that are sitting at 300mK.
- 1 to 6 flex cables need per array



Kapton Cable Overview

- EM1 Kapton/Constantan Flex Cable Design
  - Proof of concept cable
  - Cable design:
    - 0.025mm Kapton cover layer
    - 0.005mm Constantan wires
      - **50 µm to 75µm wide, 95mm long**
      - **75µm wide, 1000 µm long wirebond pads (300mK stage)**
      - **75 µm wide, 500 µm long wirebond pads (2K stage)**
      - **Interleaved ground wires**
      - **2 voltage bias for redundancy**
    - 0.100mm Kapton bottom layer
  - Cable yield:
    - 90% line yield
    - Lead resistance is 100-200 Ω

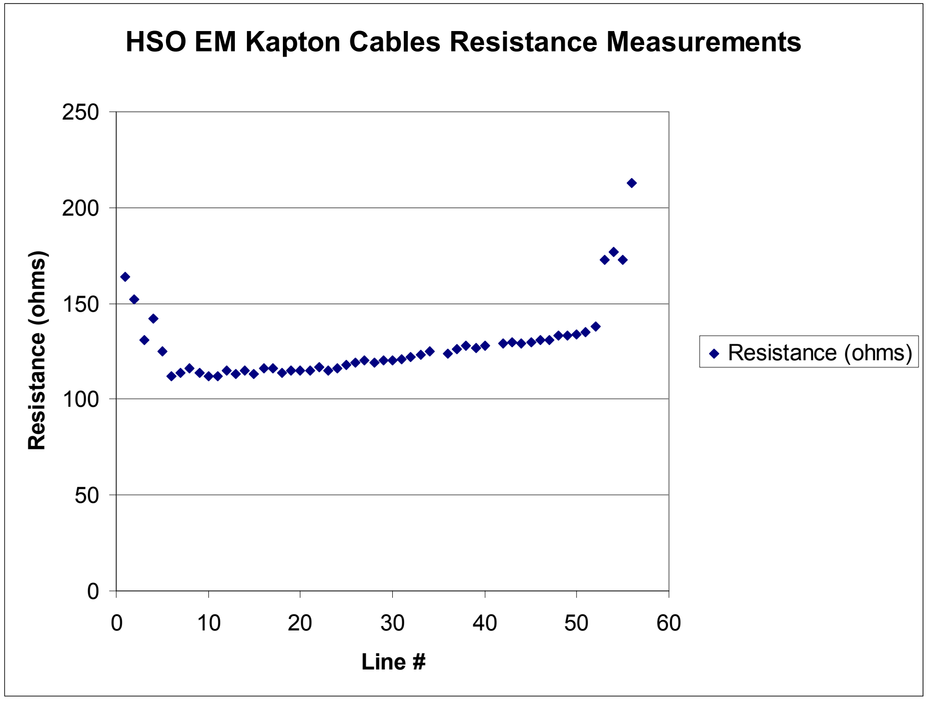
Sketch of Cable design



EM1 Kapton Flex Cable

Kapton Cable Status

- Initial EM1 Cable yield:
  - Line yield 90% (50um lines)
  - Line resistance is 100-200 ohms for lead lines
  - Handling issues
- Wirebond tests
  - Wirebonds successful but difficult on EM1 cables
  - G10 backing board added into design for structural support during wirebonding
- Thermal Test
  - Initial thermal tests



Environmental Tests

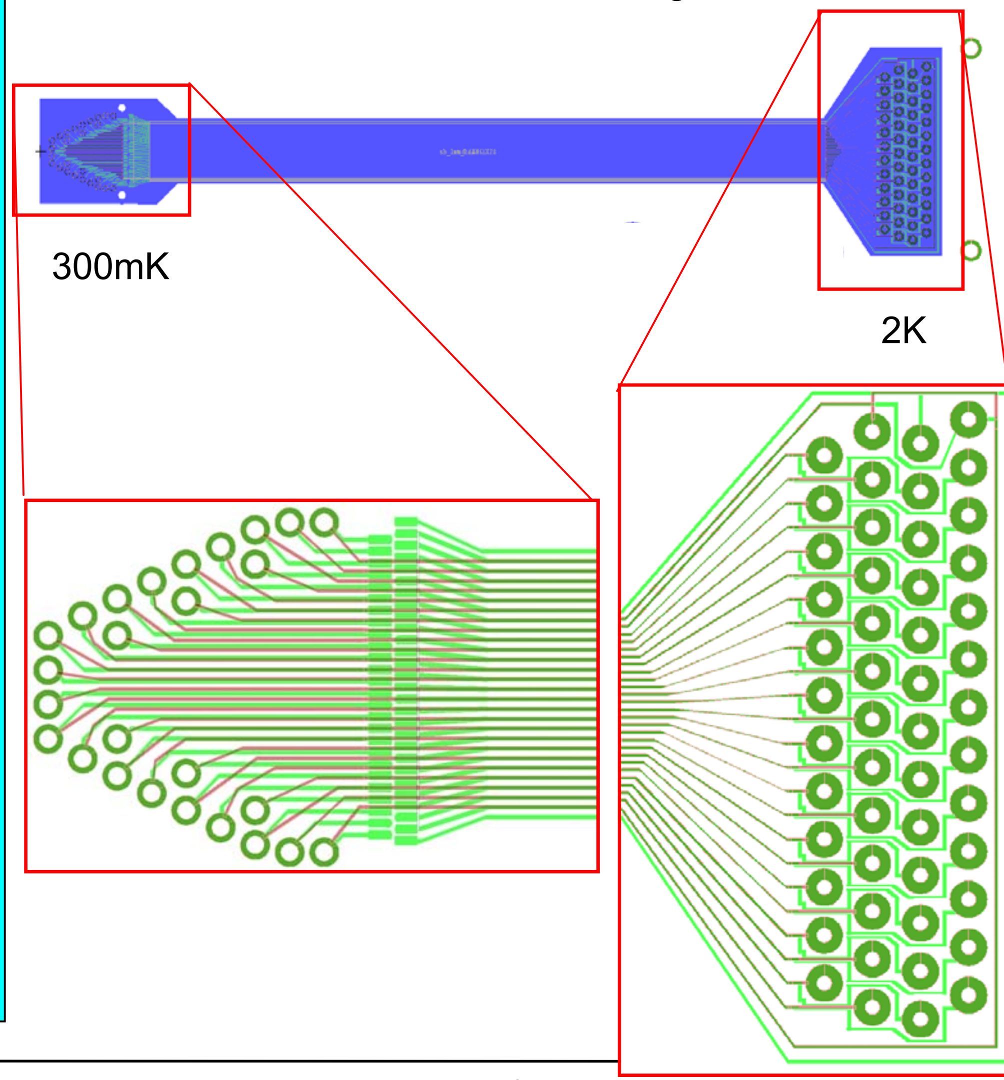
- Test at LN2 temperature did not have any failures
- Further tests and pictures will be presented

Kapton Cable Overview

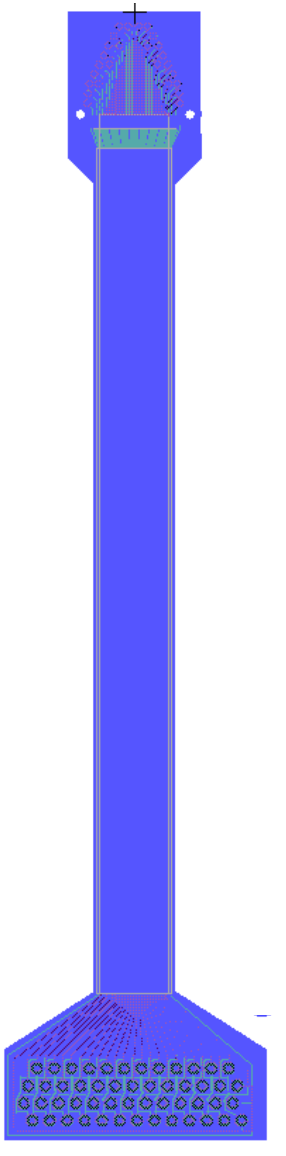
EM2 Kapton Cable Design

- More manufacturable cable
  - **Constantan wires now 100 µm wide**
  - **Interleaved ground lines removed**
  - **Eliminated wirebonds at 2K stage and replace with plated thru holes for solder bonds to Nanonics connectors**
  - **G10 support board added to 300mK stage connect to support wirebond pads. G10 support board added to 2K stage to support solder bond areas**
- The Flex cables consist of:
  - **Kapton cover layer (0.025mm)**
  - **Constantan foil conductors (0.005mm)**
  - **Kapton center layer (0.075mm)**
  - **Constantan foil conductors (0.005mm)**
  - **Kapton cover layer (0.025mm)**
  - **G10 support board (one on each side)**
  - **Copper plated thru holes**

EM2 Flex Cable Design



Kapton Cable Fabrication



- Cables are being fabricated by Circuit Solutions Inc. Monrovia, CA
- Cables will be tested at JPL/Caltech for thermal constraints and thermal conductivity properties
- Circuit Solutions Inc. Process steps
- Standard flex circuit processes
  - Laminate constantan foil to Kapton for both sides of cable
  - Pattern and etch constantan foil into conductors
    - 0.100mm lines with 0.100mm spaces
    - Approximately 100mm in length
    - Terminations are a copper plated thru holes for solder bonds to Nanonics connectors at the 2K stage and Ni/Au plated up areas for wirebonding at the 300mK stage
  - Laminate Kapton cover layer onto etched conductors
  - Drill and back etch plate thru holes
  - Copper Flash and plate thru holes
  - Plate up wirebond pads (Ni/Au)

Open Issues

- Open Issues
  - Constantan foil etch is difficult to control. Should be fine with new cable design 100um lines.
  - Thermal conductance of cable should be measured directly.
  - Probe testing on cable directly is difficult.
  - Have to make one more EM cable run before CQM cables.

- Mitigations
  - New design with plated through holes will be easier to test.
  - New design can also be provided by other manufactures

5.8
BDA Manufacture and Assembly

Leonard Husted

BDA Manufacture and Assembly

- Contents
  - Manufacturing Approach
  - Manufacturing Facilities
  - Personnel Skills/Certification
  - Exploded Views
  - Assembly Documentation Required
  - Manufacturing Processes
  - Tooling
  - Manufacturing Process Flow
  - Summary

Manufacturing Approach

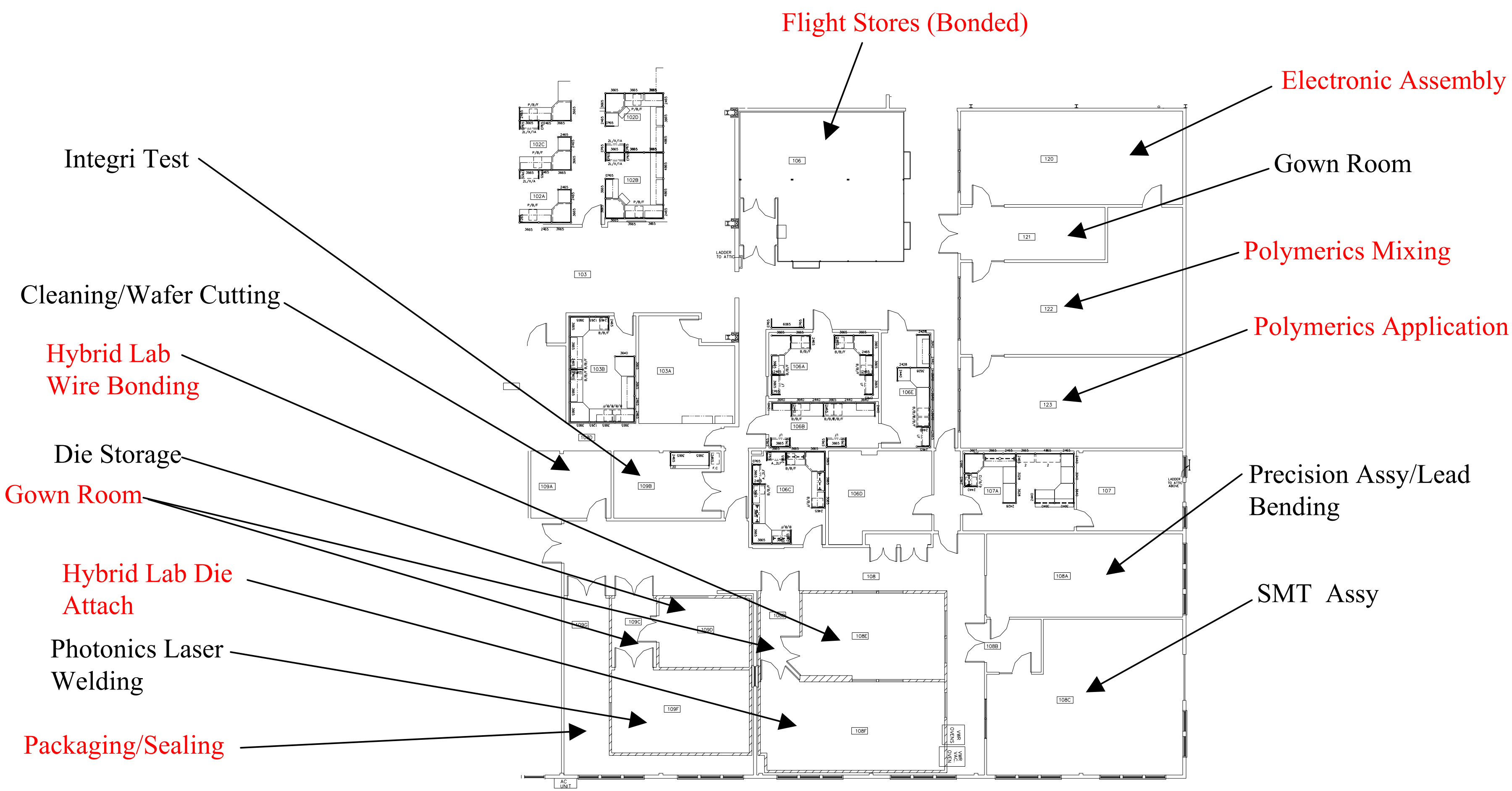
- Fabrication
  - Competitive procurement of mechanical hardware from 2 sources: ASI or Swales
  - Electronic hardware produced in JPL's MDL
- Assembly
  - Detector assembly will be produced in Electronic Packaging (Bldg. 103)
  - Suspension assembly will be produced in Mechanisms Assembly Laboratory (Bldg. 170)

Facilities

- **Building 103 Flight Assembly**
  - Controlled Access
  - Temperature Controlled 72+/- 3 deg
  - Humidity Controlled 30-70%
  - Conductive Floor Tiles
  - ESD Certified
  - Hybrid Lab 10,000 Class
  - O2 Sensors

Facilities

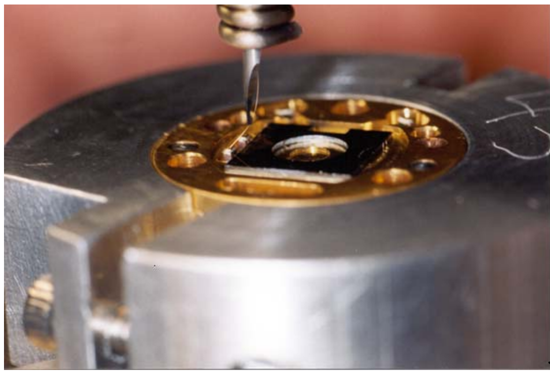
- **Building 103 Flight Assembly**



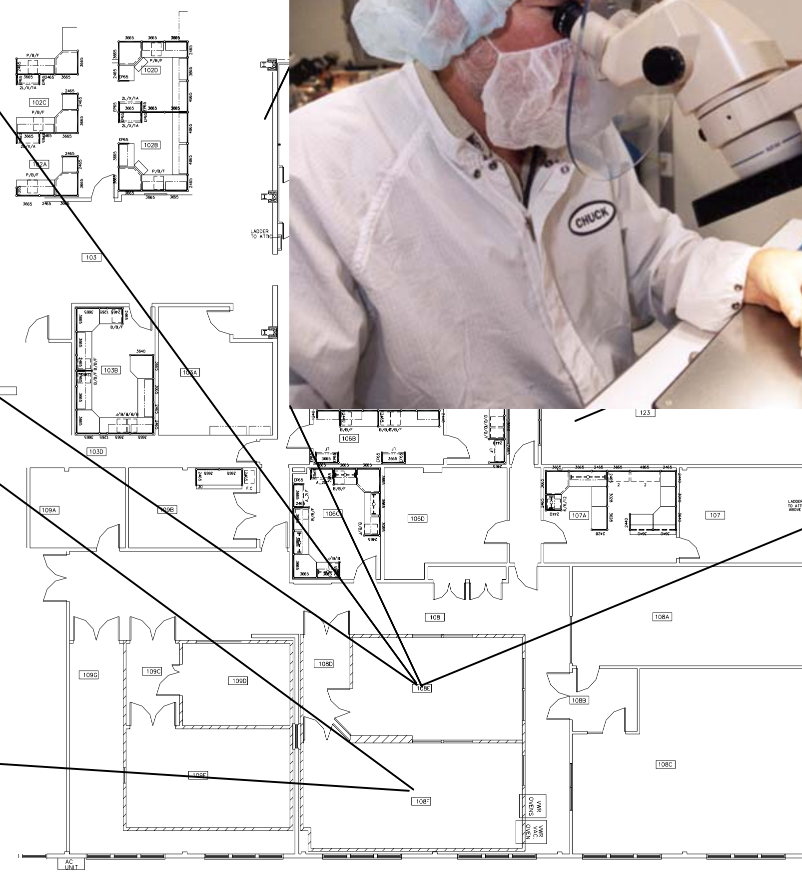
Facilities

- **Building 103 Flight Assembly**

Wire Bonding



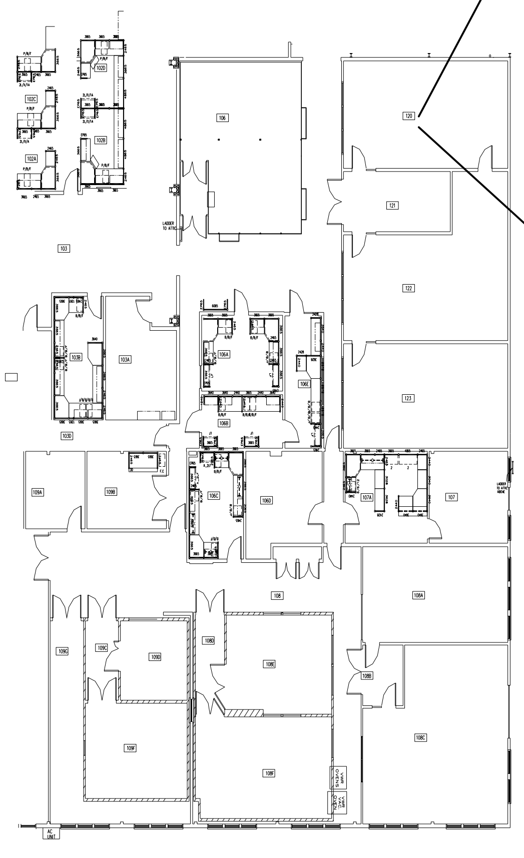
Wire Bonding- Bolometer/Load Resistor/Flex Harness



Component Attach- Bolometer/Load Resistor/ Flex Harness

Facilities

- **Building 103 Flight Assembly**



Electronic Assembly- Flex Harness Assembly

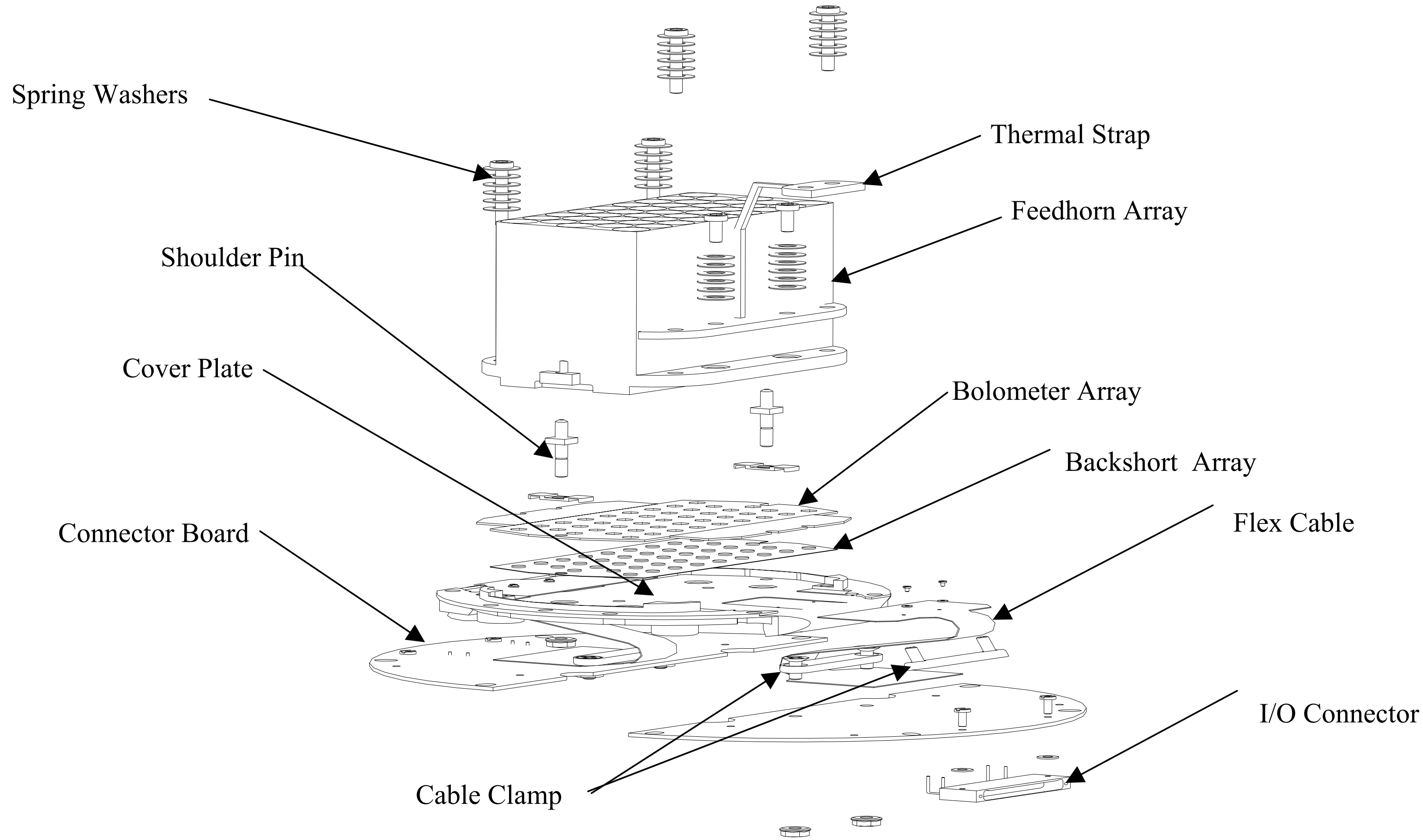
Personnel Skills/Certification

- Skills

Certified Personnel	COURSE NAME	COURSE CODE	NASA STD	SPIRE Skills Needed
26	Hand Soldering to NASA STD 8739.3	AA0003	8739.3	X
22	Crimp, Cable & Harness	BB0003	87394	
5	Wire Wrap	DD0003 / HH0006		
4	Fundimentals of SMT Fab	KK1003	8739.2	
17	Flight Polymerics / Conformal Coating Oper / Insp	NN2003 / NN2006	8739.1	X
27	Connector CSFT/ Mate & Demate & Torquing	NN3003		X
25	Flight System Connector Cleaning	NN4003		X
13	Flight Systems Mechanical Hardware	NN6003		X
25	Inspect, Measure and Testing Equip	IMTE	8739.3	X
3	Semi-Rigid Coax Cable	OO2003	8739.3	
20	Integrated Cicuit & Lead Forming & Trimming	OO9003	8739.3	
2	Fiber Optic Termination	PP0003	8739.5	
28	Critical H/W Handling	RR2006		X
23	ESD Avoidance	ER3003	8739.7	X
4	Wire Bonding	Trained by Equip Mfgr		X

Detector Assembly

- Detector Exploded View



BDA Assembly Manufacturing

- Documentation Required

Document Title	Number	Status		
		In work	Complete	Released
BDA Assembly Drawing	10209800	X	80%	8/17/01
Detector Assembly Drawing	10209810	X	80%	8/17/01
Detector Wire Bonding Diagram	TBD			8/24/01
Load Res/Flex Cable Wire Bond Diagram	TBD			8/24/01
AIDS-Detector Assemby	TBD	X	75%	8/24/01
AIDS-BDA	TBD			8/24/01

BDA Manufacturing

- Manufacturing Processes

Process	Std	Procedure	Requirement
Cleaning	YES	FP 513414 Sect 2.3.1	Drawing
Adhesive Bonding	YES	FP 513414 Sect 9.0	Drawing
Wire Bonding	YES	FP 513414 Sect 10.18	Mil-Std-883 M2011.7
Die Attach	YES	FP 513414 Sect 10.14	Mil-Std-883 M2019.5
Soldering	YES	FP 513414 Sect 6.1.2	D 8208
Solder Tinning	YES	FP 513414 Sect 6.2.2	D 8208
Torque	YES	ES 517040	Drawing
Vacuum Bake	YES	FP 513414 Sect 6.1.2	
Mechanical Assembly	YES	AIDS	Drawing
Inspection	YES	AIDS	Drawing
Resistance Test	YES	AIDS	Drawing
Conformal Coat	YES	FP 513414 Sect 9.5	Drawing
Identification	YES	FP 513414 Sect 9.0	Drawing

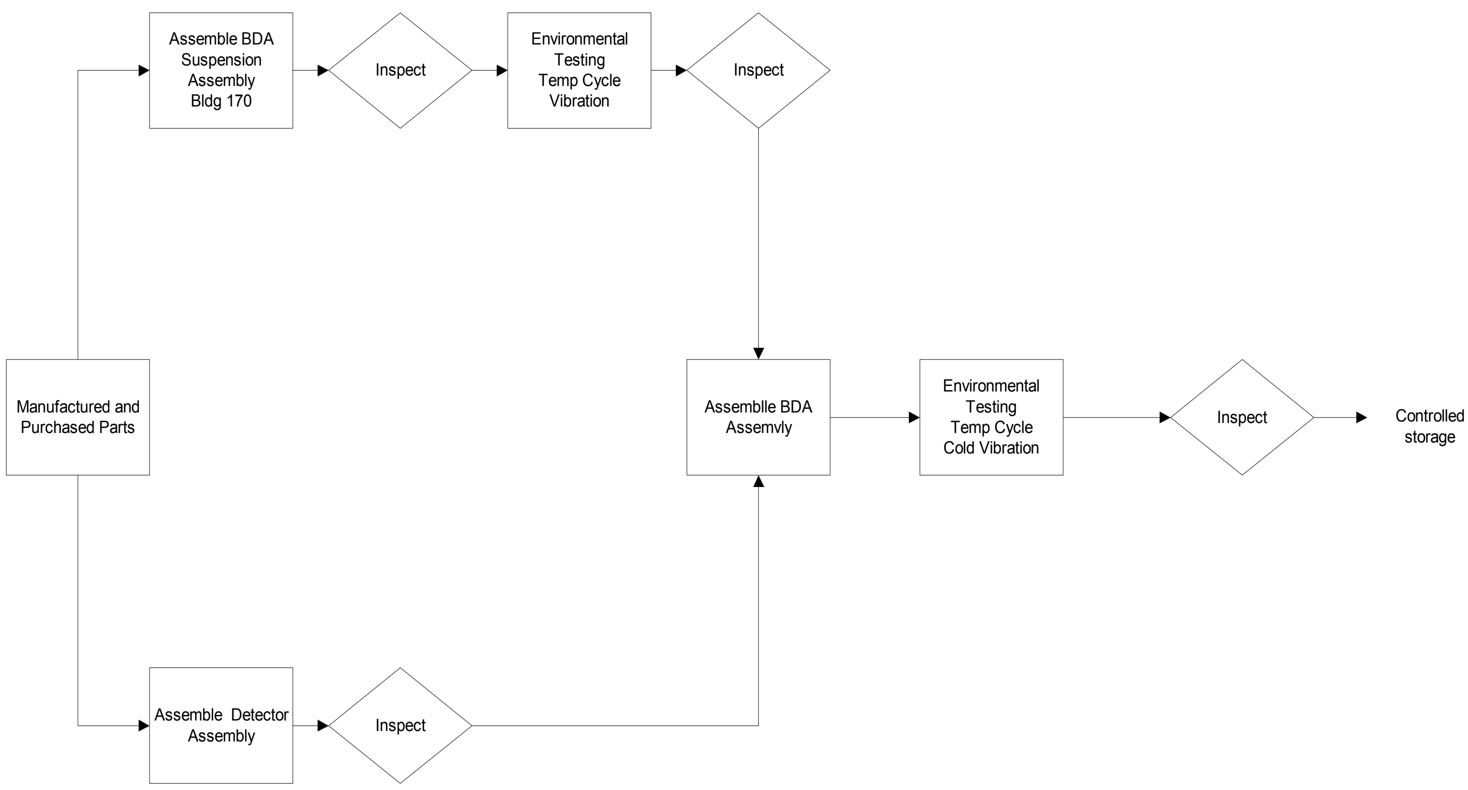
Detector Assembly Manufacturing

- Tooling Required

  - Detector Assembly
    - Load Resistor Adhesive Bonding Fixture
    - Wire Bonding Fixture
    - Flex Print Harness Assembly Fixture
    - Holding Fixture

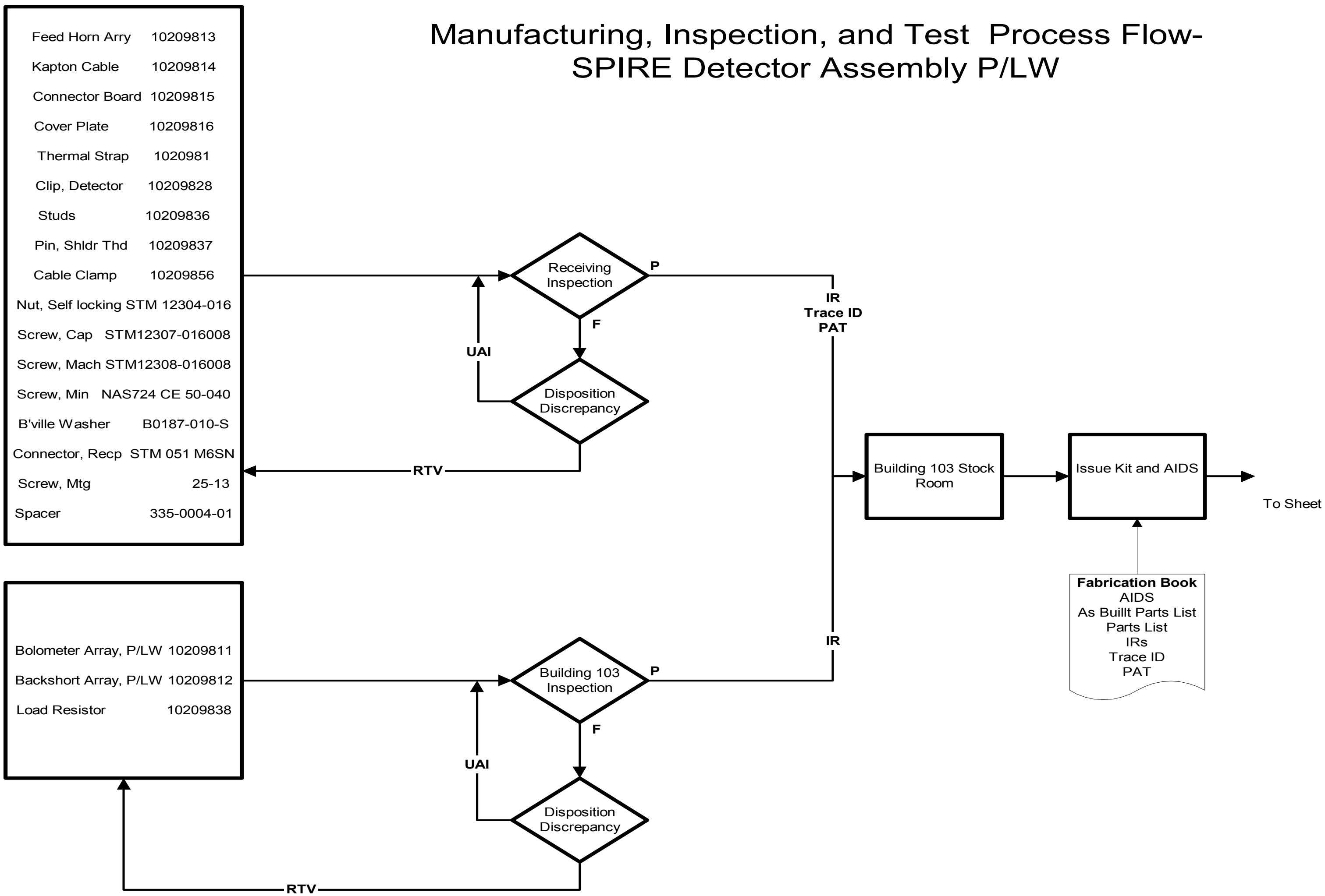
BDA Assembly

- BDA Assembly Flow

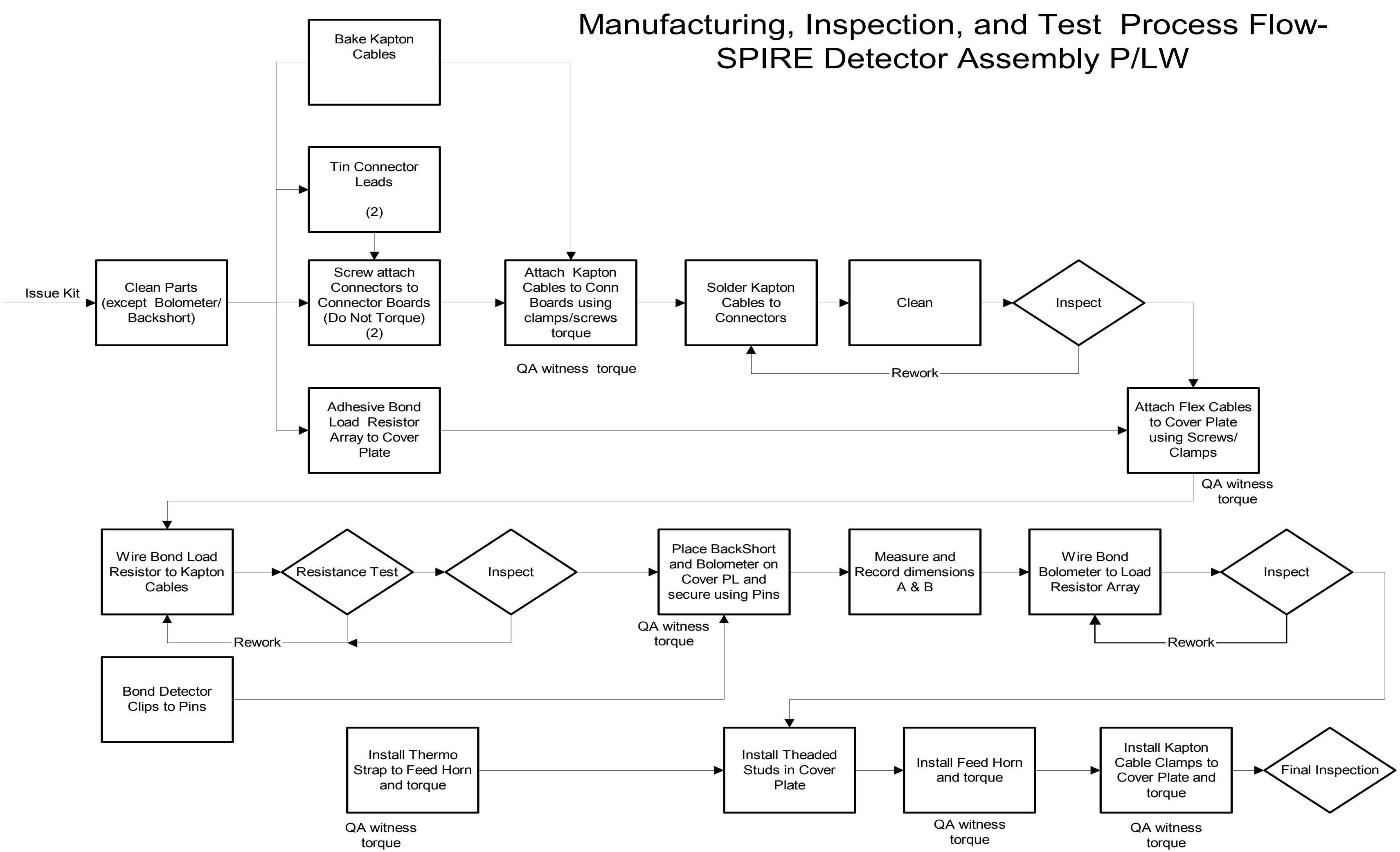


Detector Assembly

Manufacturing, Inspection, and Test Process Flow- SPIRE Detector Assembly P/LW



BDA Manufacturing



BDA Manufacturing

- Summary
  - Methods/Process Development Needed
    - Cold Wire Bonding Bolometer
    - Wire Bonding to Flex Harness
    - Adhesive type and how applied
    - Tooling
  - Open Issues
    - Epoxy selection
    - Drawings incomplete
    - AIDS incomplete
    - Connector Savers

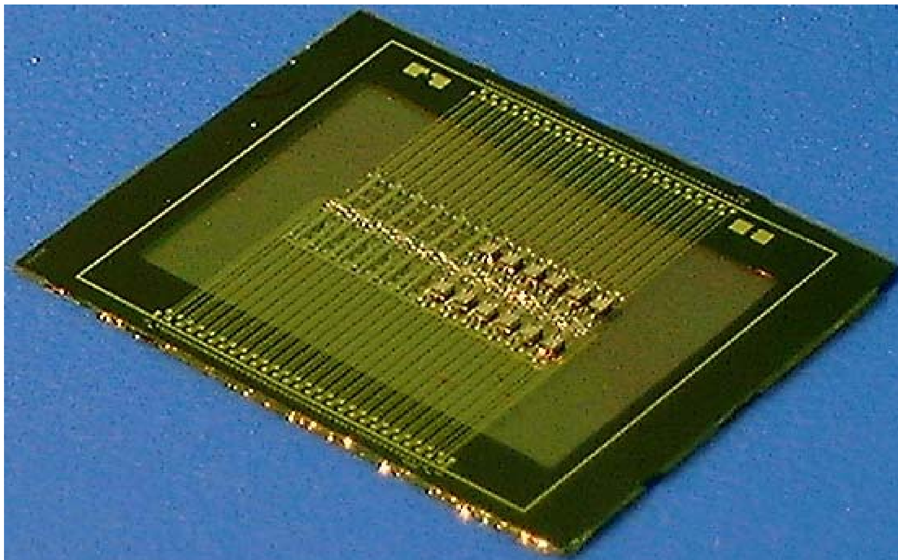
6.0
JFET Modules

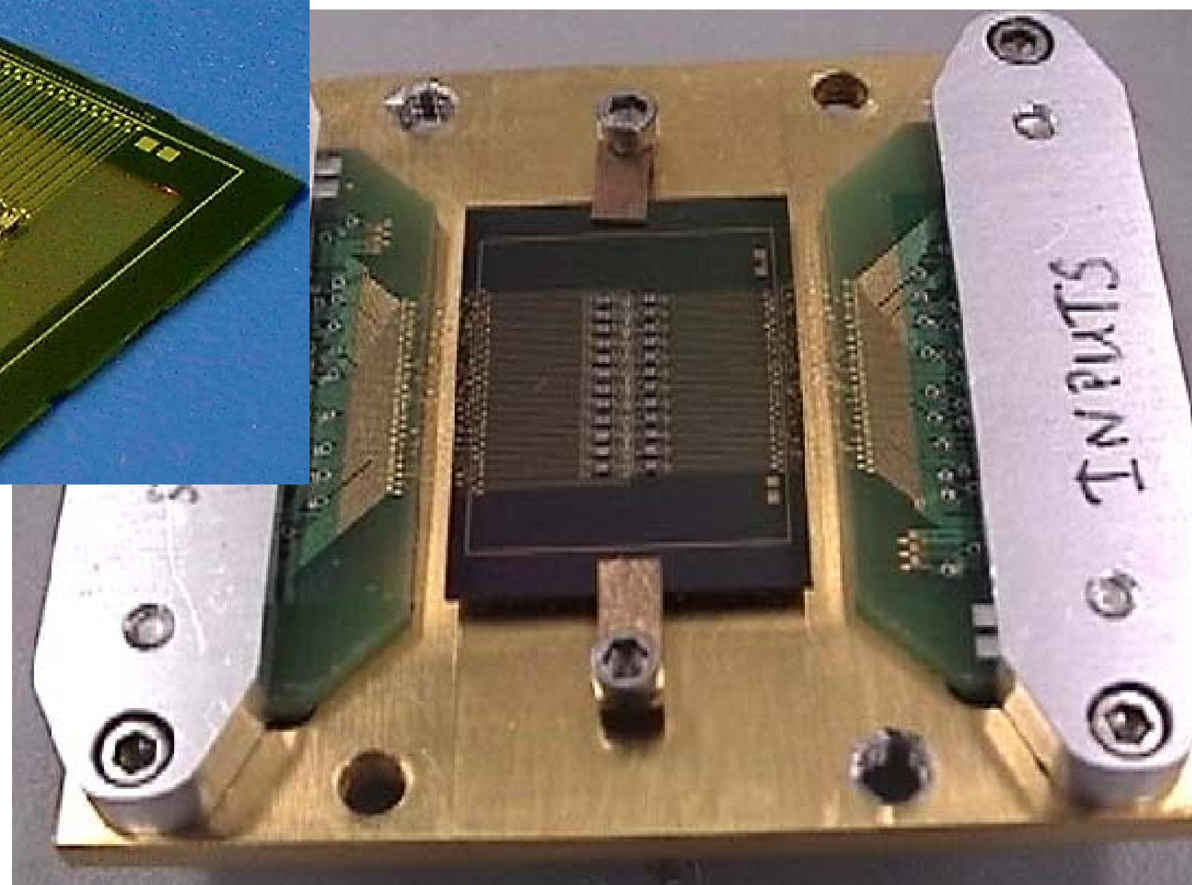
6.1
JFET Testing Status

Jamie Bock

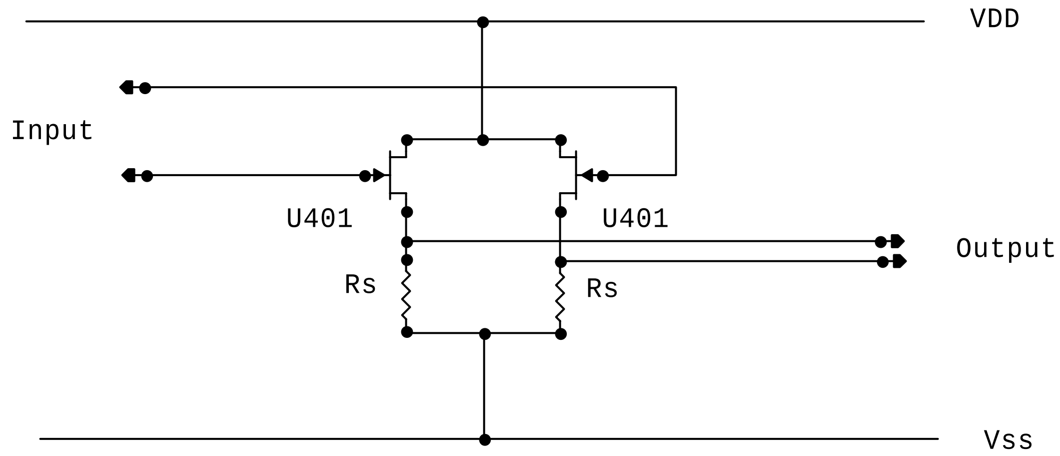
JFET Testing Status

James J. Bock
Jet Propulsion Laboratory





Main Design Features

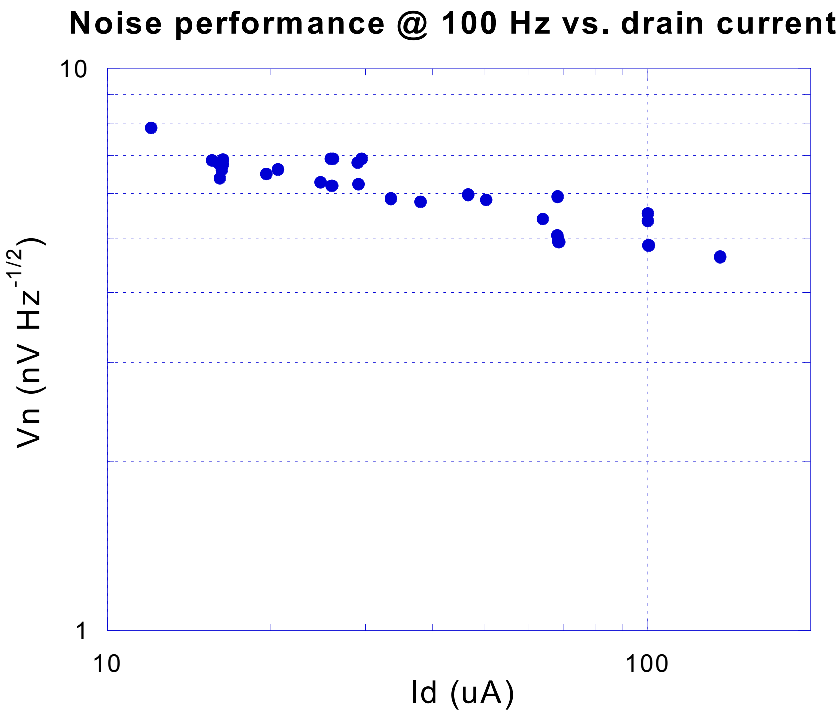


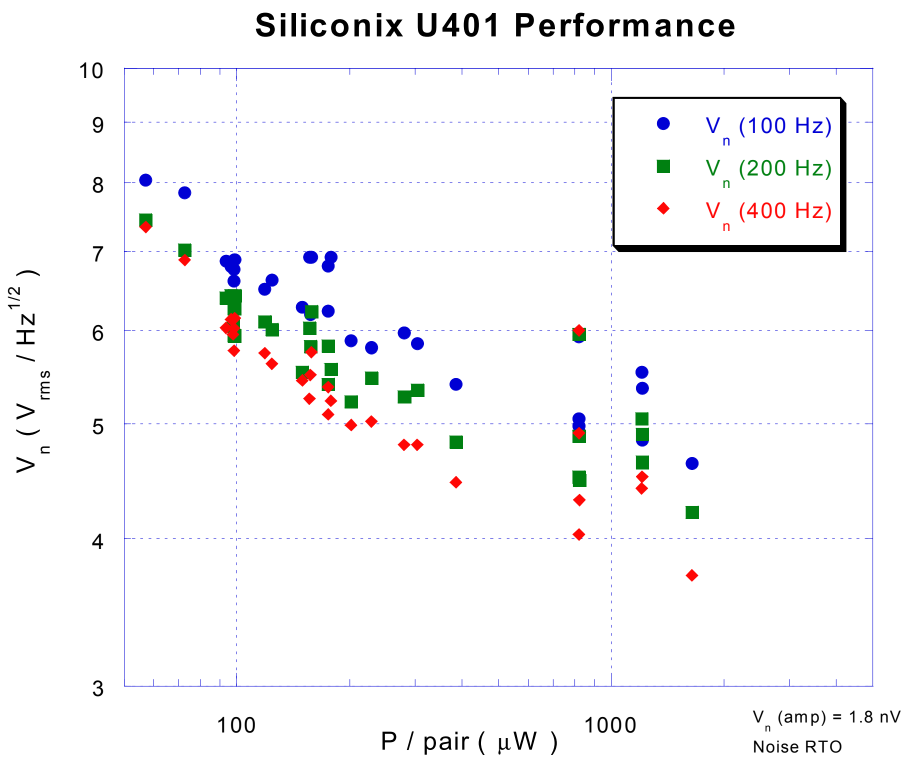
- Silicon JFETs flown on COBE, IRAS, IRTS
- U401 is a reliable dual package
- Differential readout
- Low noise and power

Table 1. JFET Power Dissipation (JFET-TEC-04)

Power (mW)	/pair	/membrane	/module	/phot	/spect
Design value	0.115	2.75	5.5	33	8.25
1.5 * DV	0.170	4.13	8.25	49.5	12.38
Min. P. value	0.230	5.5	11	66	16.5

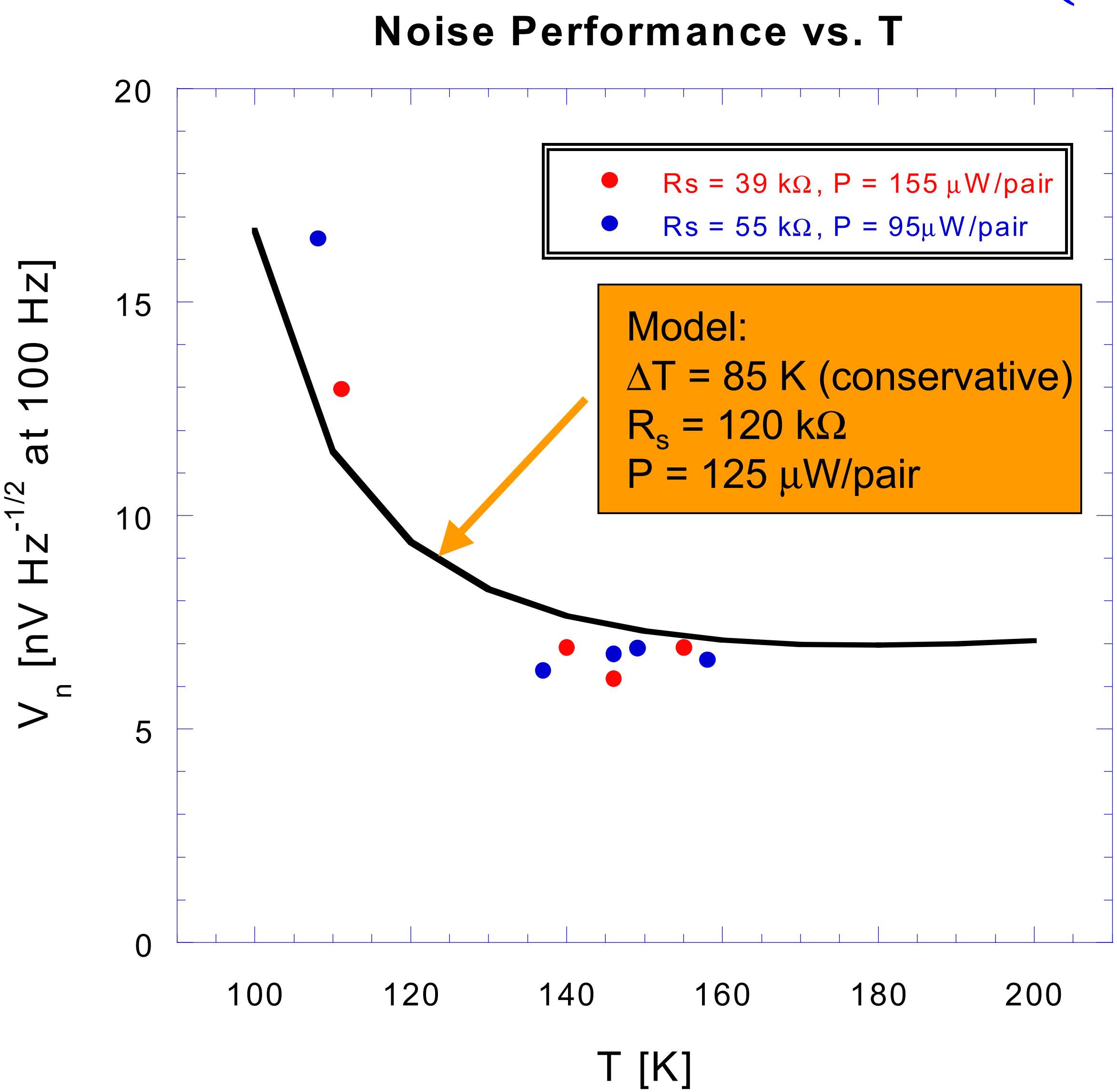
U401 Noise Performance (1)





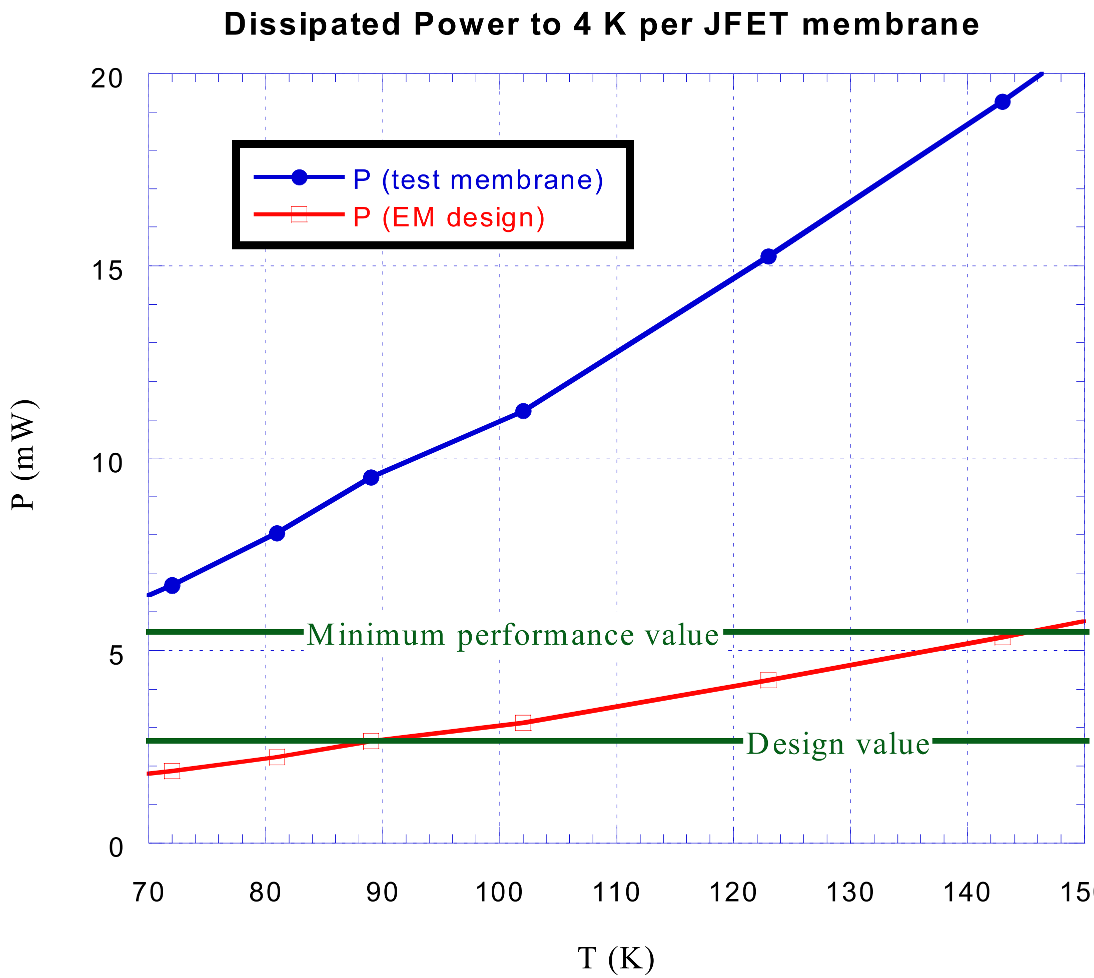
V_n (amp) = 1.8 nV / Hz$^{1/2}$
Noise RTO
P = 2*[P(Rs) + P(JFET)]
c/o Brett Kornfeld

U401 Noise Performance (2)

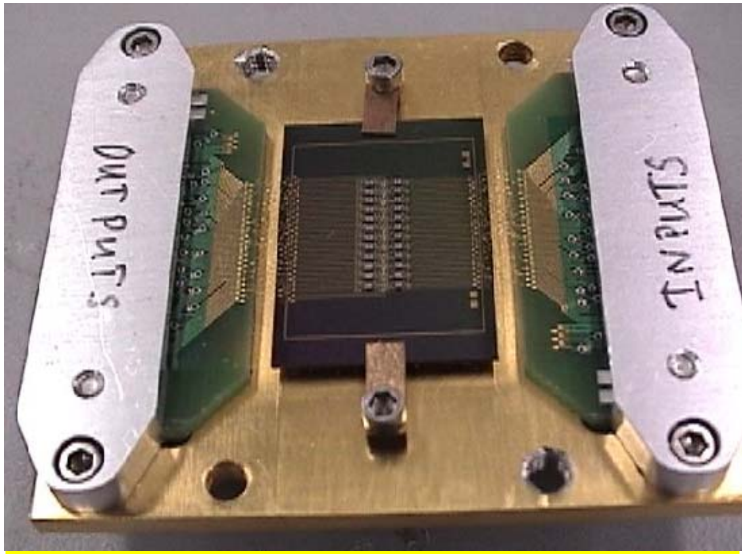


Membrane Thermal Conductivity

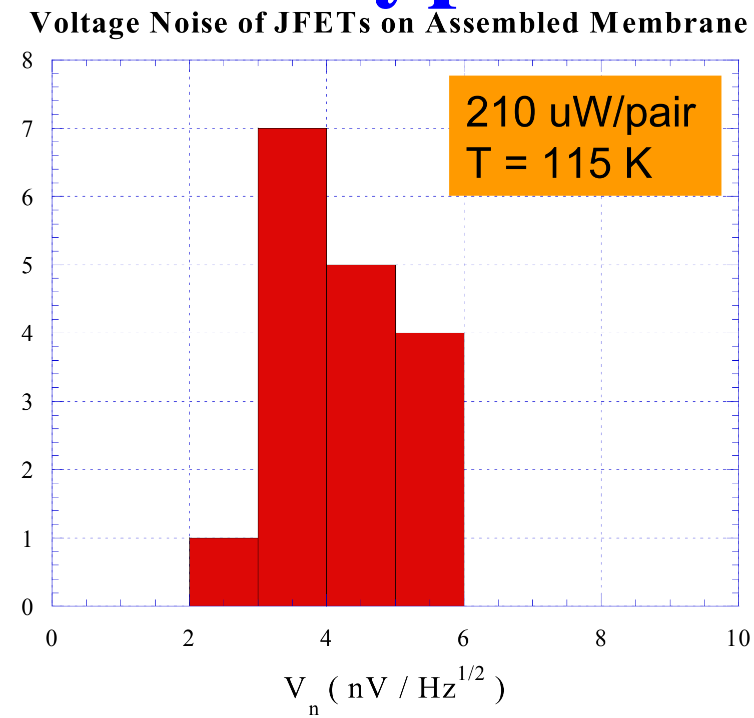
- Conductivity measured on 12 x 12 mm test structure with Δx = 1 mm gap
- Estimated for EM membrane assuming square geometry
- Terry will present detailed thermal analysis for the EM membrane



Tests on Unetched Prototype

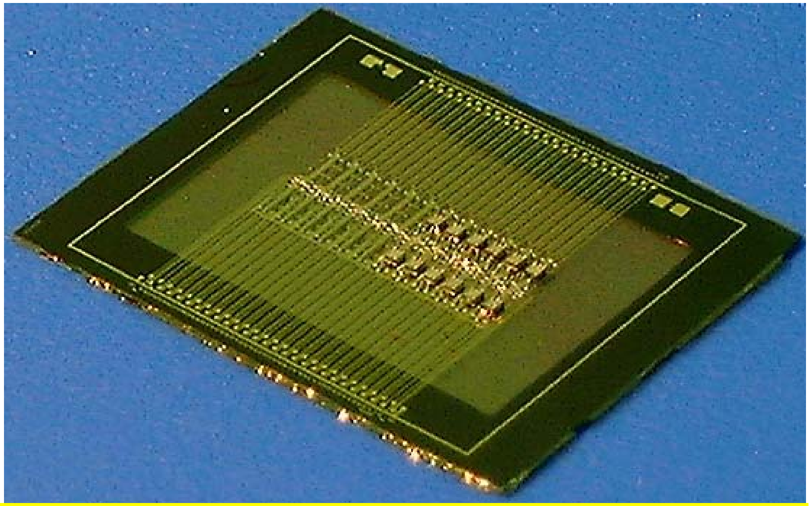


Unetched prototype test sample



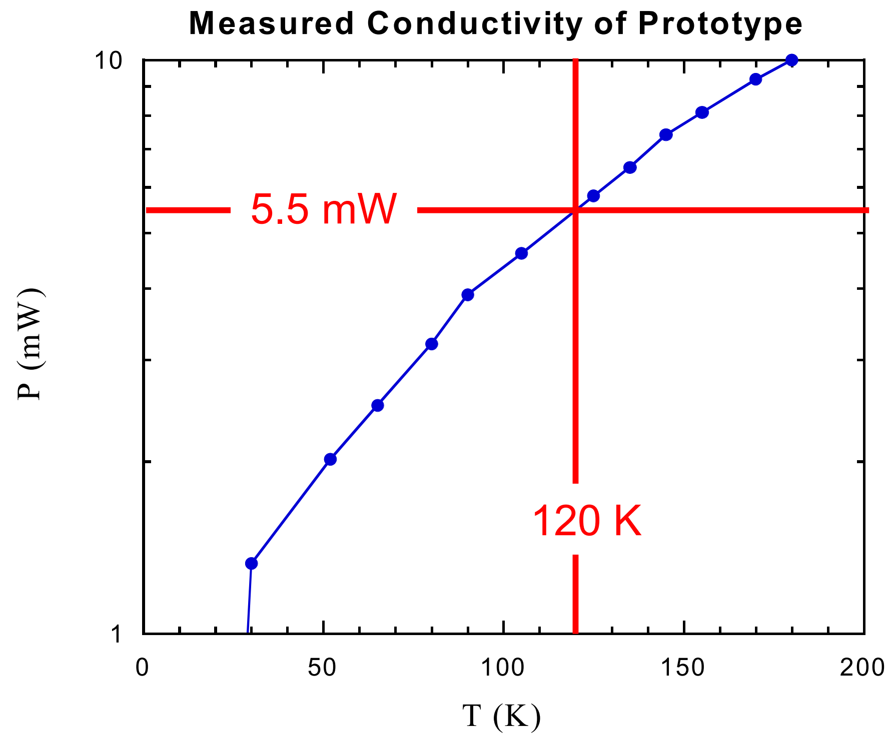
- No excess noise associated with lithographed resistors
- Leads metalization too thick
- Some difficulties in etching and yield on source resistors
- Open gates are ESD sensitive

Thermal Conductivity of Etched Prototype



Etched prototype test sample

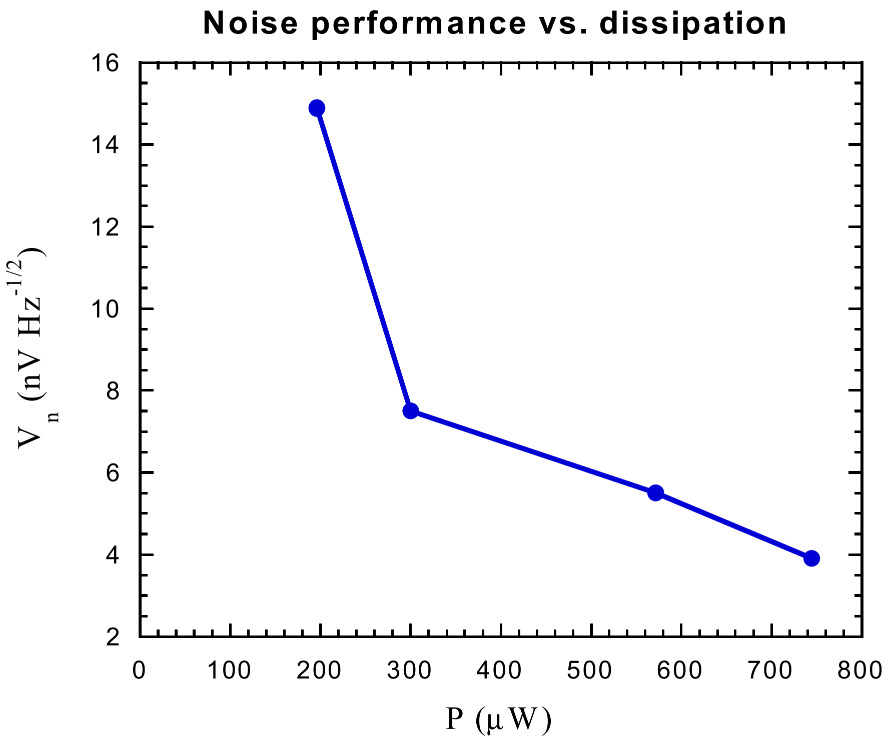
- Half populated with JFETs
- 1.8 μm membrane thickness
- Difficult geometry to model thermally
- Estimated conduction of leads is 3.2 mW based on impedance at 77 K and Wiedemann-Franz relation

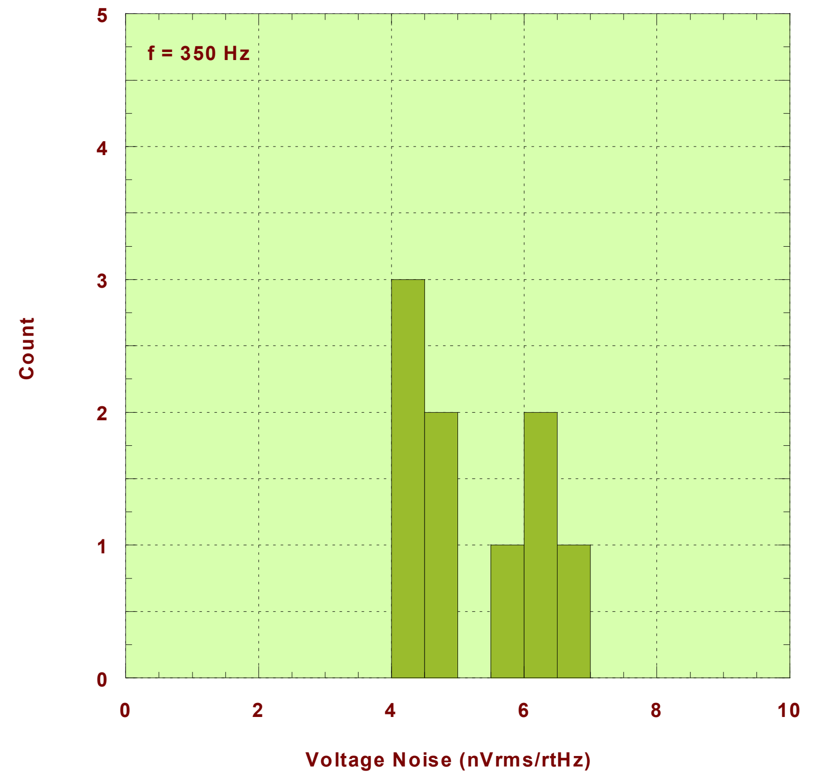


5.5 mW/membrane = "*minimum performance*"

- 90 s start-up time to 120 K (fast!)

Noise Tests on Etched Prototype



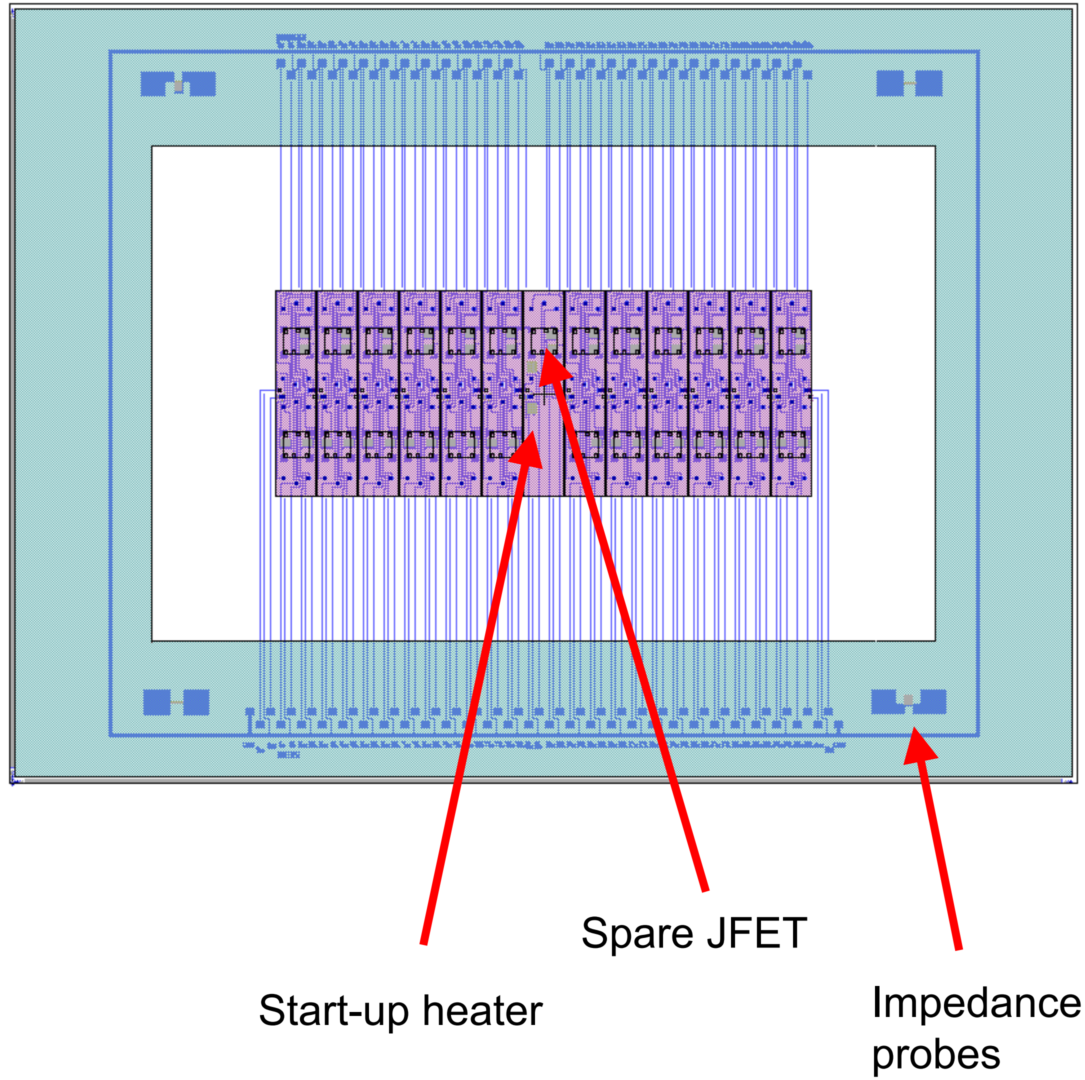


Performance within specification at P > 300 μW/pair, or 3.6 mW/membrane

Performance at 7.5 mW/membrane

Development of EM membranes

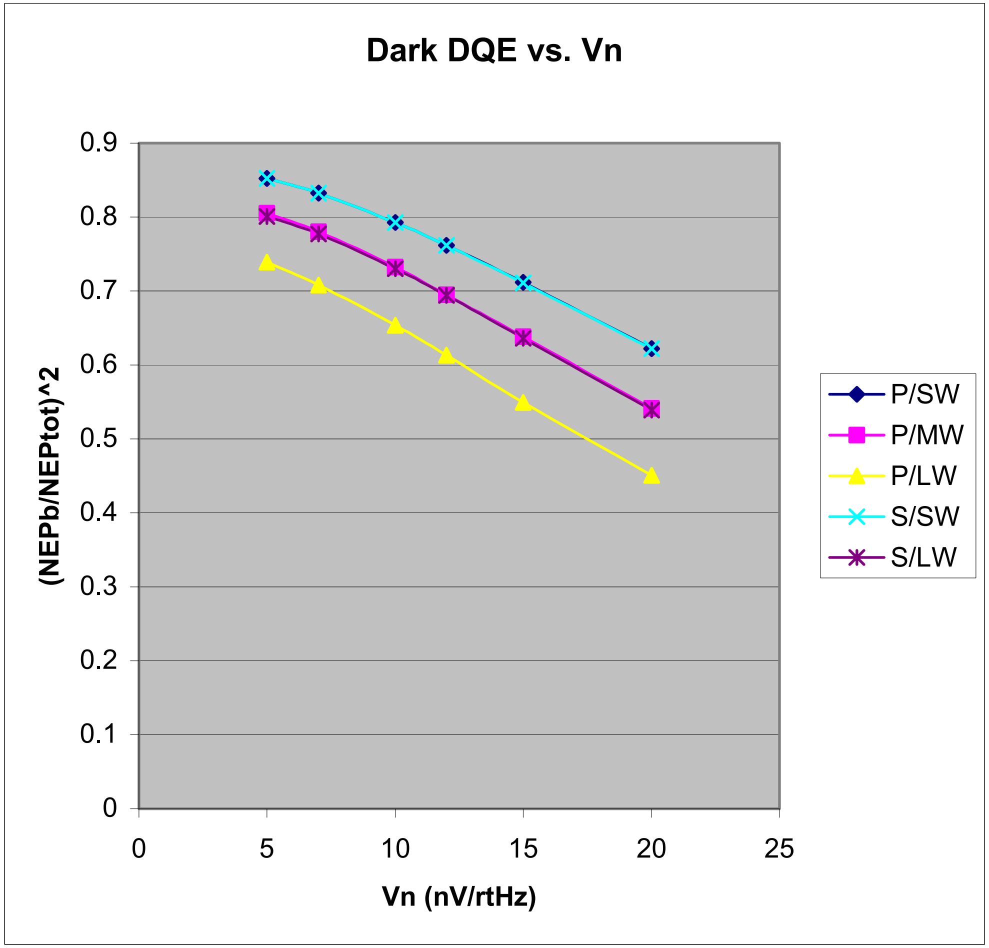
- **E-beam written resistors + passivation layer give high yield, no failures on thermal cycling to 77 K**
- **Thinner leads metalization reduces lead conduction by 9.5 (resistance at 77 K + W-F)**
- **Start-up heater to avoid dissipation on 300 mK stage.**
- **DRCU also has diodes to ground for conventional start up mode.**
- **1.0 μm membranes are too difficult to fabricate.**



Expected Tests Prior to Review

- Vibration and thermal cycle testing of mechanically representative membrane and housing with boards, connectors and RF filters
- Noise testing on unetched EM unit at operating temperature

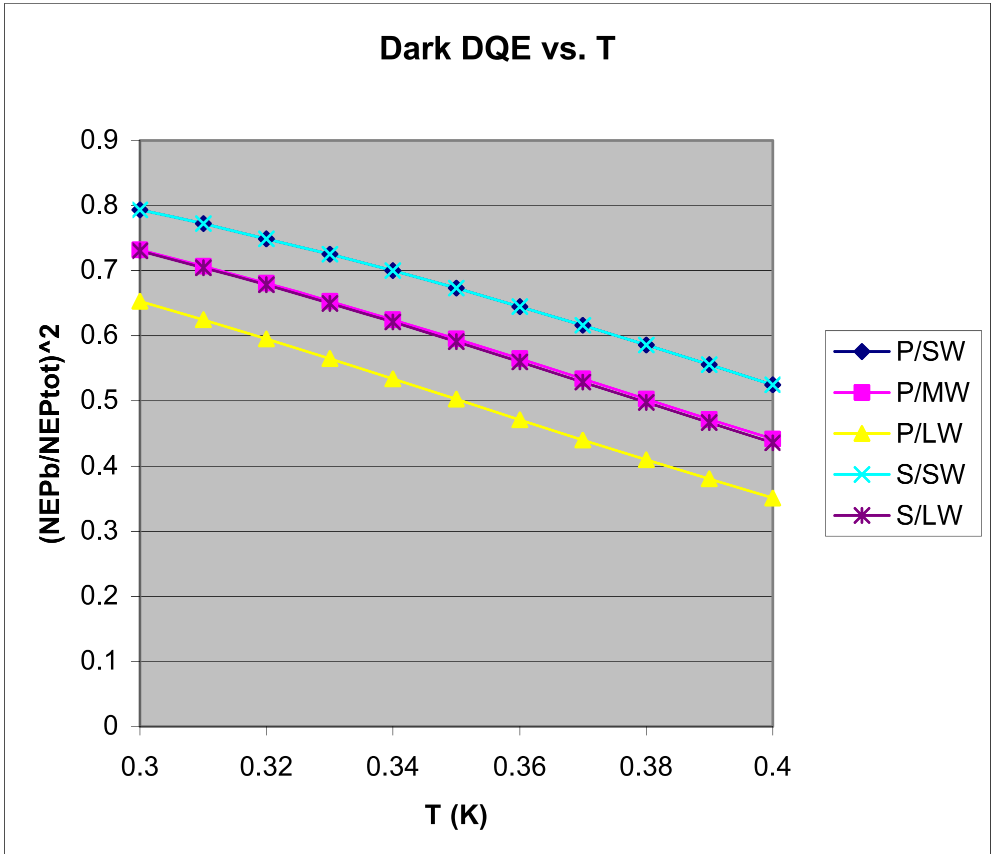
Systems Noise Issues with JFETs



- Reduction in mapping speed with amplifier noise is small

< 20 % reduction if JFET noise increases to 15 nV/√Hz.

Systems Thermal Issues with JFETs



JFET dissipation reduces mission life:

2.3 % reduction in life at 1.5 x DV
4.7 % reduction in life at 2.0 x DV

JFET dissipation increases detector T:

6 mK increase at 1.5 x DV, and
< 4 % reduction in M.S. at 1.5 x DV

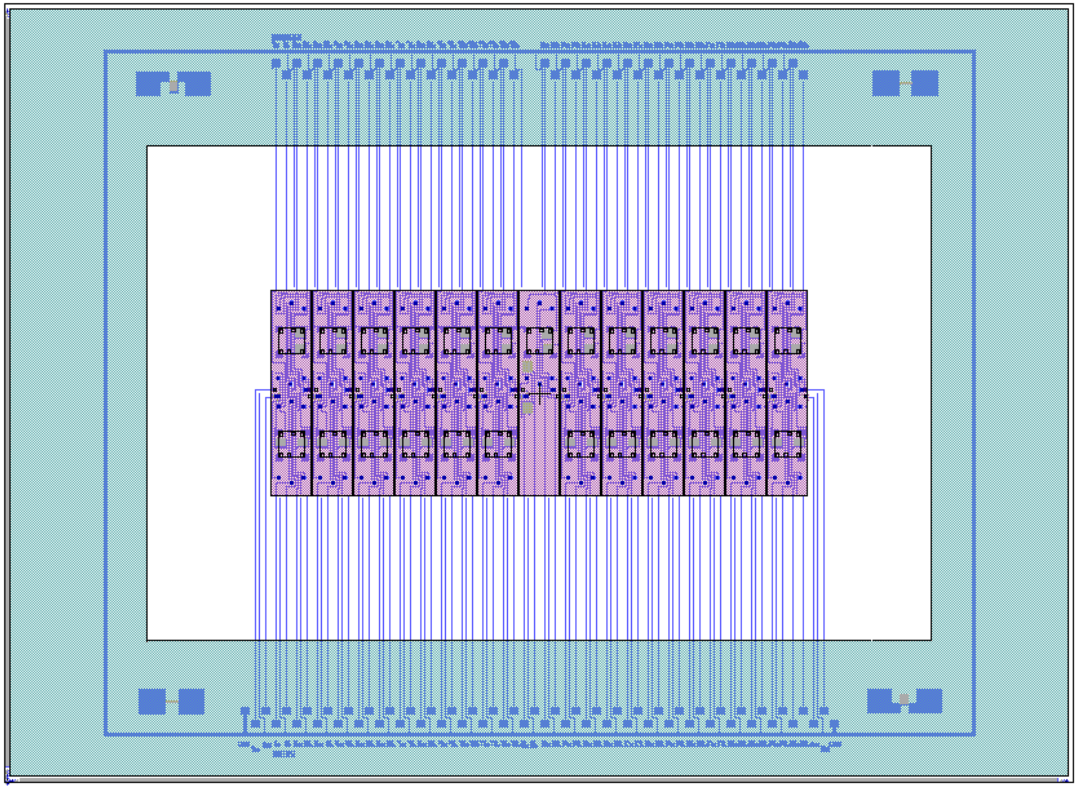
Transient effects from switching JFETs on and off to the instrument performance are uncertain

6.2
JFET Thermal Model

Terry Cafferty

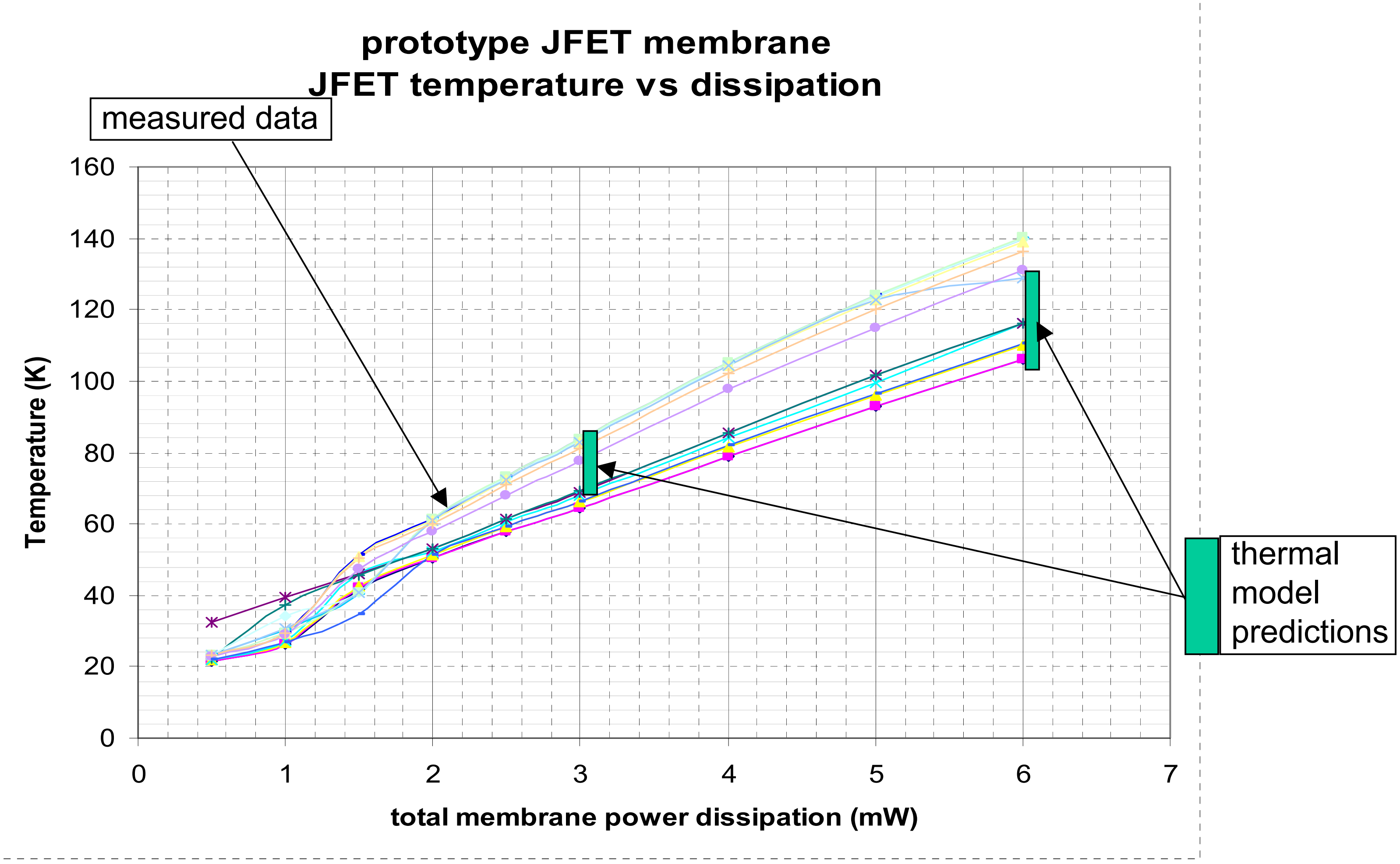
JFET membrane detailed thermal models

Terry Cafferty



2-D SINDA/G model
228 membrane nodes
728 conductors
leads broken into 1 mm lengths
temperature dependent conductances

JFET prototype membrane measured vs predicted thermal performance



JFET EM Membrane Thermal Model Predictions

- Similar to prototype membrane model, symmetrical heat input
- Leads conductance ~ 0.105 x prototype (measured cold)
- Design value module dissipation 5.5 mW

JFET dissipation uW/pair	Module dissipation mW	JFET temp range K
100	4.8	92 – 102
110	5.3	98 – 108
125	6.0	107 - 118
150	7.2	121 - 134

JFET Power Dissipation (JFET-TEC-04)

Power (mW)	/pair	/module	/phot	/spect
Design value	0.115	5.5	33	8.25
1.5 * DV	0.170	8.25	49.5	12.38
Min. P. value	0.230	11	66	16.5

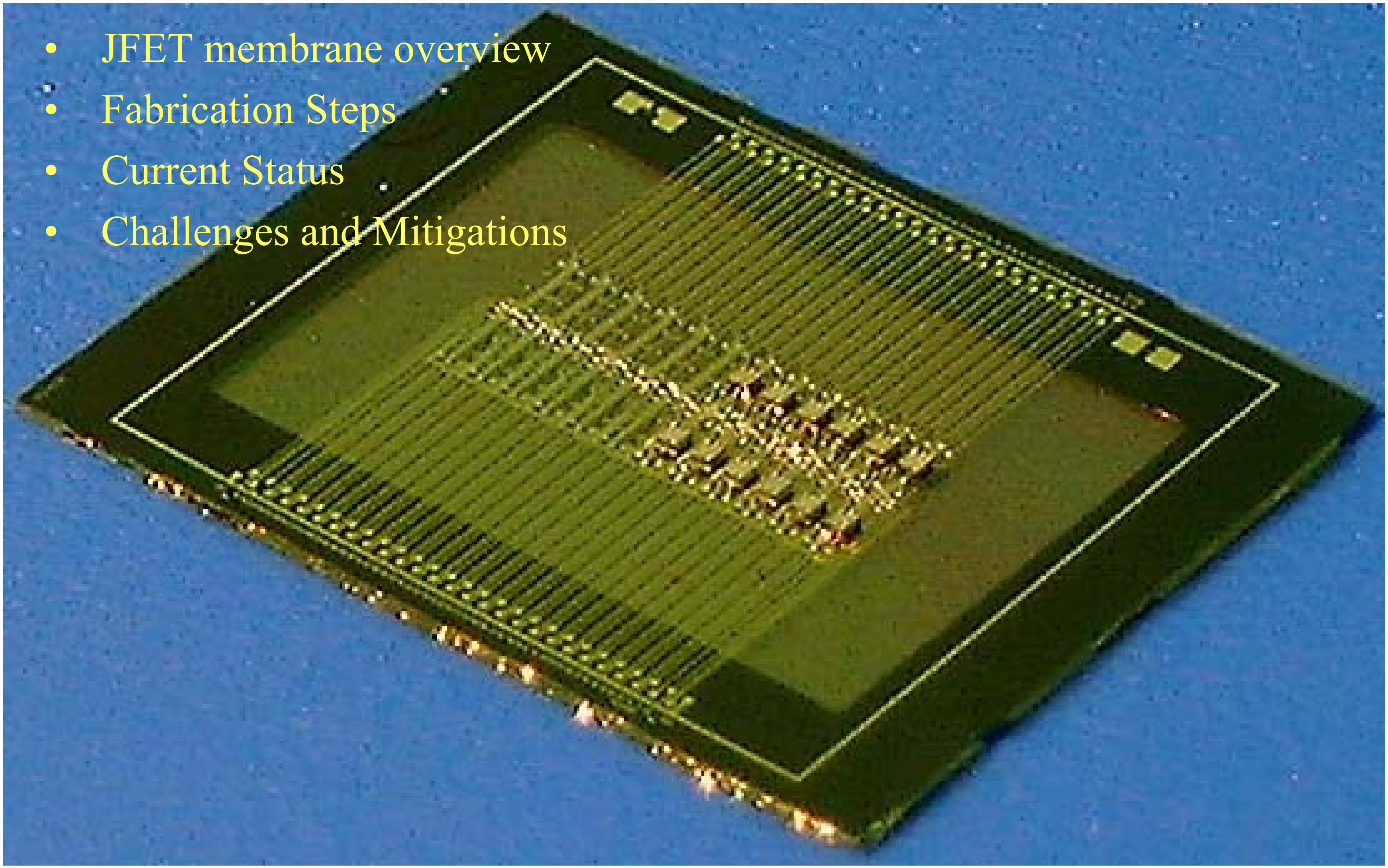
JFET membrane thermal summary

- Prototype membrane thermal measurements correlate well with detailed 2D thermal model
- EM/flight membrane identical to prototype, except lead conductance smaller by a factor of ~10; thermal model probably accurate
- We know JFETs perform well for T > 120 K, maybe colder
- EM membrane thermal model predicts $T_{\mathbf{jfet}}$ > 120 K @ 150 uW/pair
- 150 uW/pair implies module dissipation of 7.2 mW (5.5 mW goal)
- EM membrane JFET thermal tests will be performed to find T_{min} and corresponding minimum dissipation

6.3
JFET Membrane Fabrication

Anthony Turner
Eric Jones
Shrinivasan Sethuramen

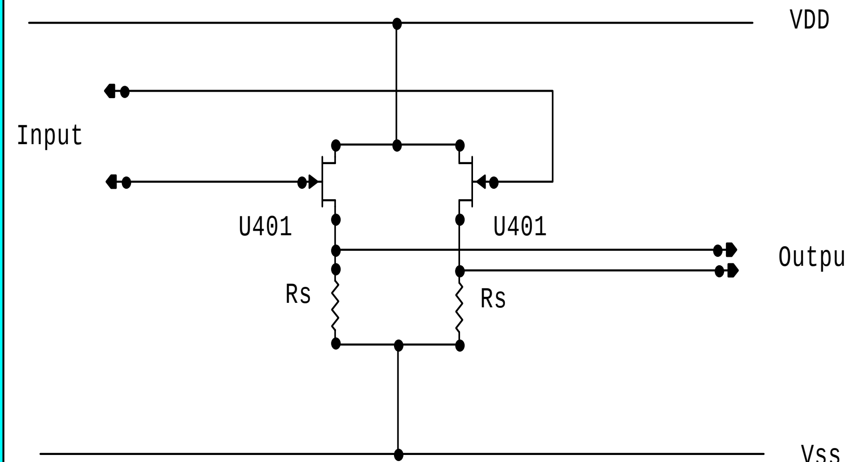
Overview



- JFET membrane overview
- Fabrication Steps
- Current Status
- Challenges and Mitigations

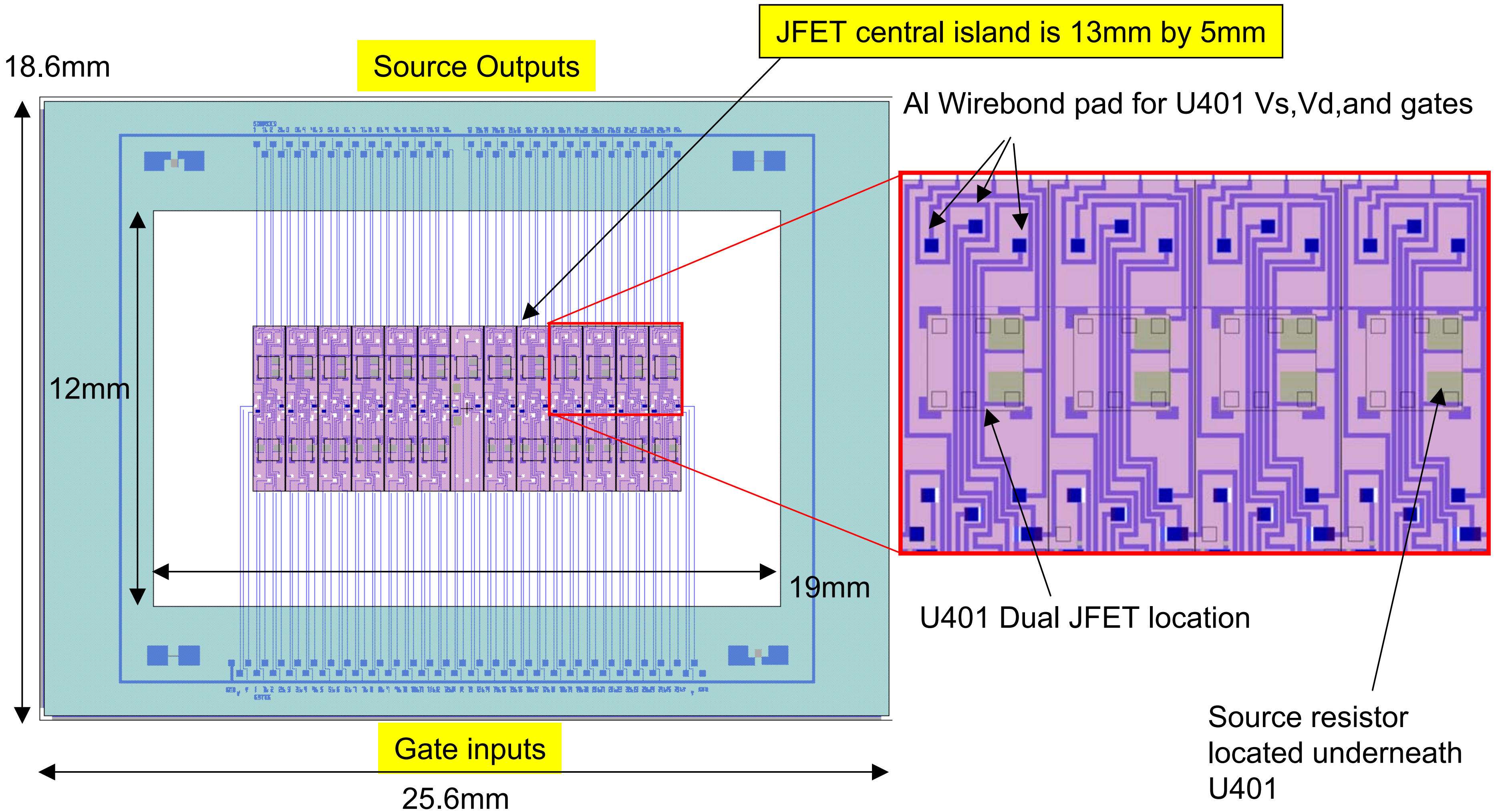
JFET Module Overview

- JFET module forms the detector readout circuitry for all bolometer arrays
- Each JFET module provides:
  - 24 channel differential amplifier readout circuits
  - Differential design reduces susceptibility to microphonics and RF
- Each JFET modules design features changes from EM:
  - 25 channels (24 plus one redundant channel)
  - NiCr thin film source resistors (100kΩ) placed underneath U401 to help heat U401 to operating temperature
  - Au interconnect lines thinned down to 15μm wide and metalization thinned down to 50 nm.
  - 24 dual U401 JFETs wirebonded to center of 1.8μm SiN membrane structure
  - Central membrane heater added onto membrane



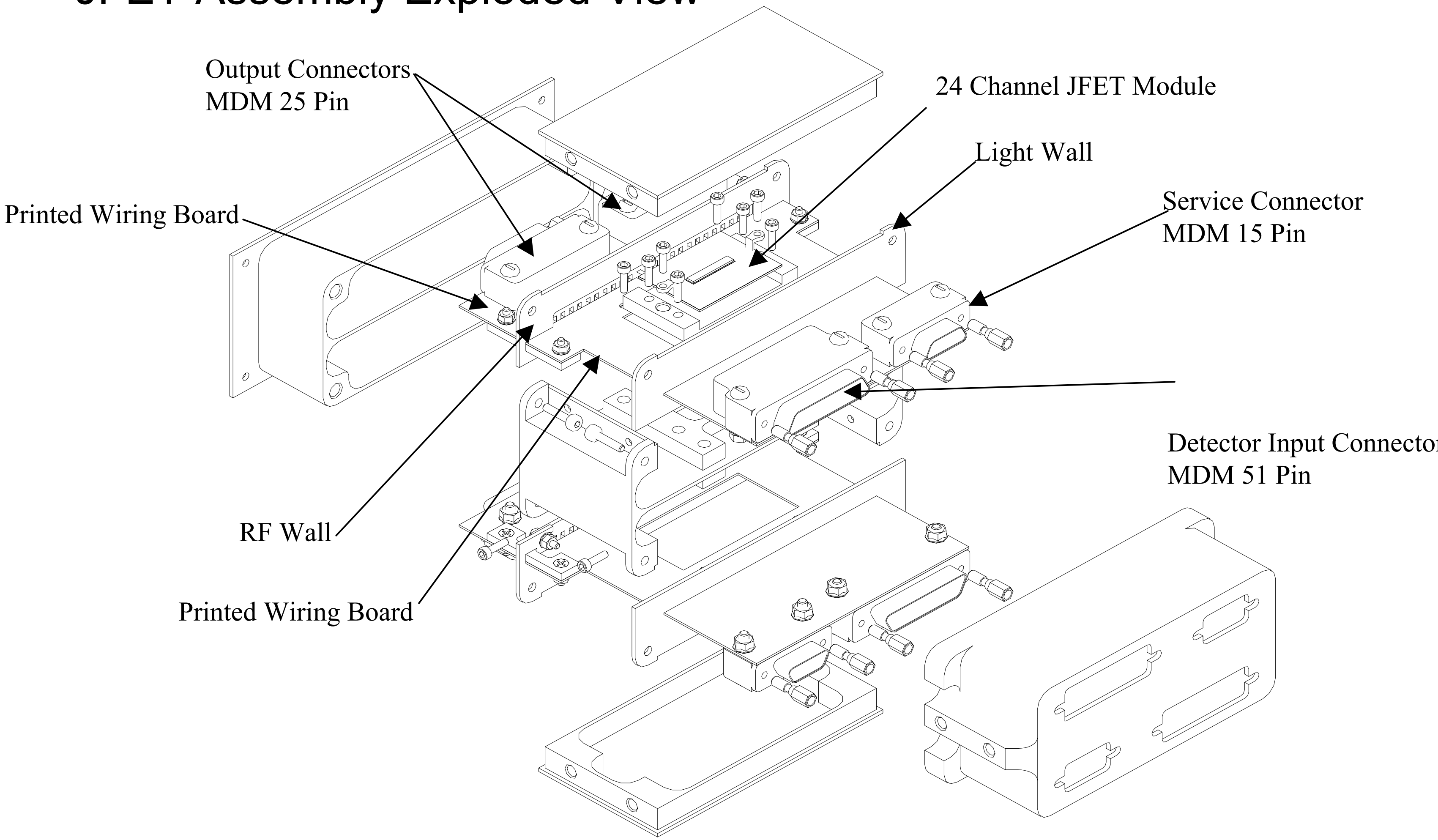
A schematic of a single channel of a JFET readout is shown. The source resistors are placed on the membrane to minimize sensitivity to the wiring harness to the cold electronics, although significant power dissipation comes from the source resistors.

JFET Module Overview



JFET Module Packaging Overview

- JFET Assembly Exploded View

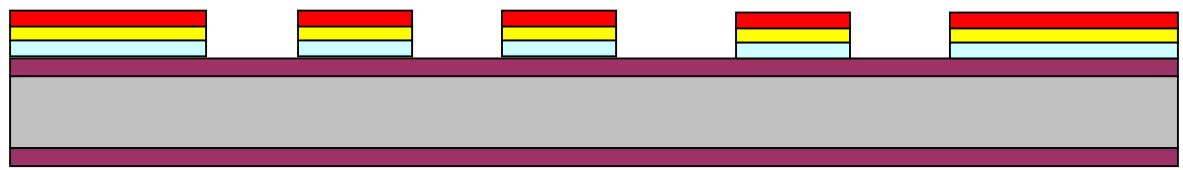


JFET Module Fabrication

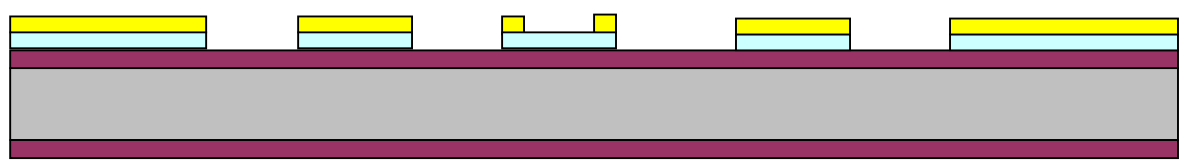
•3 in DSP Si Wafer with
1.8um low stress SiN

•Blanket deposit NiCr/Au
•Pattern resistors and leads

•Etchback NiCr/Au by Ion Mill

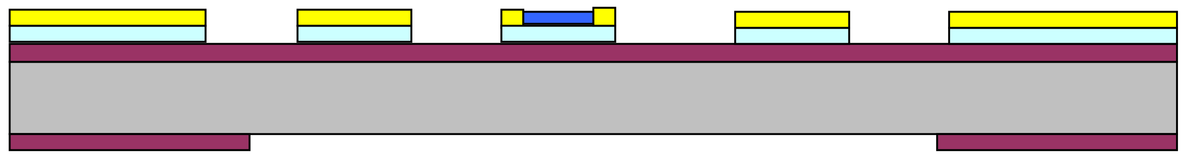


•Etchback Au over resistors

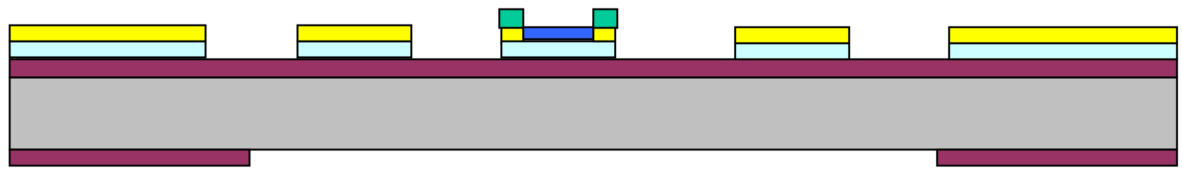


JFET Fabrication (continued)

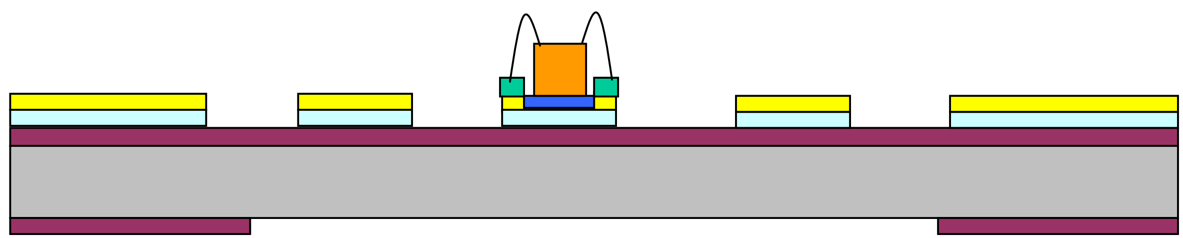
- Passivate entire surface with SiO2
- Etchback SiO2 to cover resistors only



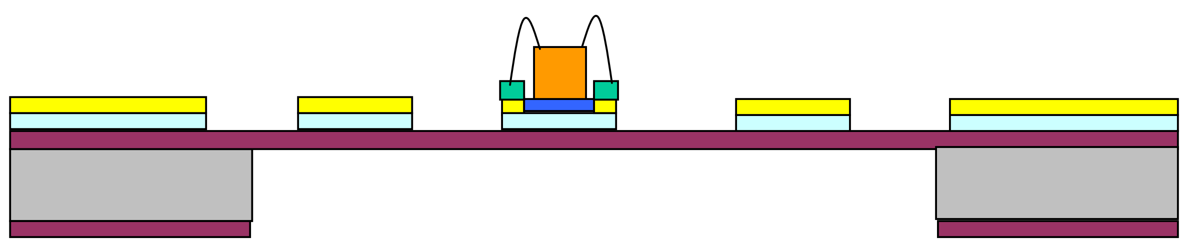
- Pattern and Etch Backside nitride for Si window etch
- Pattern and deposit Ti/Au for wire-bonds to U401 chips



- Dice devices off wafer
- Epoxy bond U401 bare dies to device
- Al Wirebond U401 dies to device



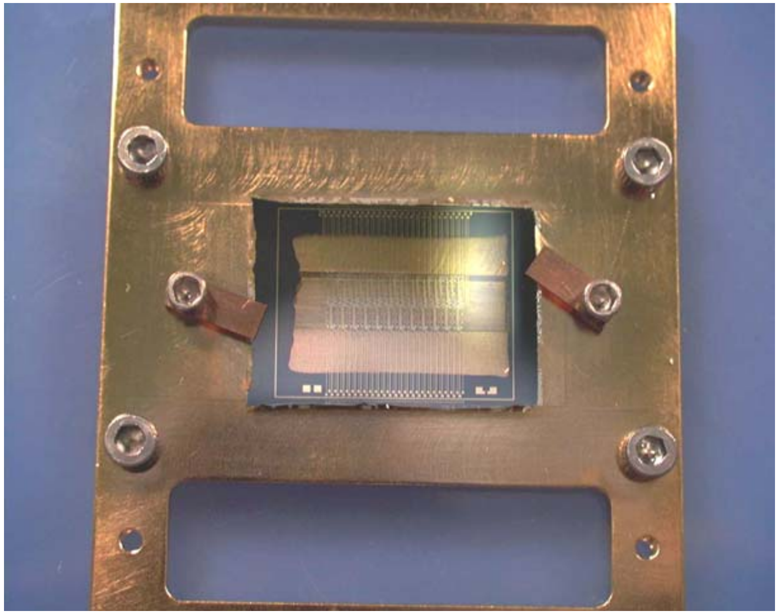
- Etch Si from underneath SiN membrane



JFET Module Status

- Fabrication notes:
  - Low yield on 1um SiN membranes (<10%)
  - High yield on 1.8um SiN membranes (~50%)
  - 2 partially populated membranes completed
  - 1 fully populated membrane completed
  - Process modifications completed

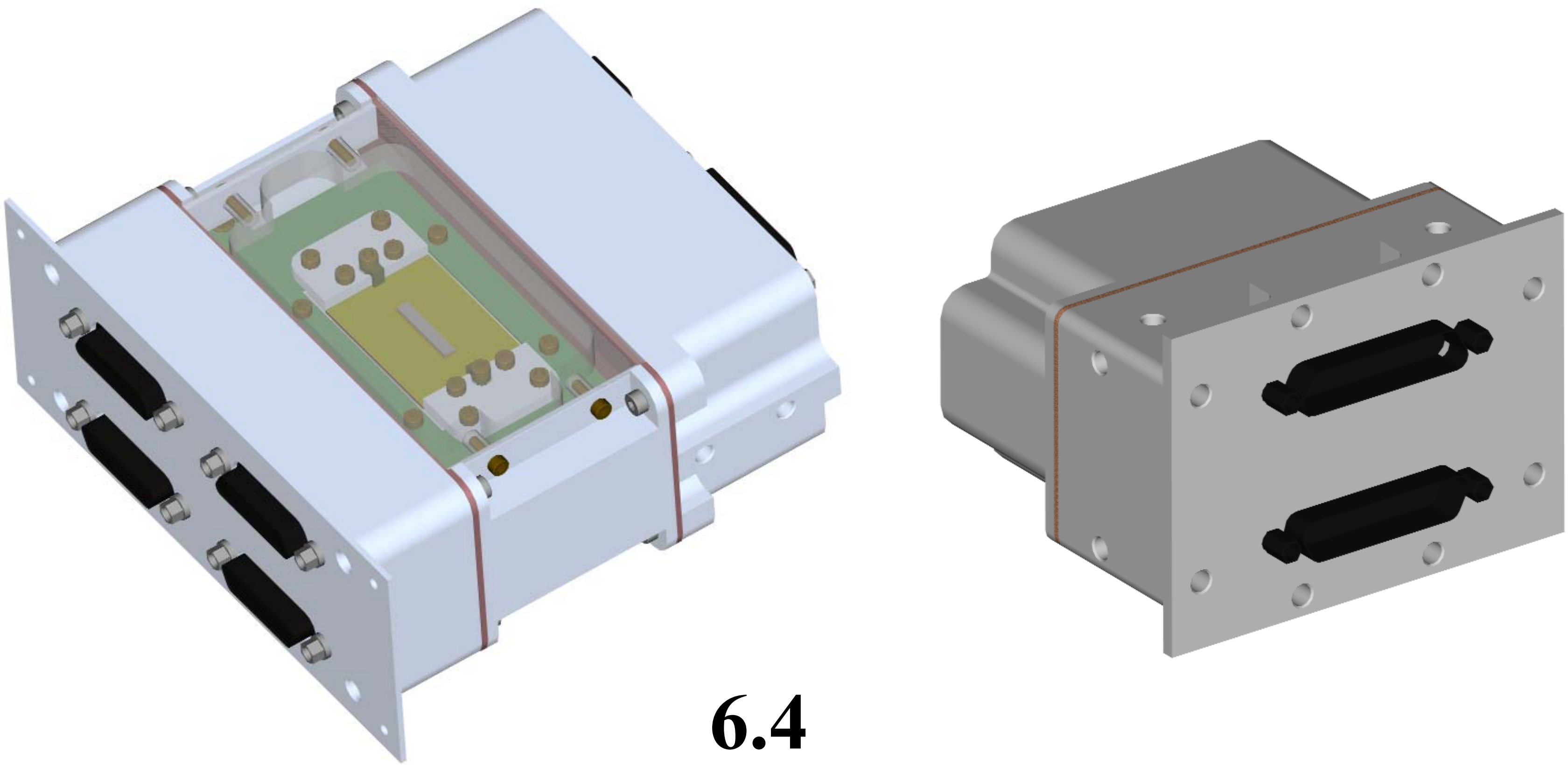
- Testing overview
  - Unetched modules
    - Noise performance completed
  - Representative etched membrane
    - Vibration tested (sine sweep 7.5g amplitude 30-400Hz,15g amplitude 400-2500Hz)
    - Membrane rupture strength is ~ 150g
  - 2 PM modules populated with 12 U401 JFETs
    - Noise and thermal testing completed
  - 1 PM module fully populated
    - Under assembly for environmental testing



Initial EM JFET module (unpopulated) thru final etch

Open Issues and Mitigations

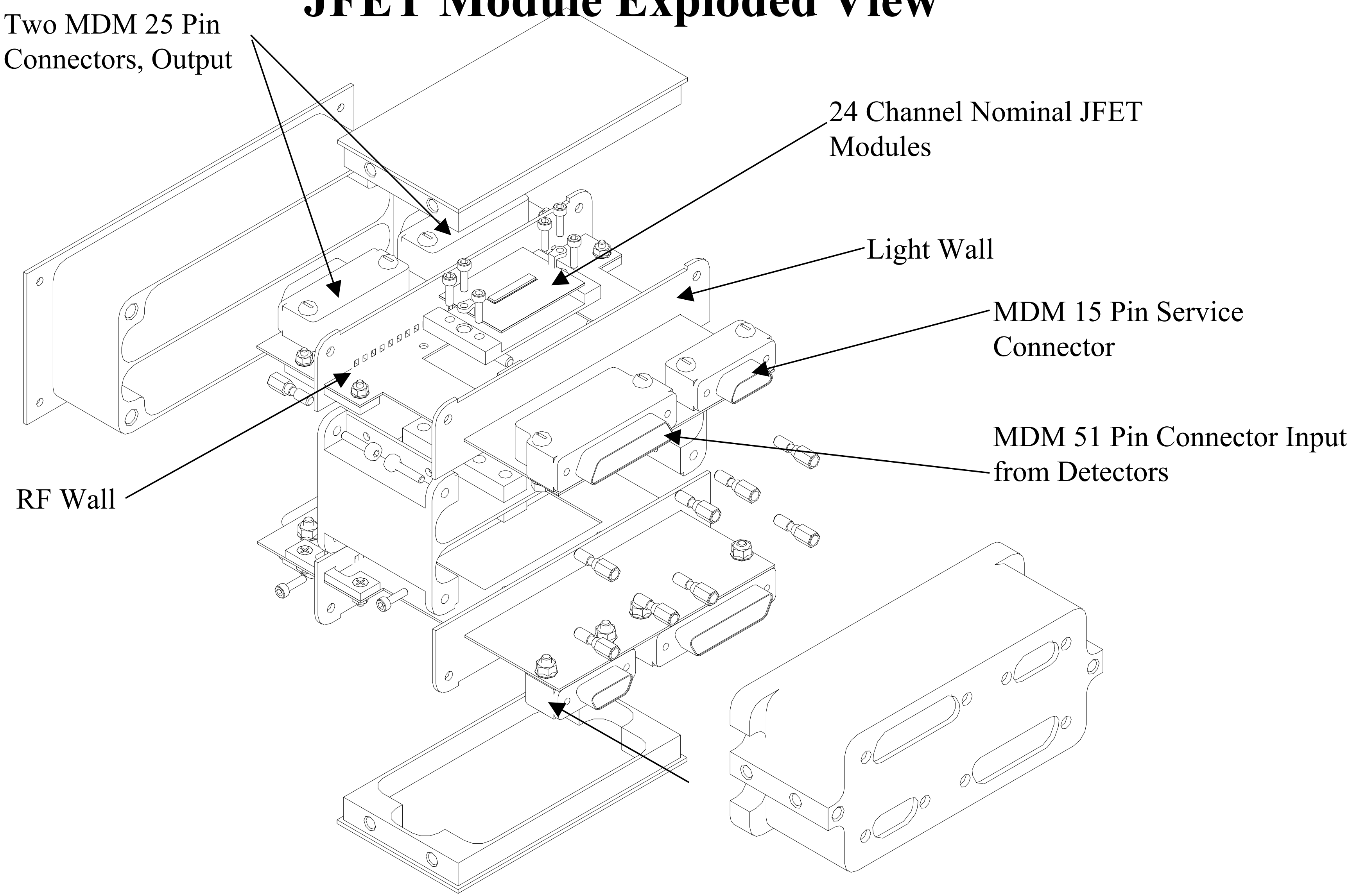
- Low yield during membrane release etch
  - Increased membrane thickness to 1.8um
  - Utilized lower stress epoxy for bonding U401 dies to membrane
  - Low stress etch fixture implemented in release etch
- Lithography errors
  - Implemented E-beam direct write for resistors and leads
- Yields
  - High yields but yet to be quantified



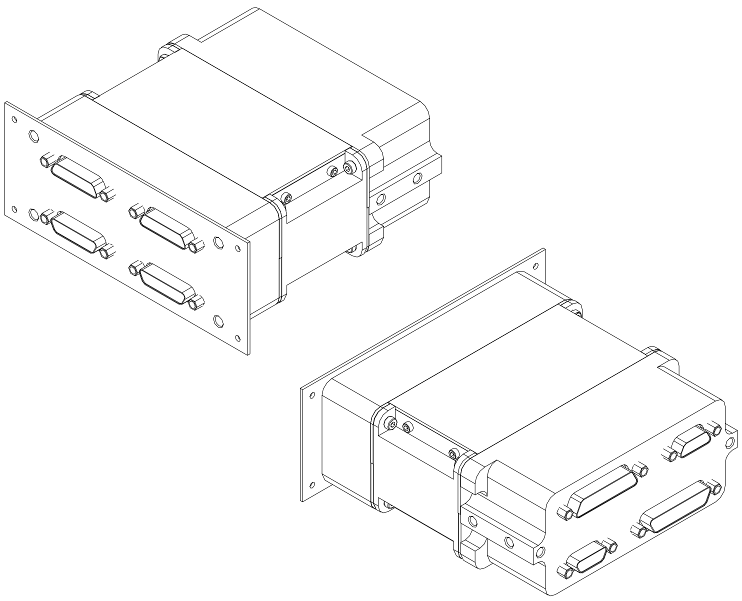
6.4
JFET and RF Module Mechanical Design

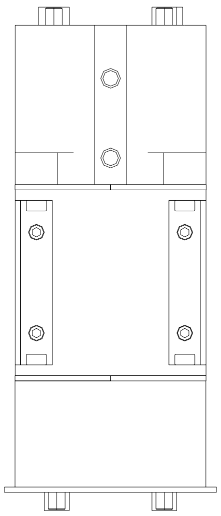
Dustin Crumb

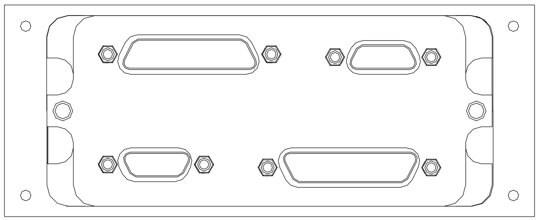
JFET Module Exploded View

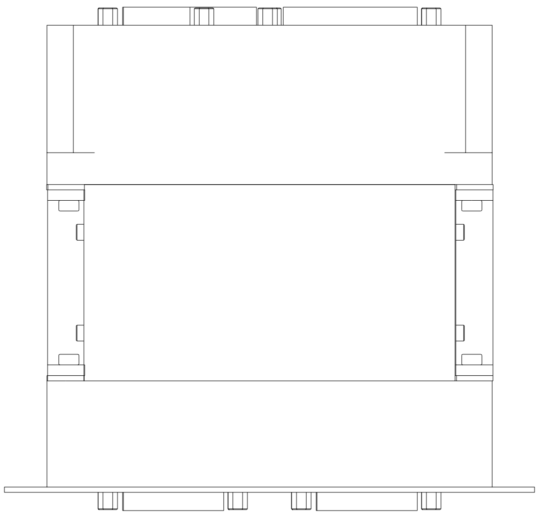


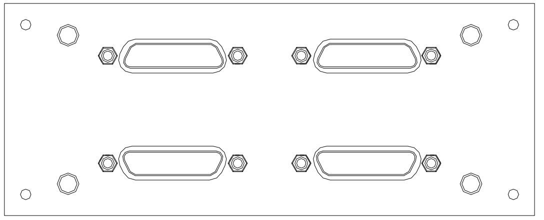
48 Channel JFET Module



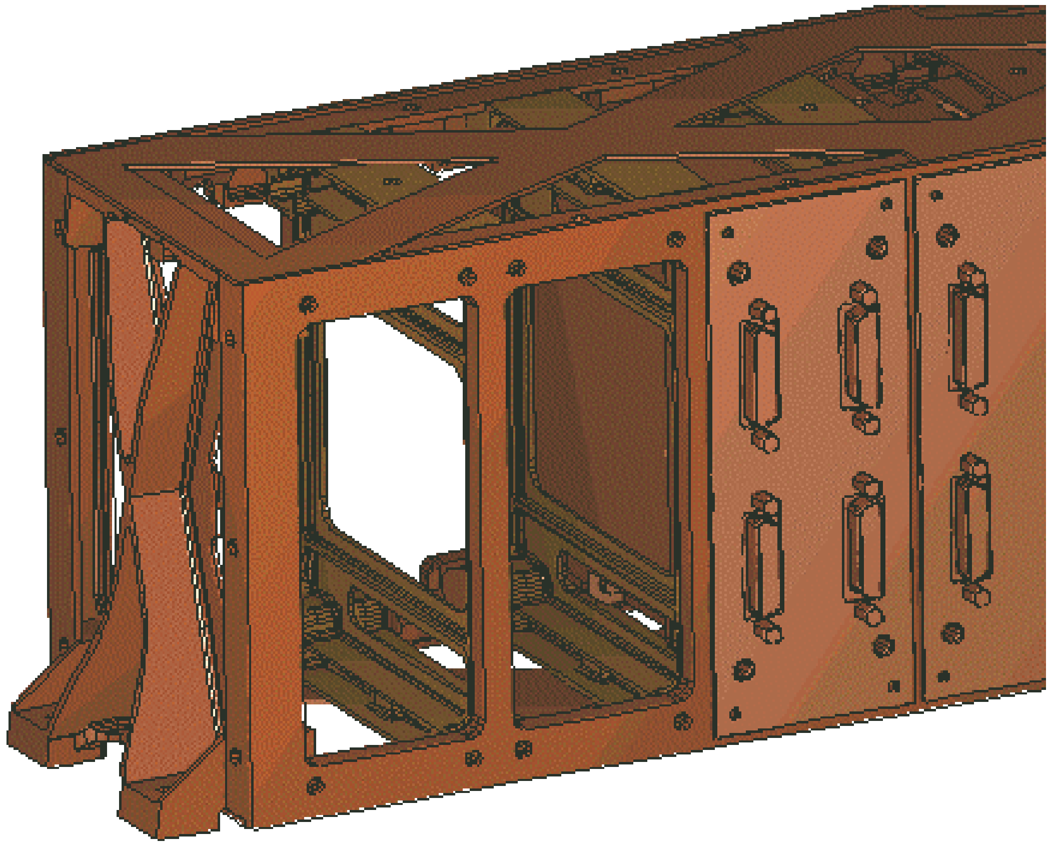






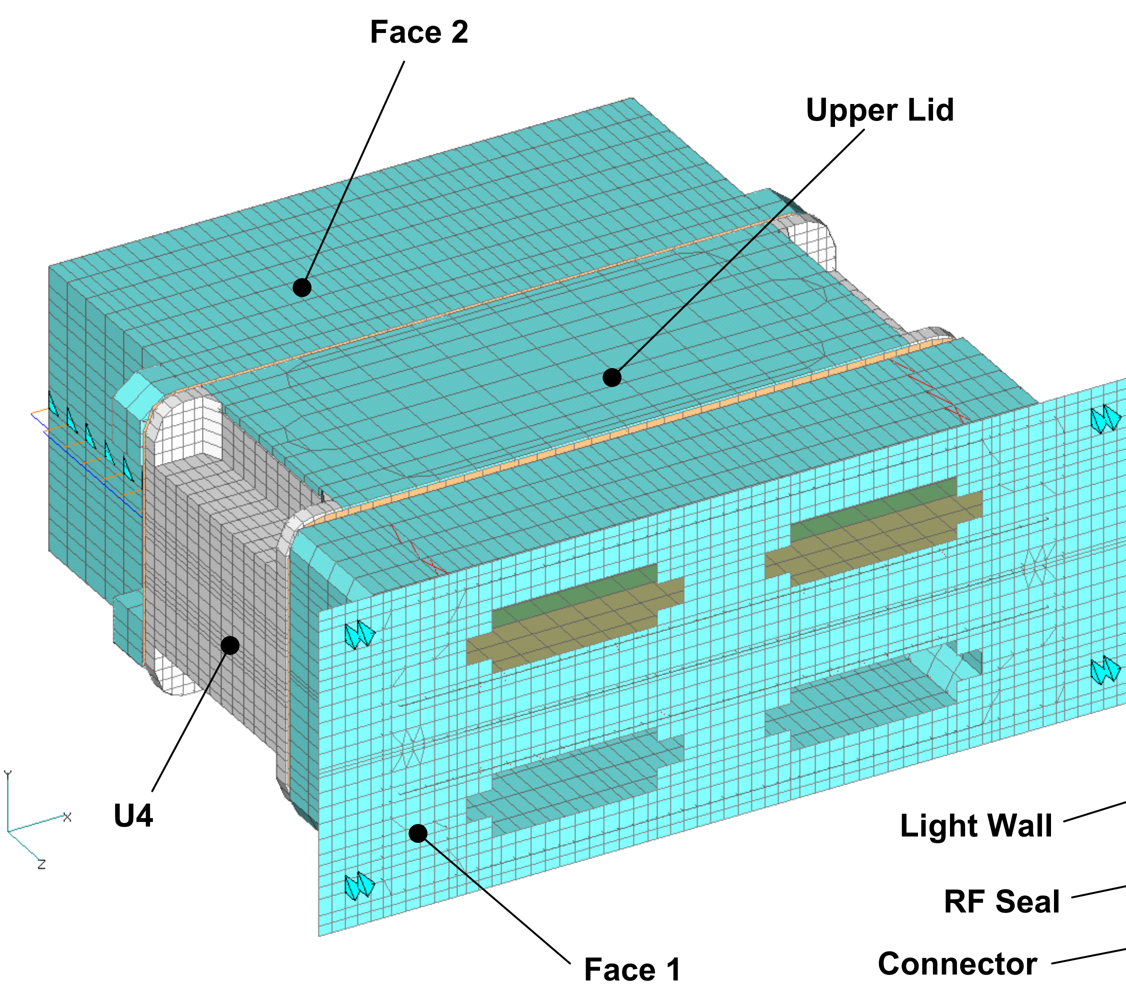


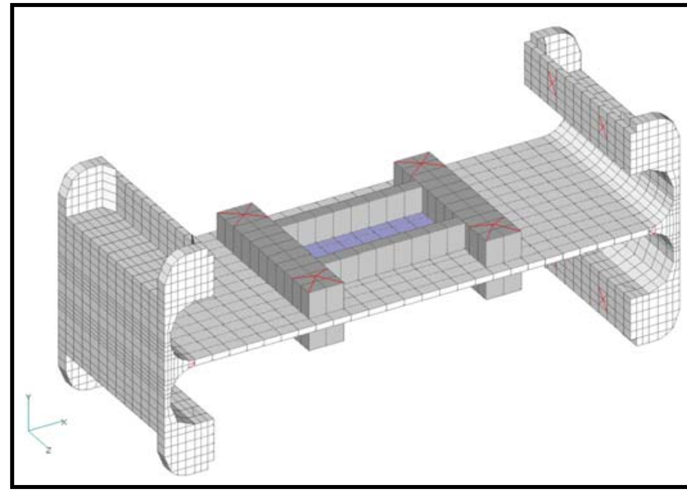
JFET Module Support Structure (RAL Responsibility)



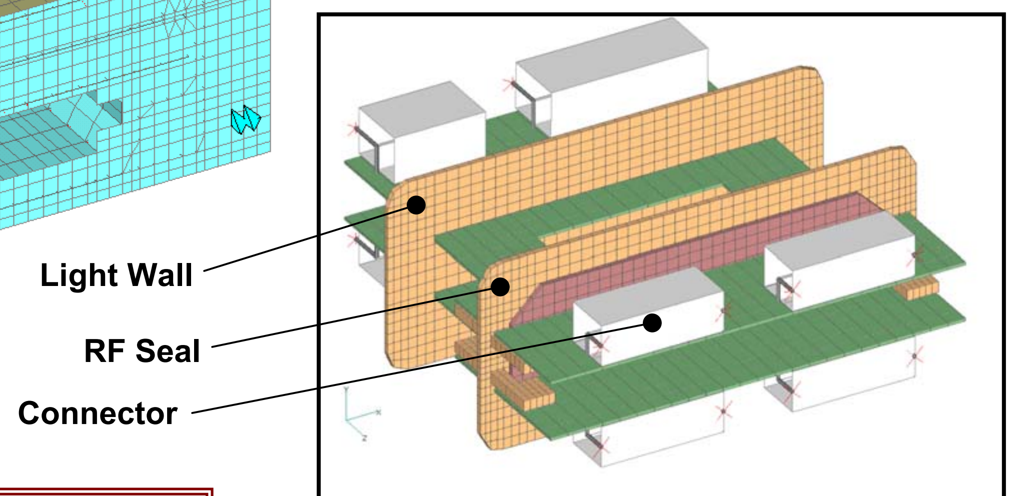
JFET Structural Analysis

Structural Analysis - JFET





U4



Internal Electrical Components

Mass = 277 grams   Elements = 14940   Nodes = 12100

Structural Analysis - JFET

Part = = = = = >	U4, Face 1, Face 2	Light Wall & RF Seal
Material/Temper	Alum 6061-T651 or T62	Alum 6061-T6 or T62
MIL-HDBK-5H Ref	Table 3.6.2.0(b_2)	Table 3.6.2.0(b_1)
Billet Thick Column	.250 - 2.000	.010 - .249
Form	Plate	Sheet
Basis	A	A
Ftu, ksi		
L	42	42
LT	42	42
Fty, ksi		
L	36	36
LT	35	35
Fcy, ksi		
L	35	35
LT	36	36
Fsu, ksi	27	27
Fbru, ksi		
(e/D = 1.5)	67	67
(e/D = 2.0)	88	88
Fbry, ksi		
(e/D = 1.5)	50	50
(e/D = 2.0)	58	58
E, 10^3 ksi	9.9	
G, 10^3 ksi	3.8	
μ	0.33	
ρ, lb/in^3	0.098	

Structural Analysis - JFET

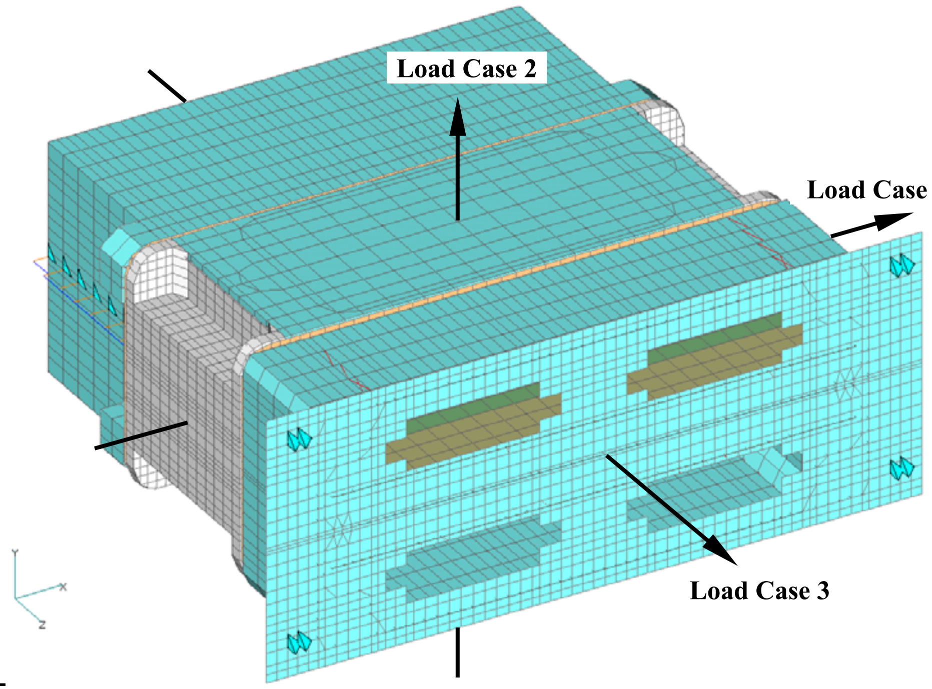
- Analysis Requirements Used to Verify Structural Integrity
  - Qualification Random Vibration (IID - A)

Location	Axis	Freq Range	Density	RMS Value
Herschel Optical Bench	ALL	20 - 80 Hz 80 - 300 Hz 300 - 2000 Hz	+3 db/Oct .077 G^2/Hz -6 db/Hz	6.67 G

  - F
    - FS_{yld} = 1.25
    - FS_{ult} = 1.4
    - Unconventional Material FS_{ult} = 2.0
  - Limit Loads (ERD D-19155)
    - 20G Any Direction

Structural Analysis - JFET

- Load Cases (applied in three directions deemed most critical for stress)
  - Each load case consists of:
    - 32 G Quasi Static Equivalent Load
      - 1.5% Damping used in RV analysis (JPL Std.)
      - 3s Value
      - Value above Limit Load requirement; wanted to assess capability
    - Thermal transistion from 70°F to -442°F
- Constraints
  - Fixed at JFET-to-JFET Rack fastener loacations



Structural Analysis - JFET

Margin of Safety Summary Tables
(In Progress, will be ready by CDR)

Structural Analysis - JFET

- Computer Model Validation - Comparison to Test Data
  - Modal Frequencies
    - Tests still need to be performed

Table of Computer Model's First Three Modes
(In progress, will be ready by CDR)

Structural Analysis - JFET

- Where Are We Now?
  - Incorporate latest design changes and finalize analysis
  - Once testing is complete, verify FEM model results against test data

6.5
JFET Module Assembly/Manufacturing

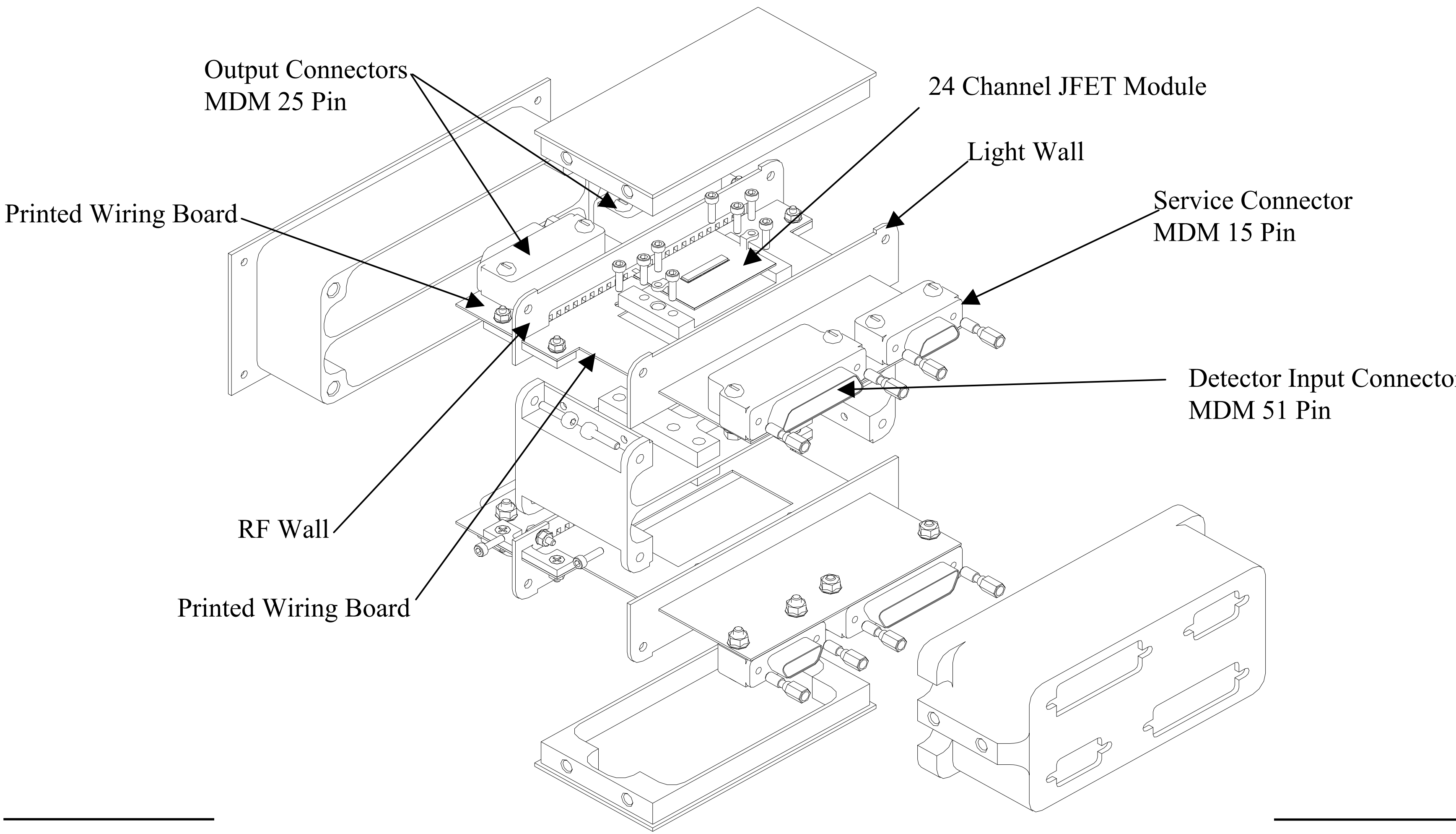
Leonard Husted

JFET Assembly Manufacturing

- Contents
  - Exploded Views
  - Assembly Documentation Required
  - Manufacturing Processes
  - Tooling
  - Manufacturing Process Flow
  - Summary

JFET Assembly Manufacturing

- JFET Assembly Exploded View



JFET Assembly Manufacturing

- Documentation Required

Document Title	Number	Status		
		In work	Complete	Released
JFET Module Assembly Drawing	10209750	x	75%	8/17/01
JFET Isolation Assembly Drawing	10209757	x	75%	8/17/01
JFET PCB Assembly Drawing	10209760	x	75%	8/17/01
JFET Wire Bonding Diagram	TBD			8/24/01
AIDS-JFET Module Assy	TBD	x	60%	8/24/01
AIDS- JFET PCB Assy	TBD			8/24/01

JFET Assembly Manufacturing

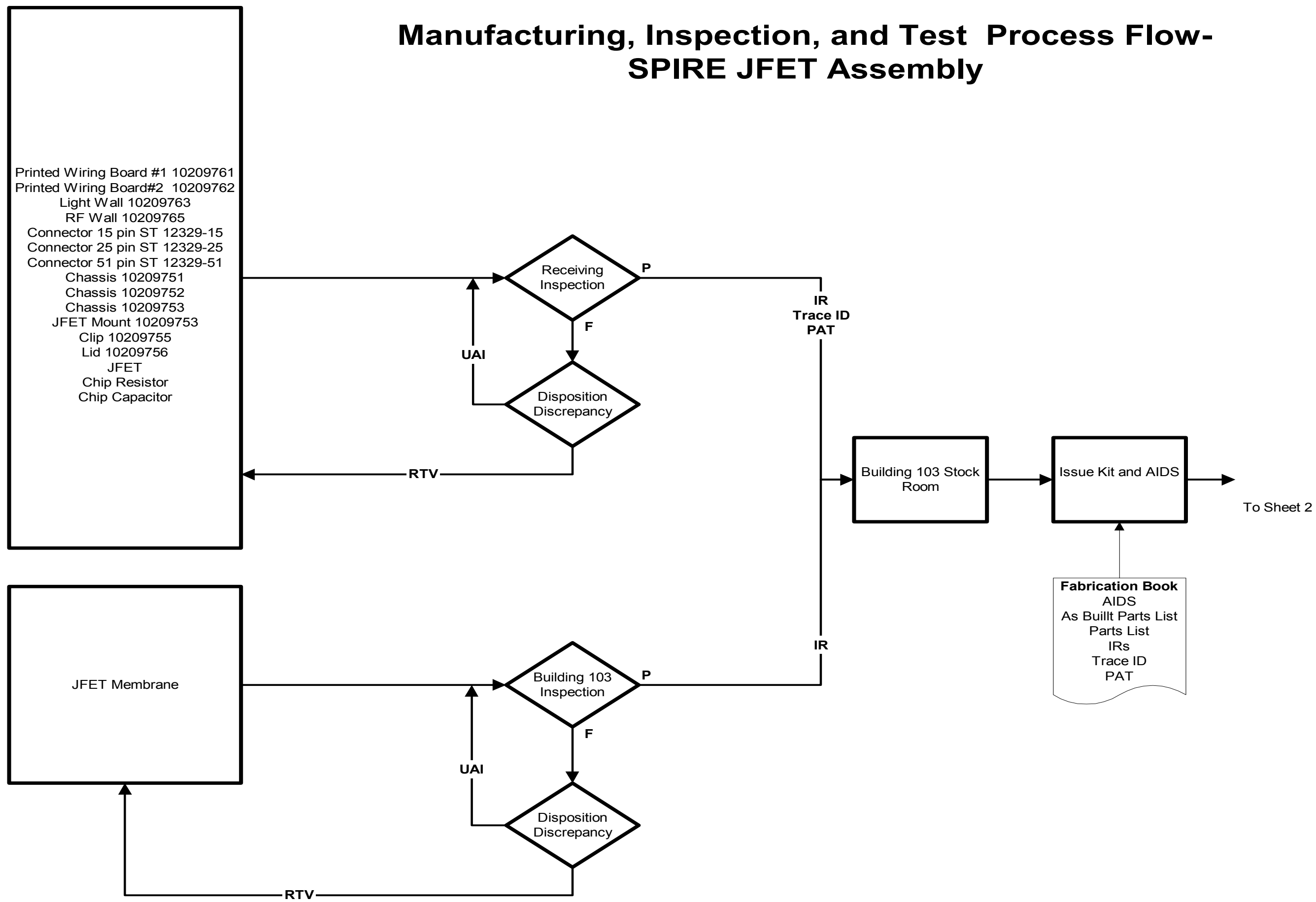
- Manufacturing Processes

Process	Std	Procedure	Requirement
Cleaning	YES	FP 513414	Drawing
Adhesive Bonding	YES	FP 513414 Sect 9.0	Drawing
Wire Bonding	YES	FP 513414 Sect 10.18	Mil-Std-883 M2011.7
Die Attach	YES	FP 513414 Sect 10.14	Mil-Std-883 M2019.5
Soldering	YES	FP 513414 Sect 6.1.2	D 8208
Solder Tinning	YES	FP 513414 Sect 6.2.2	D 8208
Torque	YES	ES 517040	Drawing
Vacuum Bake	YES	FP 513414 Sect 6.1.2	
Mechanical Assembly	YES	AIDS	Drawing
Inspection	YES	AIDS	Drawing
Electrical Test (JFET PCB Assy)	NO	Test Procedure TBD	TBD
Conformal Coat	YES	FP 513414 Sect 9.5	Drawing
Identification	YES	FP 513414 Sect 9.0	Drawing

JFET Assembly Manufacturing

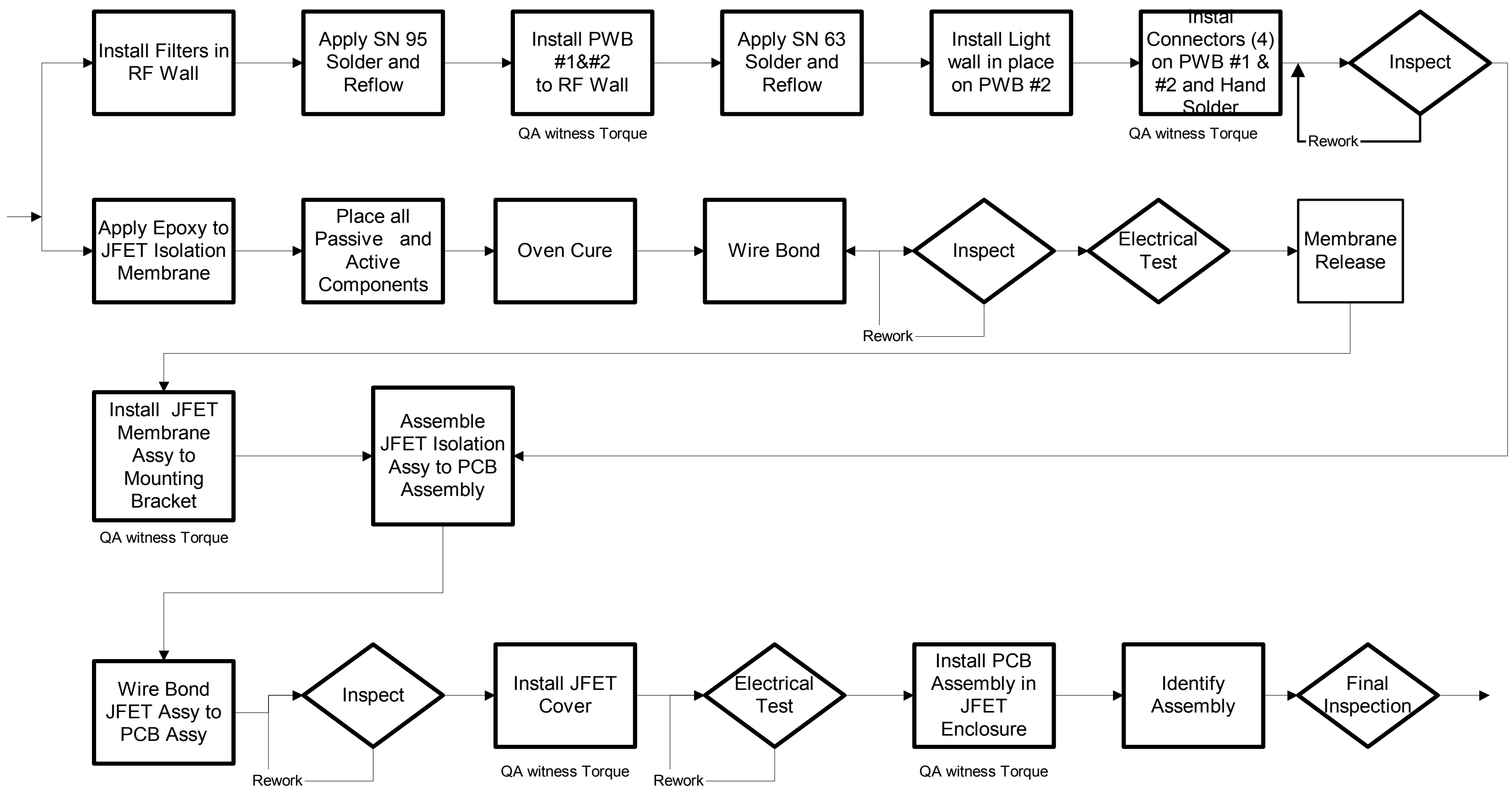
- Tooling Required
  - JFET Assembly
    - RF Wall Reflow Solder Fixture
    - Printed Circuit Board Reflow Solder Fixture
    - JFET Wire Bonding Fixture
    - Holding Fixture

JFET Assembly Manufacturing



JFET Assembly Manufacturing

Manufacturing, Inspection, and Test Process Flow-
SPIRE JFET Assembly



BDA Manufacturing

- Summary

Methods/Process Development Needed

Filter installation in RF Wall

Wire Bonding JFET Module

Wire Bonding JFET Module to PWB

Test Fixture at JFET Module Level

Assembly Tooling

Open Issues

Drawings incomplete

AIDS incomplete

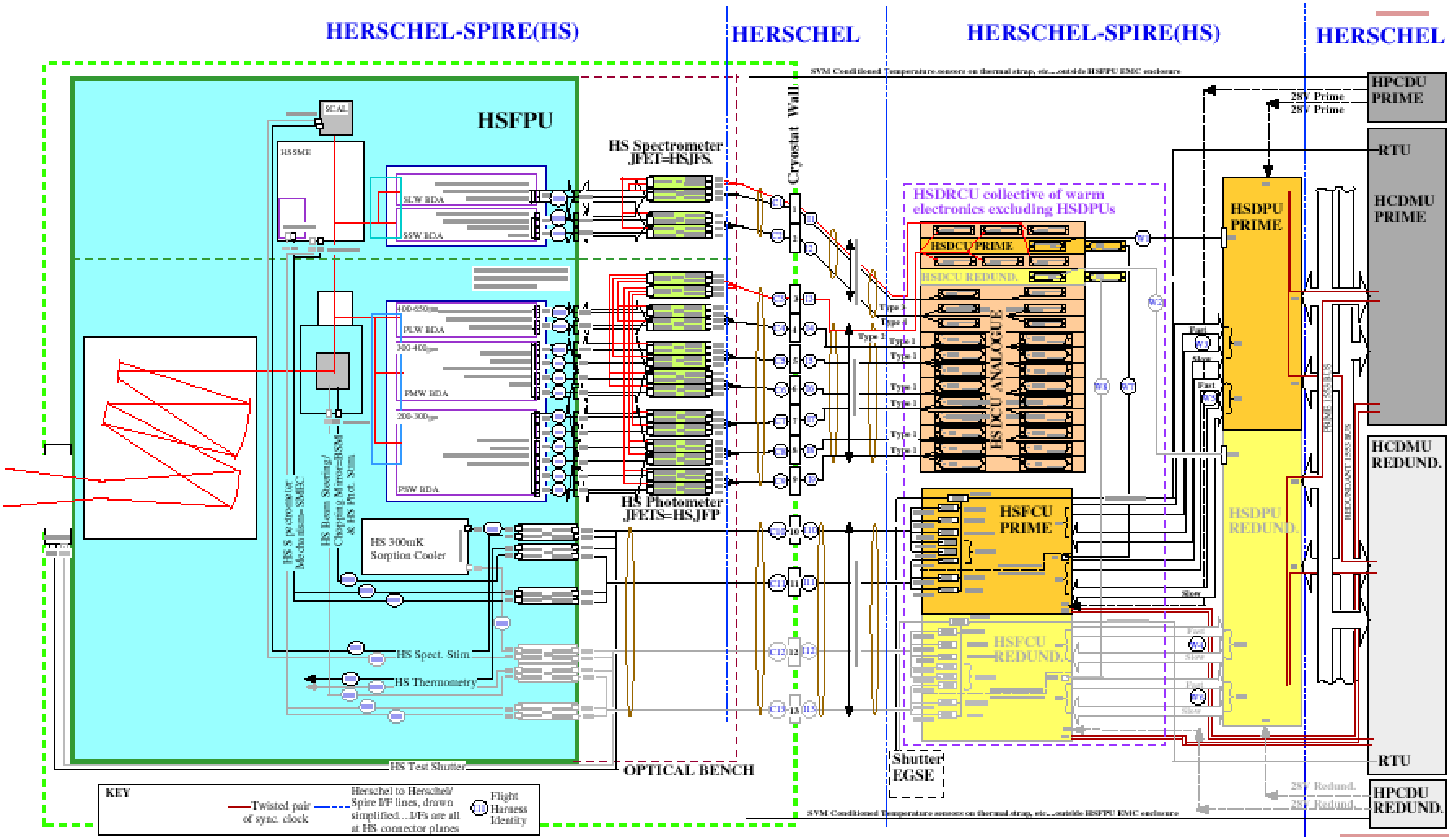
7.0
Harness Definition And Test Procedures

Viktor Hristov

Electrical Interface

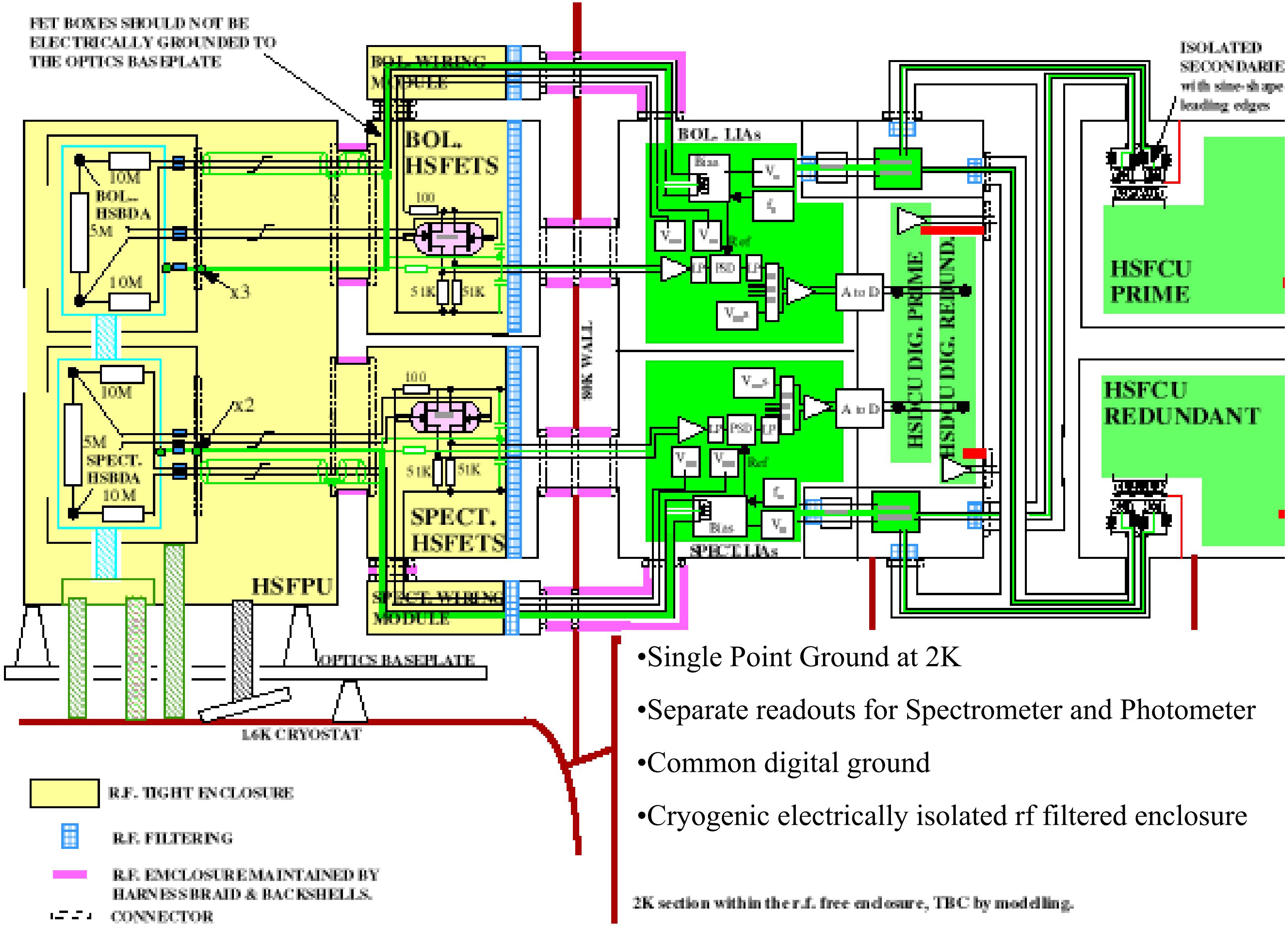
- Harness Definition Document defines the electrical interface for the various Hershel-Spire modules
- This document is written by RAL and agreed to by CEA and JPL
- The document defines the:
  - electrical connections,
  - shielding and bundling of cables,
  - grounding network,
  - cable impedance,
  - microphonics,
  - capacitance,
  - thermal properties.

SPIRE Block Diagram



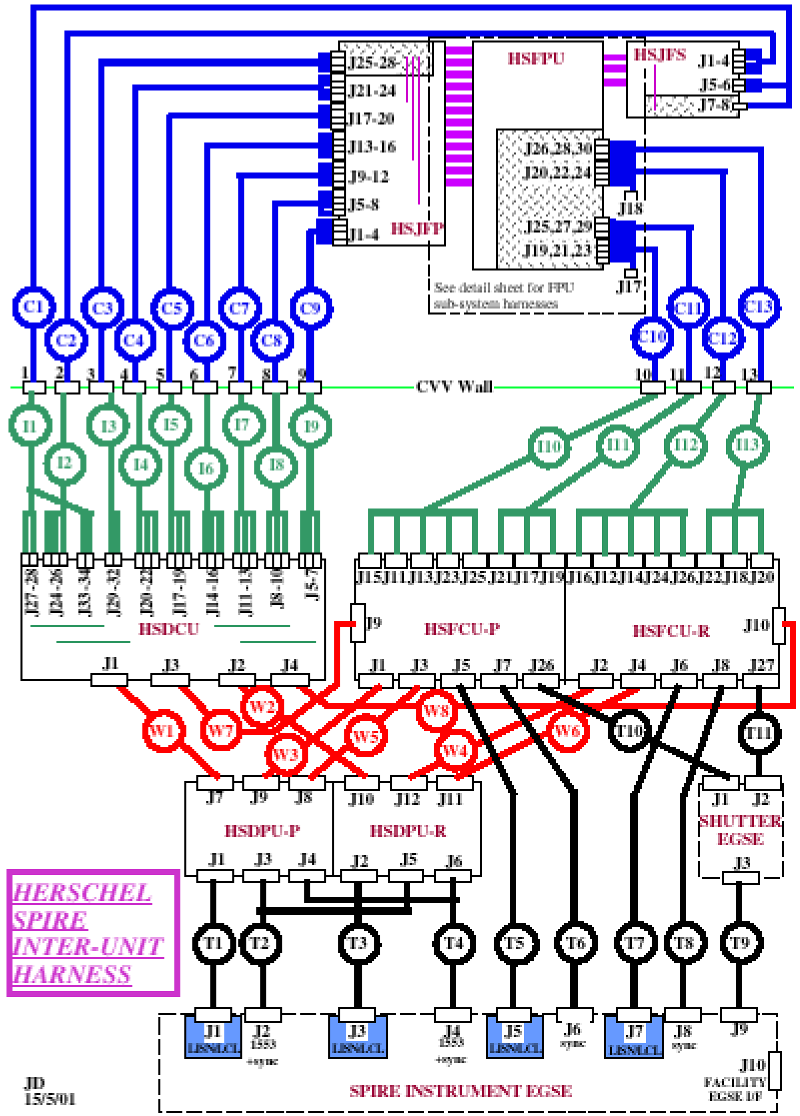
Spire Block Diagram Figure 5.2.1

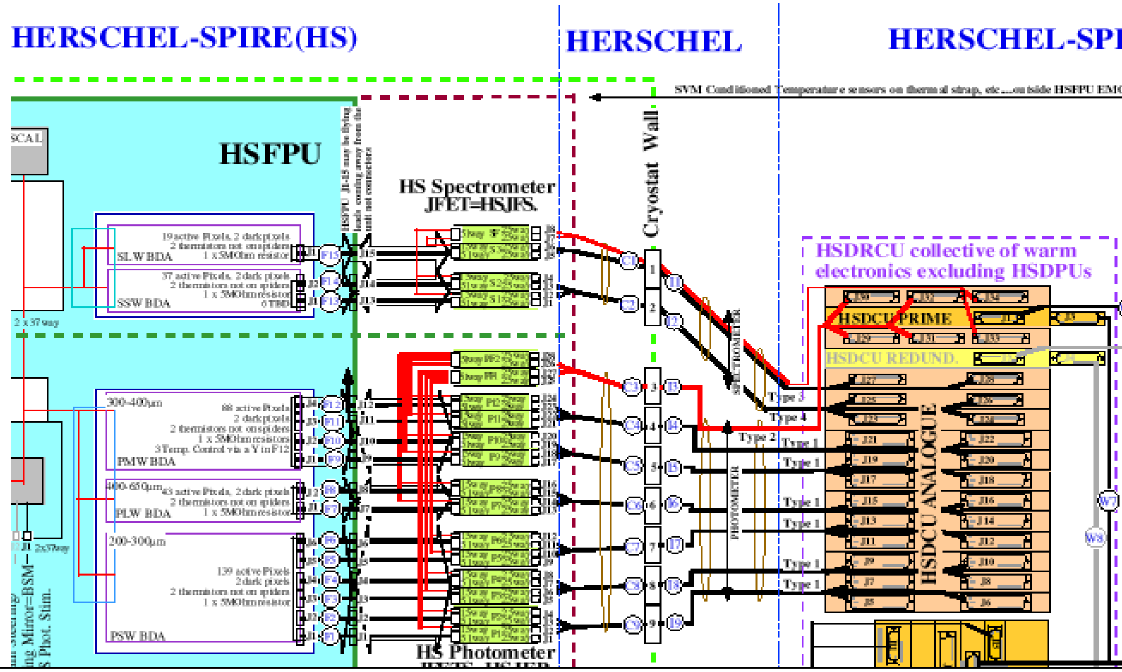
Grounding Diagram



- Single Point Ground at 2K
- Separate readouts for Spectrometer and Photometer
- Common digital ground
- Cryogenic electrically isolated rf filtered enclosure

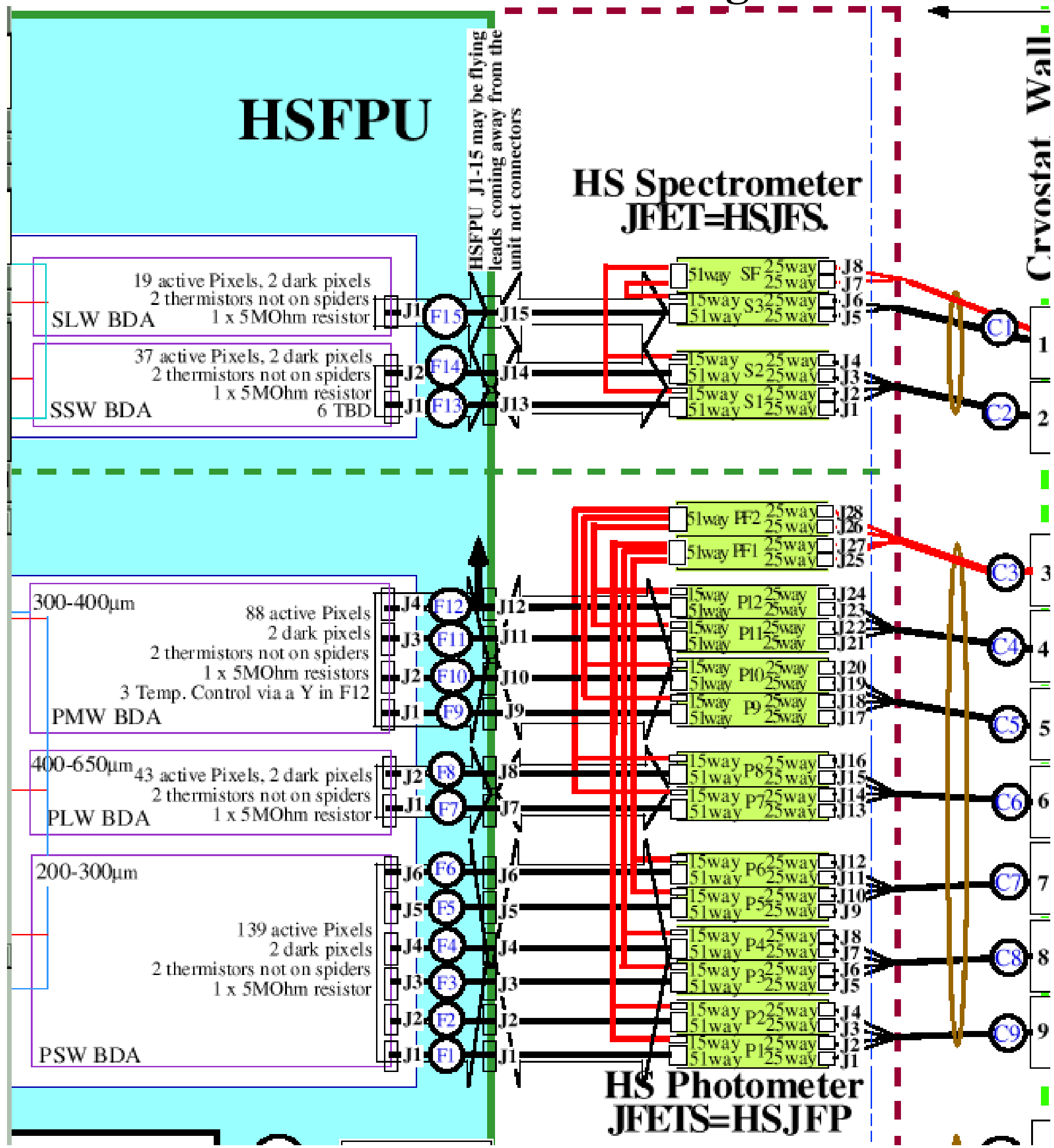
Harness Diagram



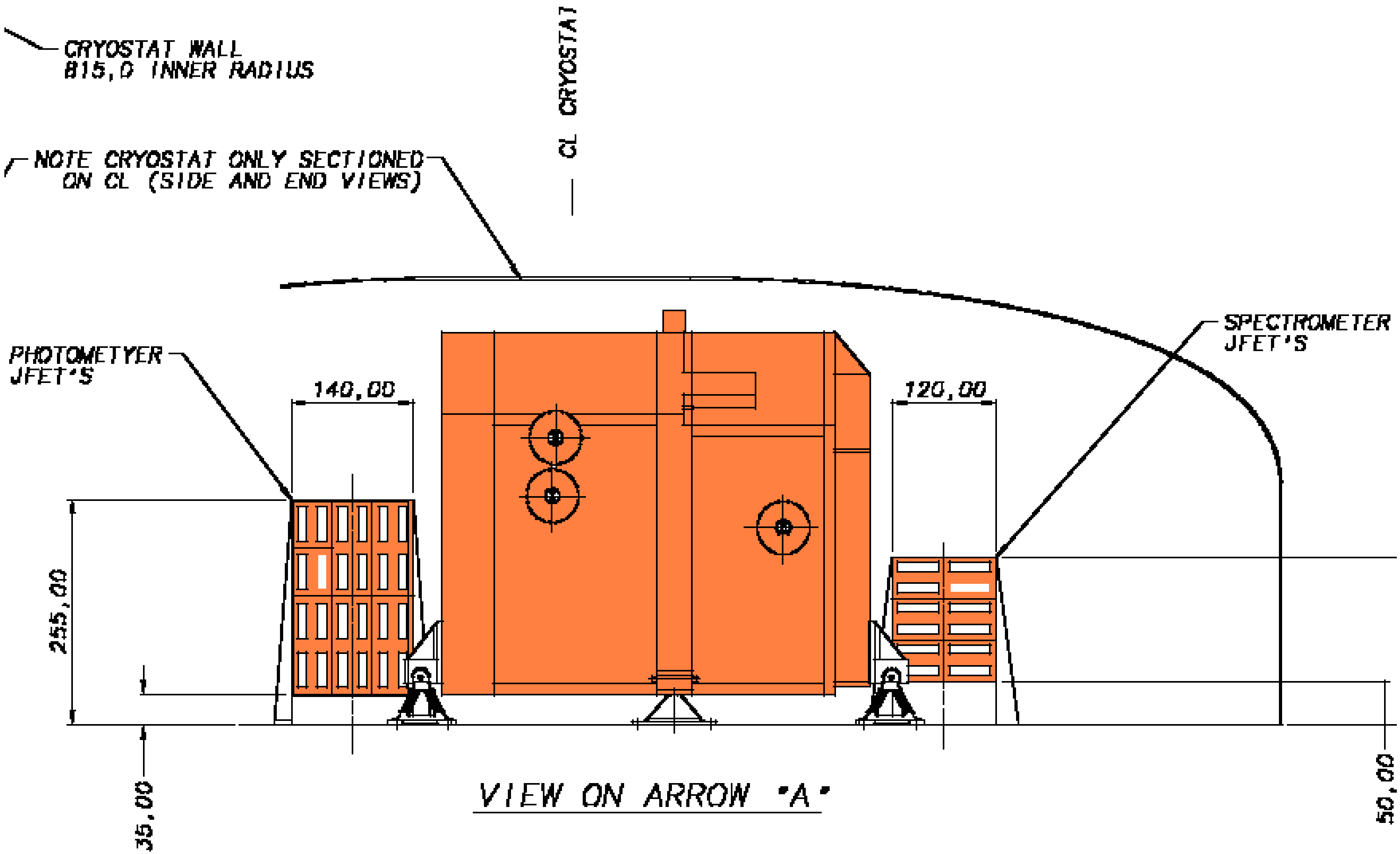


SPIRE Block Diagram
JPL Related

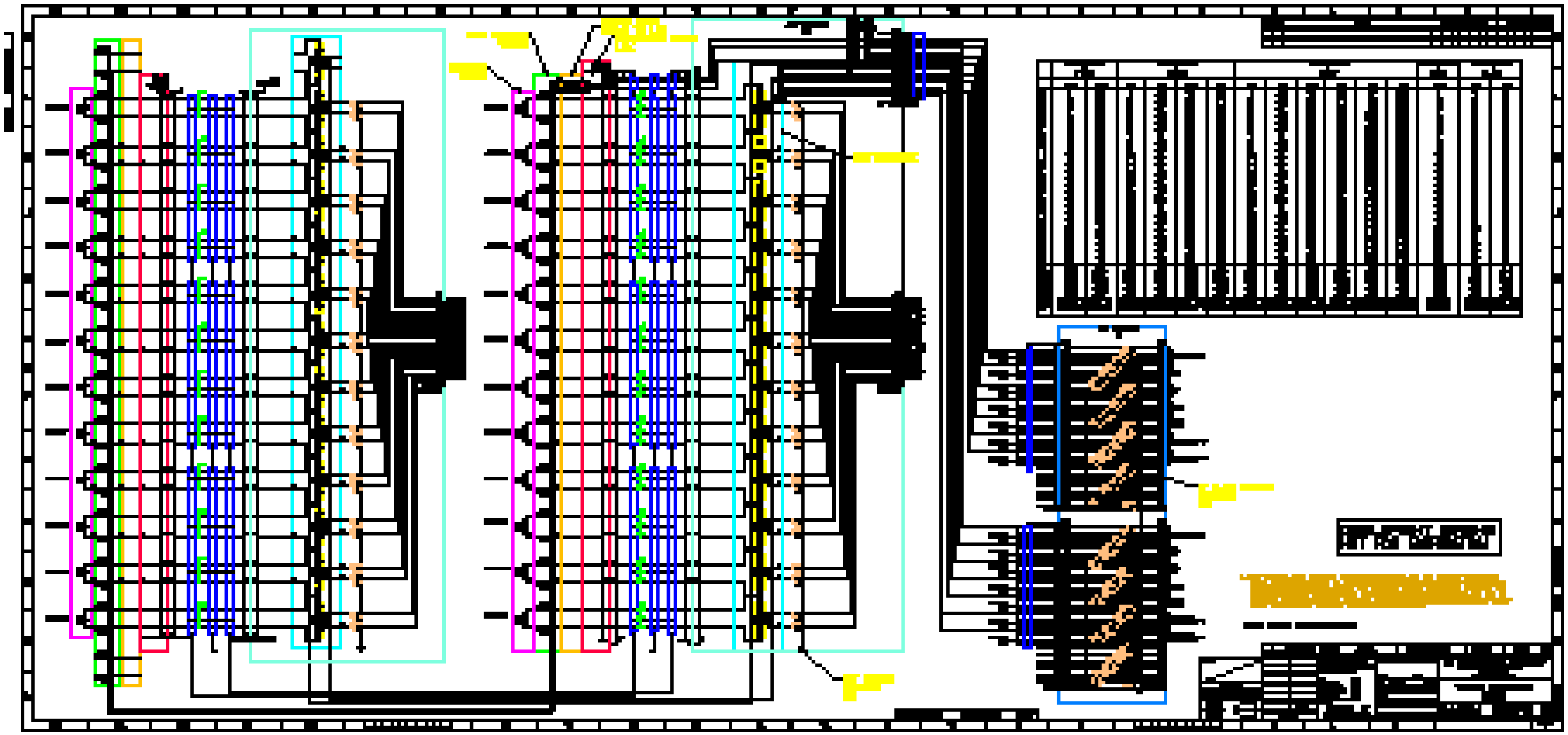
BDA to JFET Wiring



RF Architecture

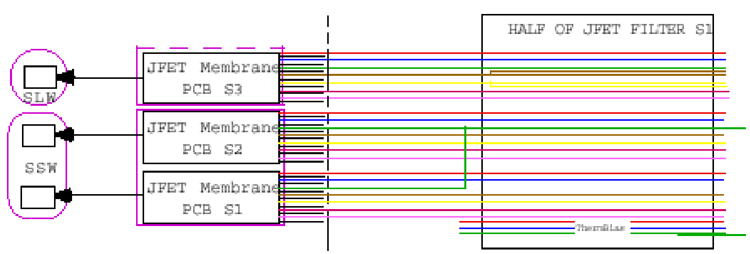


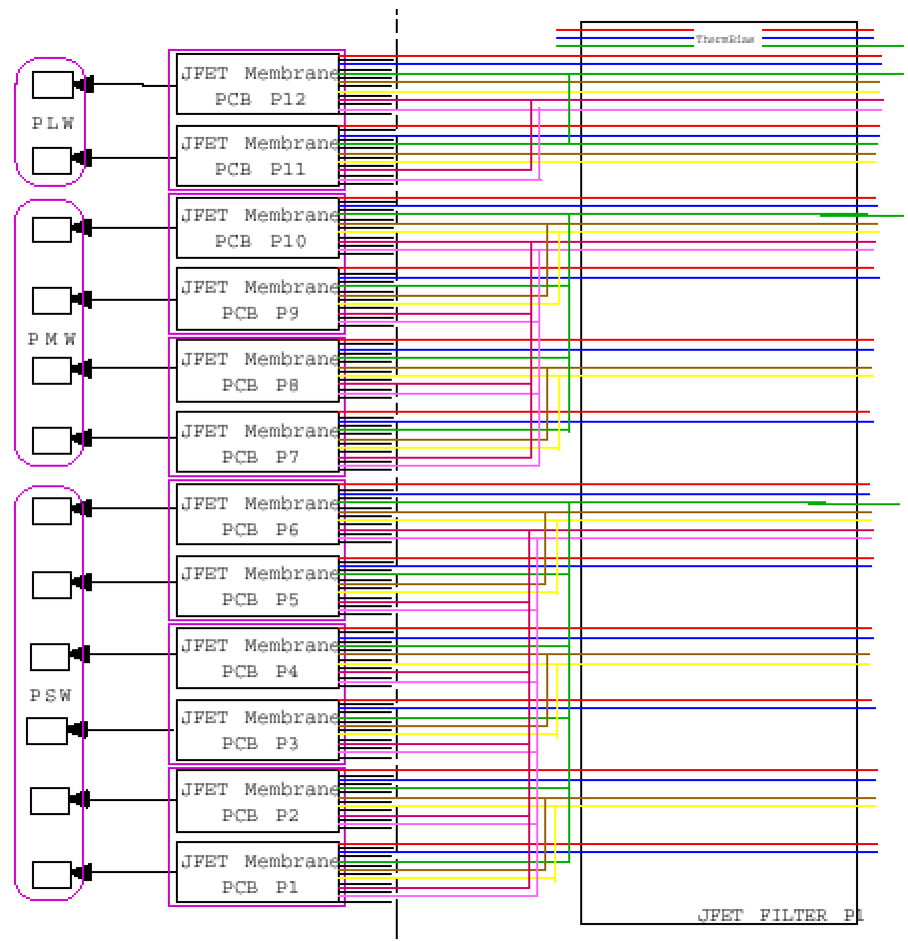
Wiring Chain



COLD RF FILTERS: BIAS AND COLD JFET POWER DISTRIBUTION

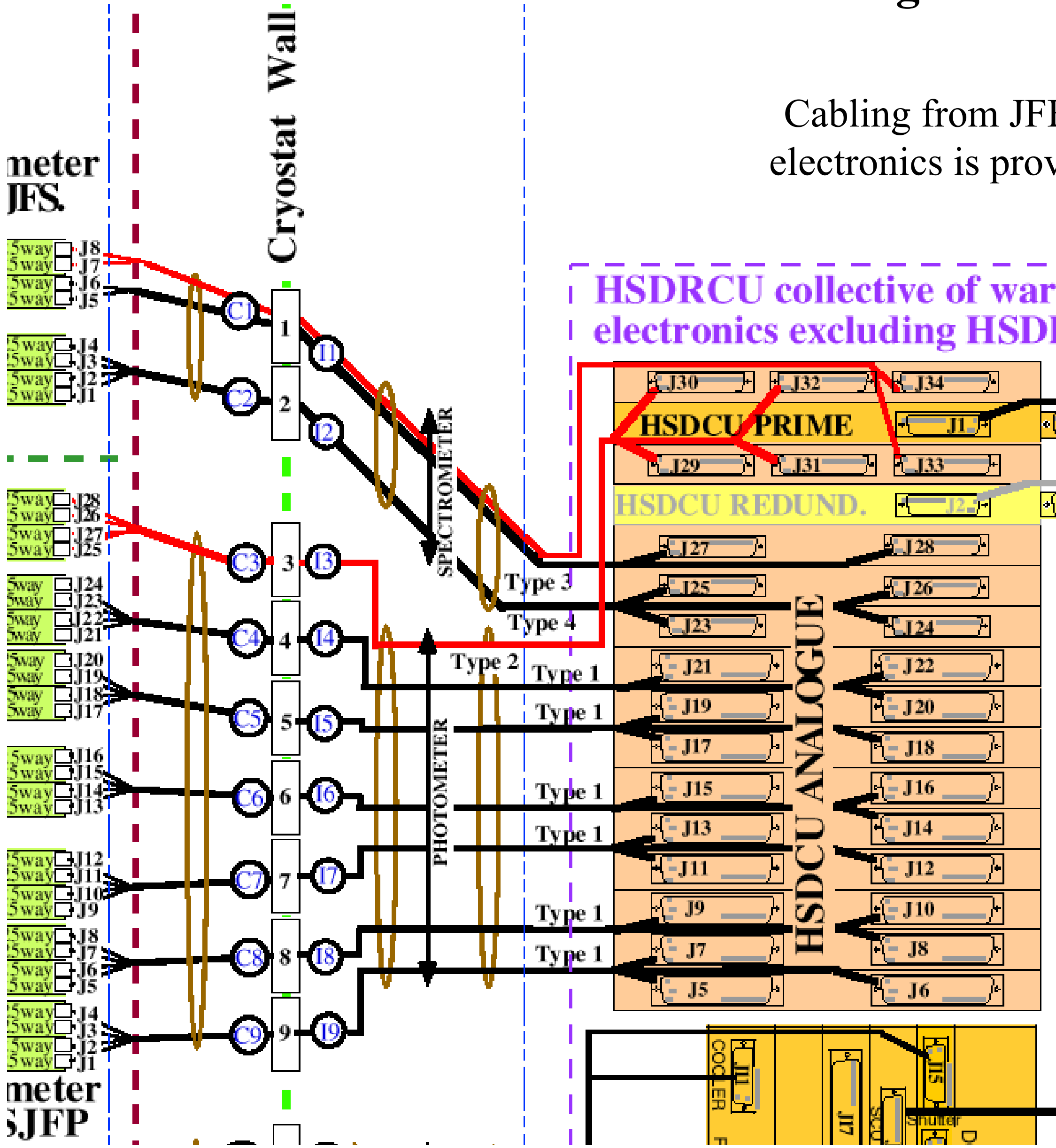
Function	A-wire	B-wire
JFET V-	1	8
JFET V +	10	14
JFET Vgnd	9	15
Bias +	2	7
Bias -	4	5
Heater +	3	6
Heater -	11	13





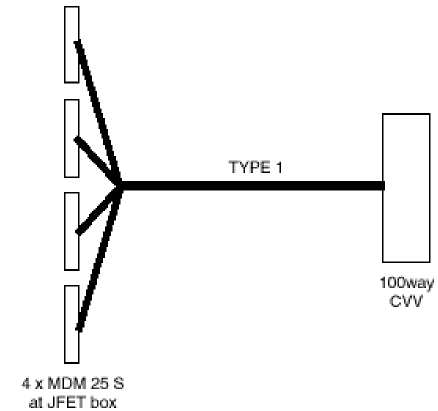
JFET to Warm Electronics Wiring

Cabling from JFETs to warm electronics is provided by ESA



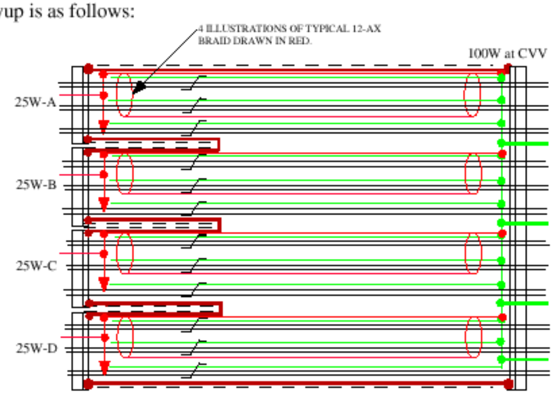
Low Impedance Cabling

Overall Mechanical Drwg.



Harness Layup

The total harness layup is as follows:

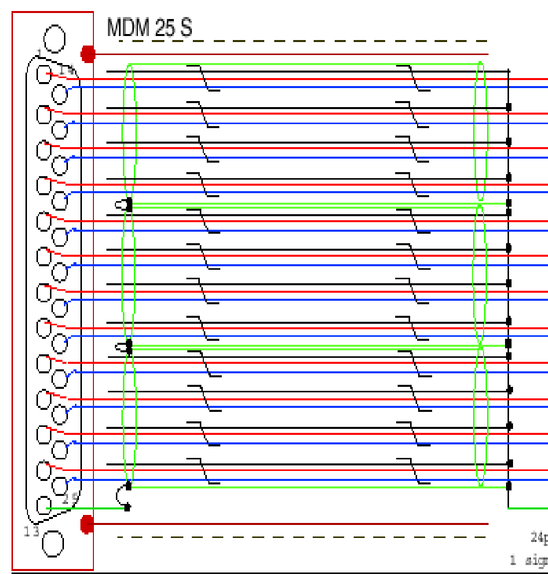


There are 48 channels each carried as a twisted triple, grouped in fours as "12-ax", each with its own insulated screen. So there are 12 x 12-ax in all with three 12-ax to each 25 way MDM. The use of a third wire twisted with each channel's + & - signal wires minimises interchnnel cross-talk inside each 12-ax.

As for the intermediate harness, 4 pins carry ground through the 100 way and carry an isolated ground ring. All the third wires are made off to this, as are all the 12-ax screens.

At the 25way MDMs, the three 12-ax braids (which have a much higher conductivity than that of the sum of all the third twisted wires) are joined and pass through pin7. The third wires are shown as left open here as physically joining them all at MDM geometry seems unfeasible and uncondicive to a neat layup.

To keep RF screening distinct from low noisr bolomter grounds, all of this harness is enclosed in separate outer r.f. screen, EMC sealed to connector boots, overwrapped with insulation.



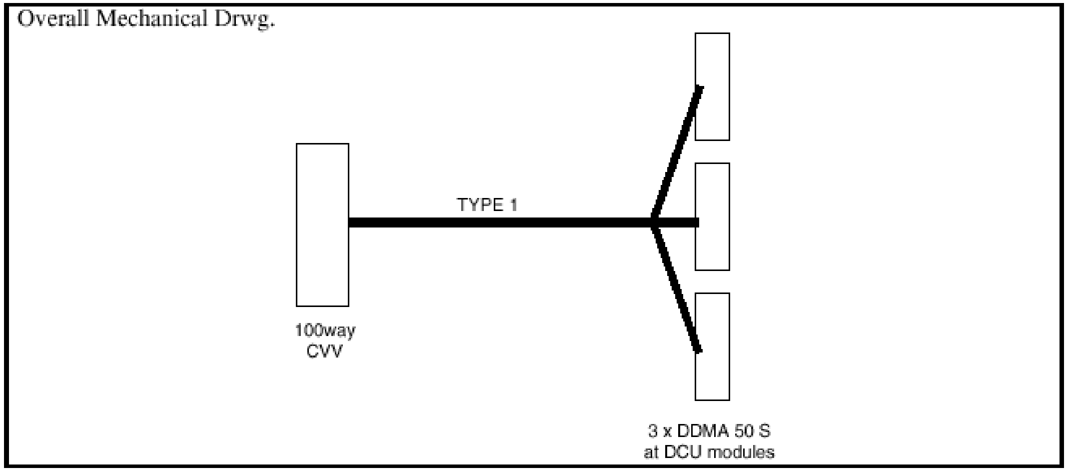
Type 1 JFET tails

Common to all 3 tails, although others have channels 12-24, etc..

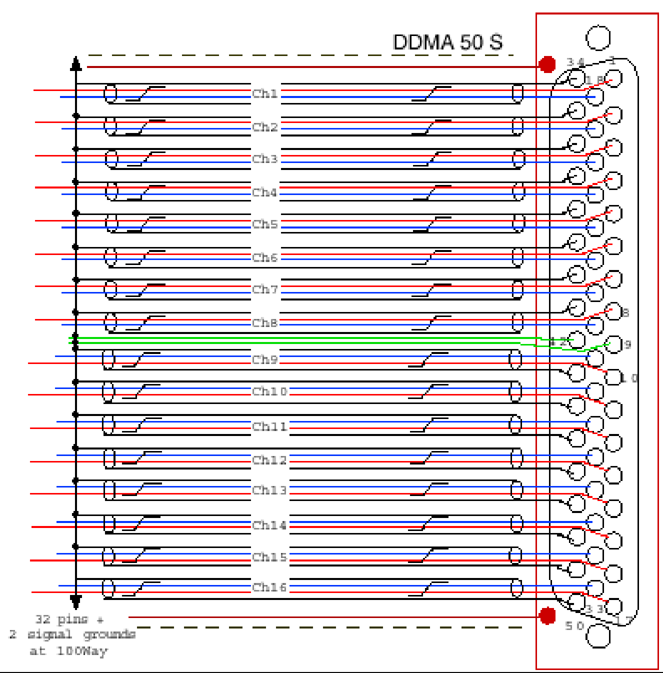
3 x 12-ax cables

The whole overlain with RF screen shown:

Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.



Harness Layup



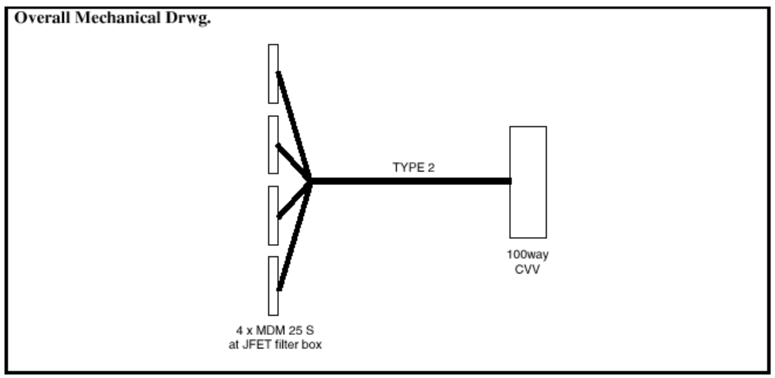
Type 1 DCU tails

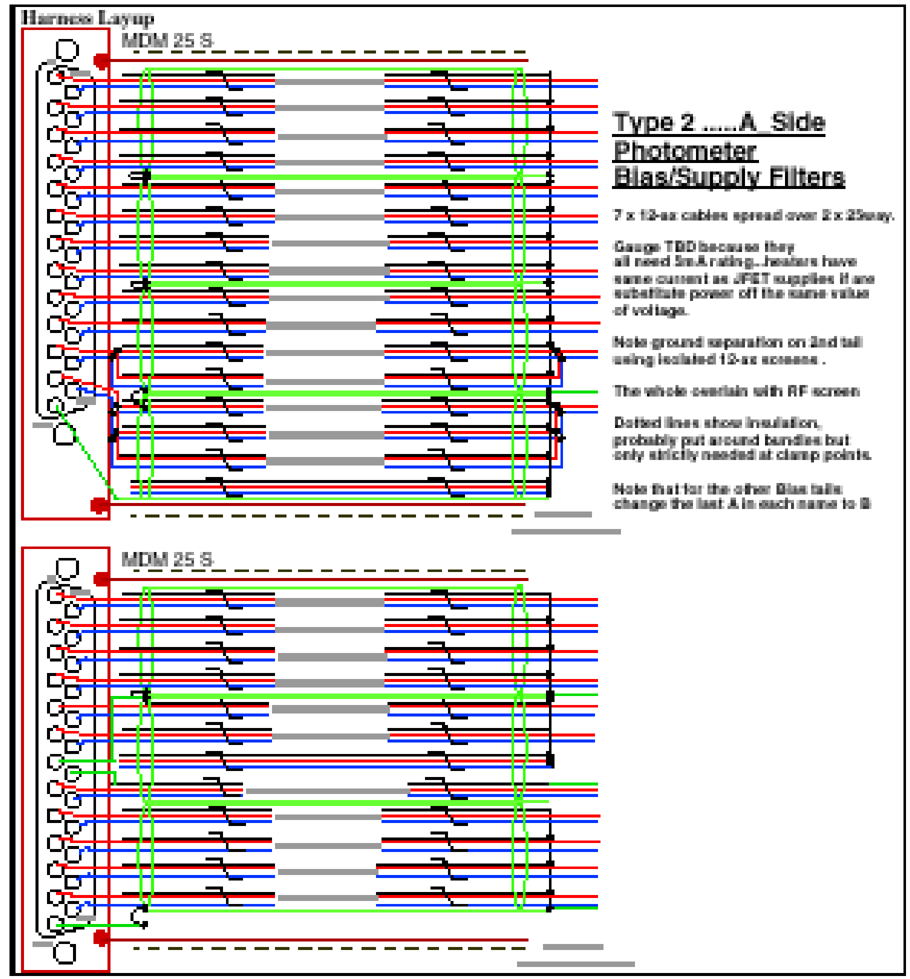
Common to all 3 tails, although others have ch. 17-32 and 33-48. Good flat layup for cryoharness

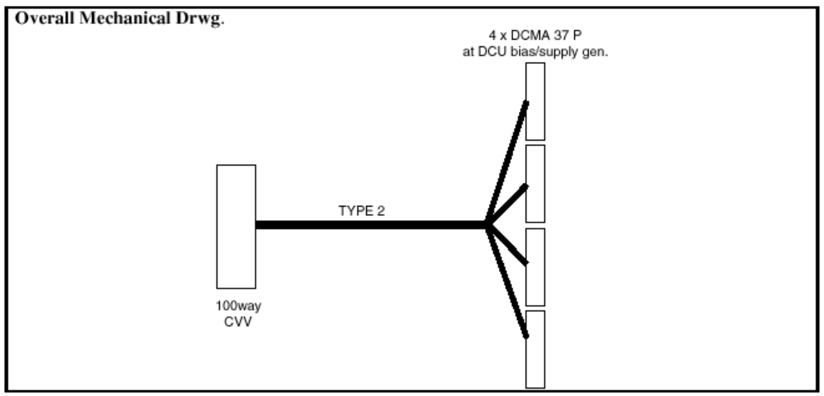
16 insulated screen twisted pairs plus 2 ground pins with single higher conductivity signal gnd. conductors.....even 2 x 28AWG standard copper might add little to total harness' conductivity TBC.

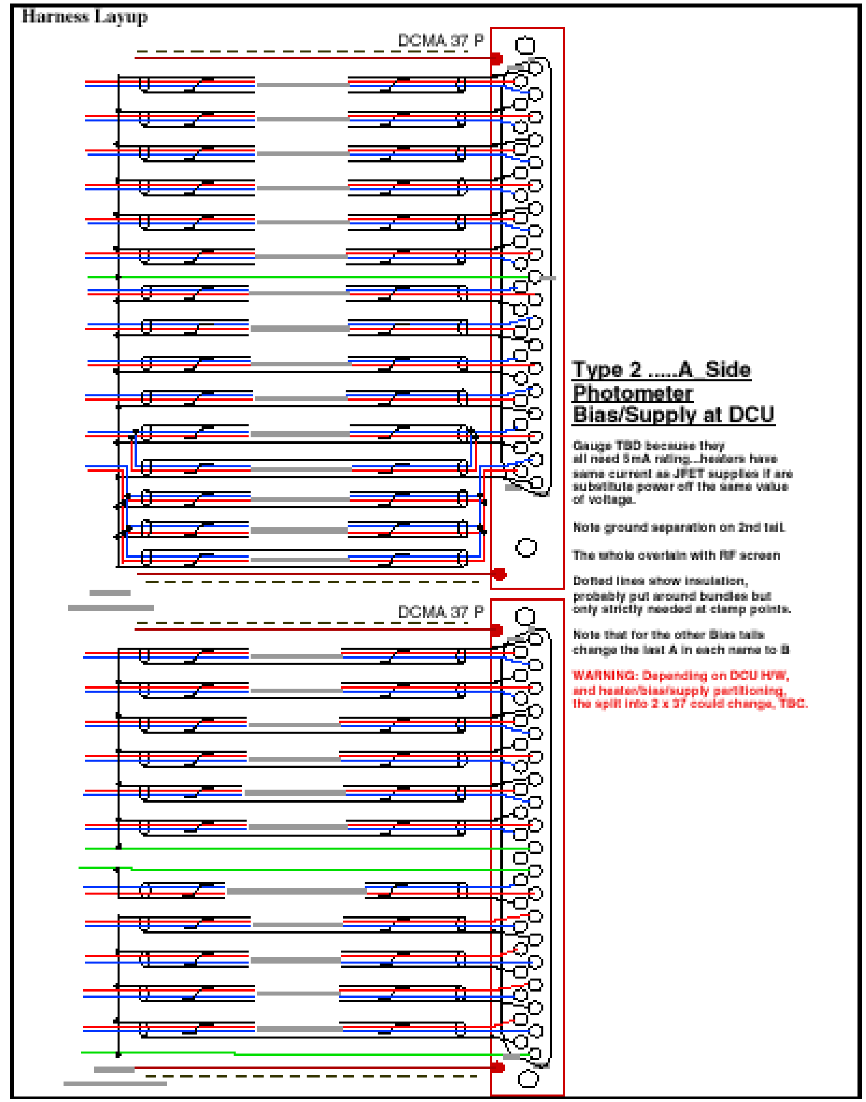
The whole overlain with RF screen shown:

Dotted lines indicate insulation, probably put all around bundles but only strictly needed at clamp points.

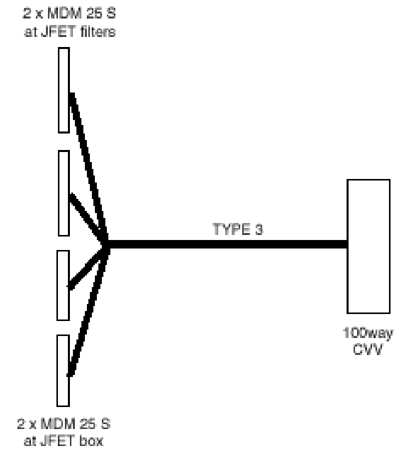

Overall Mechanical Drwg.
TYPE 2
100way
CVV
4 x MDM 25 S
at JFET filter box


Harness Layup
MDM 25 S
Type 2 .....A_Side
Photometer
Bias/Supply Filters
7 x 12-ax cables spread over 2 x 25way.
Gauge TBD because they all need 5mA rating...heaters have same current as JFET supplies if are substitute power off the same value of voltage.
Note ground separation on 2nd tail using isolated 12-ax screens .
The whole overlain with RF screen
Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.
Note that for the other Bias tails change the last A in each name to B
MDM 25 S


Overall Mechanical Drwg.
4 x DCMA 37 P
at DCU bias/supply gen.
TYPE 2
100way
CVV


Harness Layup
DCMA 37 P
DCMA 37 P
Type 2 .....A_Side
Photometer
Bias/Supply at DCU
Gauge TBD because they all need 5mA rating...heaters have same current as JFET supplies if are substitute power off the same value of voltage.
Note ground separation on 2nd tail.
The whole overlain with RF screen
Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.
Note that for the other Bias tails change the last A in each name to B
WARNING: Depending on DCU H/W, and heater/bias/supply partitioning, the split into 2 x 37 could change, TBC.

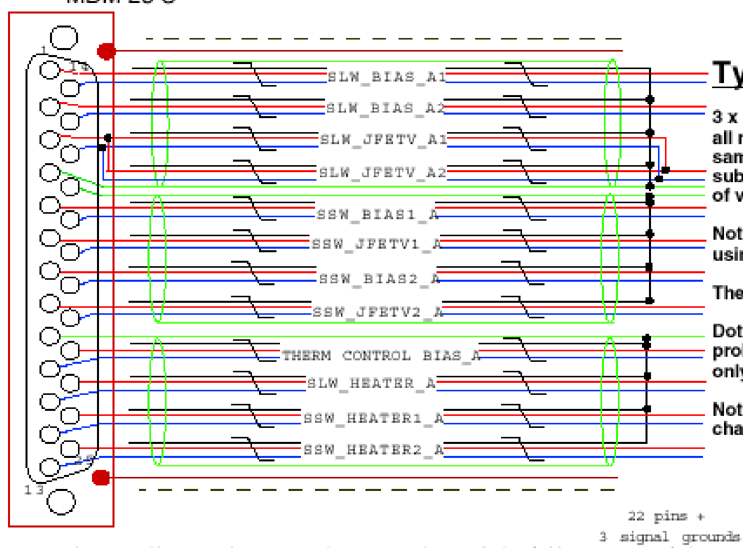
Overall Mechanical Drwg.



Harness Layup

Two 25way JFET tails, each as those in C4.

Two 25 way Spectrometer JFET Filter tails, each as follows:



Type 3 Bias Filters

3 x 12-ax cables. Gauge TBD because all need 5mA rating...heaters have same current as JFET supplies if are substitute power off the same value of voltage.

Note SLW and SSW ground separation using isolated 12-ax screens .

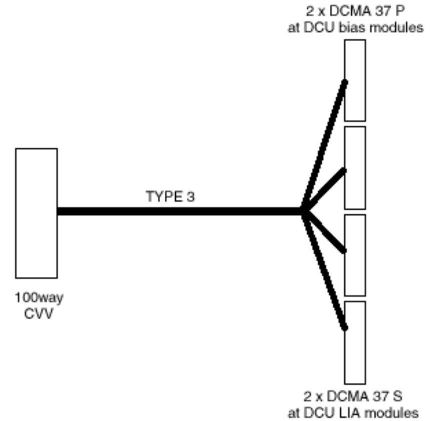
The whole overlain with RF screen

Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.

Note that for the other Bias tail change the last A in each name to B

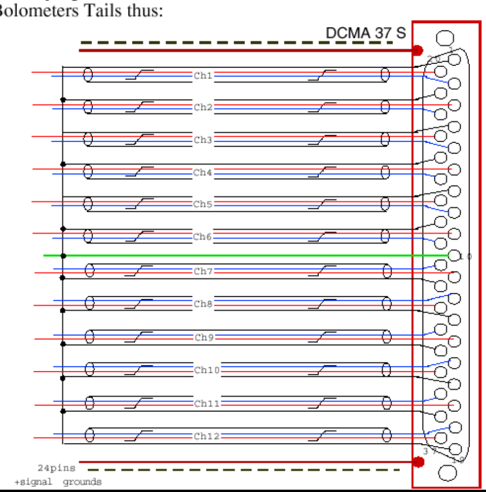
Because the small SLW has no subgroups that might fail, EACH of the two JFET membrane leads is double-wired in this cryoharness, requiring some extra wire-bonds for the bias lines in the filters.

Overall Mechanical Drwg.



Harness Lay-up

Two Bolometers Tails thus:



12 Channel Bolometer Tail (typ)

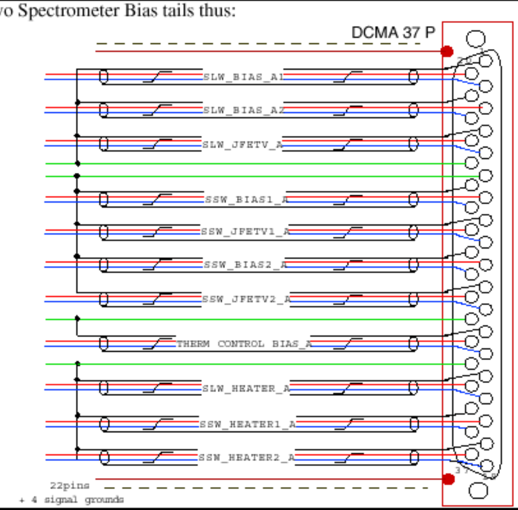
Common to all such tails, although others have ch. 13-24, etc.
Good flat layup for cryoharness

12 insulated screened twisted pairs plus 1 ground pins with a good conductor attached.

The whole overlain with RF screen

Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.

Two Spectrometer Bias tails thus:



DCU Type 3 Bias.

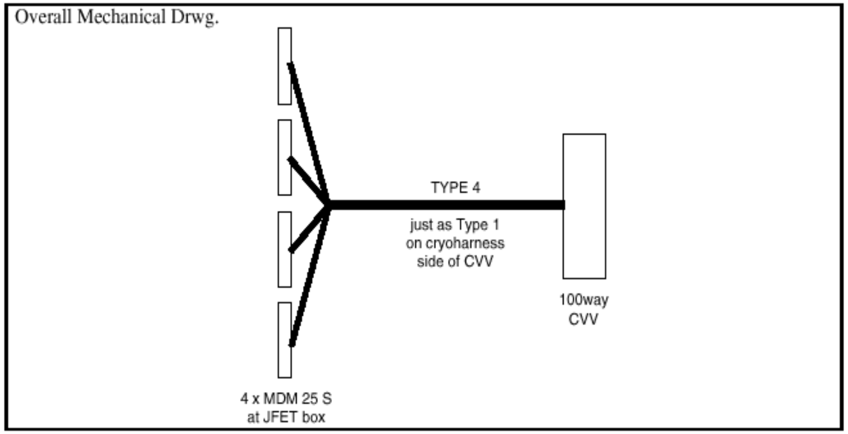
Two such tails, other with B instead of A at end of each name.

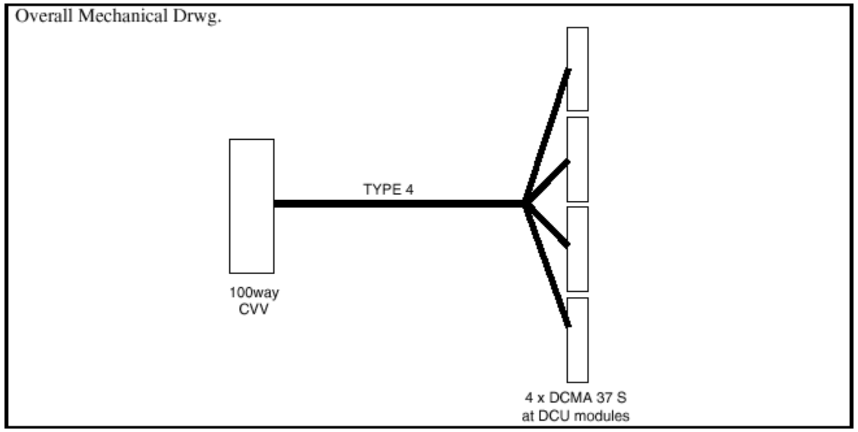
Good flat layup for cryoharness

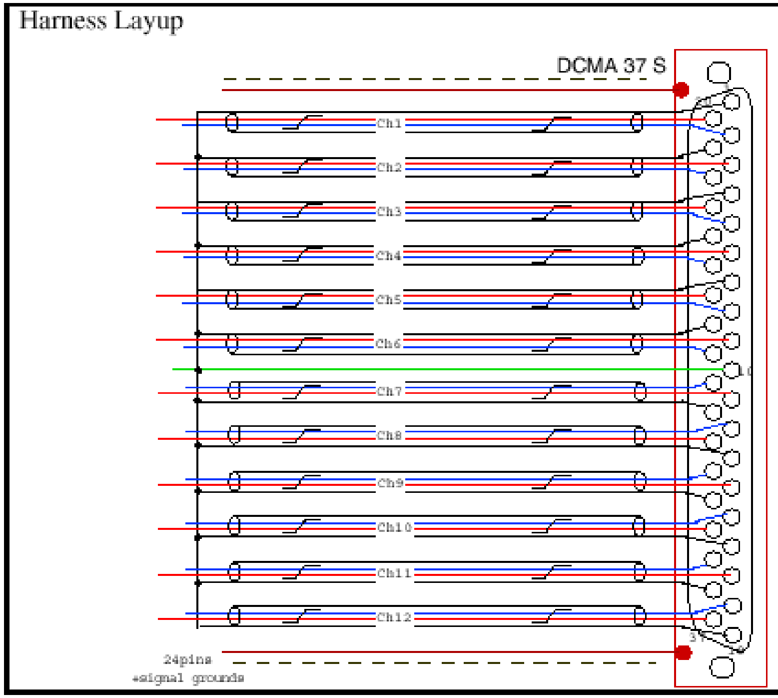
11 insulated screened twisted pairs plus 4 ground wires.
Gauge TBD because all TPs need 5mA rating...heaters have same current as JFET supplies if are substitute power off the same value of voltage.

The whole overlain with RF screen

Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.







12 Channel Bolometer Tail (typ)

Common to all such tails, although others have ch. 13-24, etc.
Good flat layup for cryoharness

12 insulated screened twisted pairs plus 1 ground pins with a good conductor attached.

The whole overlain with RF screen

Dotted lines show insulation, probably put around bundles but only strictly needed at clamp points.

Cryo Harness Pre-Integration Testing (RAL)

CRYOHARNESS TESTS

- Tests of installed cryoharness.
- Tests after installing the JFETs.
- Tests after installing the internal harness.

EQUIPMENT Needed for the Tests

- Model of flight DCU.
- DC preamplifier with external bias and JFET power supply for 24 channels (JPL Supplied).
- Spectrum analyzer.
- JFET simulator (STM, JPL Supplied).
- JFET x-talk simulator (JPL Supplied).
- .High-impedance bolometer array simulator (STM, JPL Supplied).
- Low-impedance bolometer simulator (JPL supplied).
- Bolometer x-talk simulator (JPL Supplied).

TESTS OF INSTALLED CRYOHARNESS

• Check the electrical continuity and shorts to ground and shield for all signal wires.

• Measure the resistance and the capacitance of each signal wire.

• Measure the microphonics spectrum, using a JFET simulator and Spectrum Analyzer with a loudspeaker attached to the chirp source.

• Measure the demodulated noise using the JFET simulator.

• Measure the electrical x-talk using the JFET x-talk simulator.

TESTS AFTER INSTALLING THE JFETS

• Check for shorts to ground and shield for each signal wire with JFET gates shorted to ground. No JFET power applied.

• Confirm the DC offsets and the offset mismatch for each JFET pair with JFET gates shorted to ground and JFET power applied.

• Measure the demodulated noise using low-impedance bolometer array simulator at room temperature.

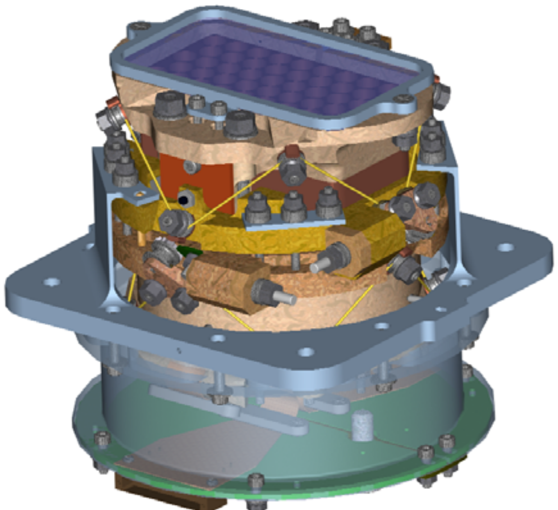
TESTS AFTER INSTALLING THE INTERNAL HARNESS

- Measure the electrical x-talk using the bolometer x-talk simulator at room temperature.
- Measure the demodulated noise using the low-impedance bolometer array simulator at room temperature.
- Measure the transfer function of the system, using the high-impedance bolometer array simulator at room temperature.
- Measure the microphonics spectrum using the high-impedance bolometer array simulator, DC bias, loud speaker plugged to the Spectrum analyzer's chirp source at 2K.
- Measure the transfer function of the system, using the high-impedance bolometer array simulator at 2K.
- Measure the demodulated noise using the high-impedance bolometer array simulator at 300 mK.
- Measure the heatload due to the internal harness, derived from the 3He fridge temperature.

HSO/PLANCK

SPIRE Instrument Detector Arrays CDR

July 30-31, 2001

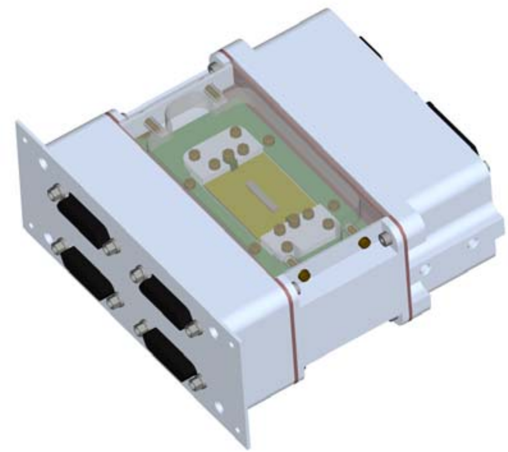


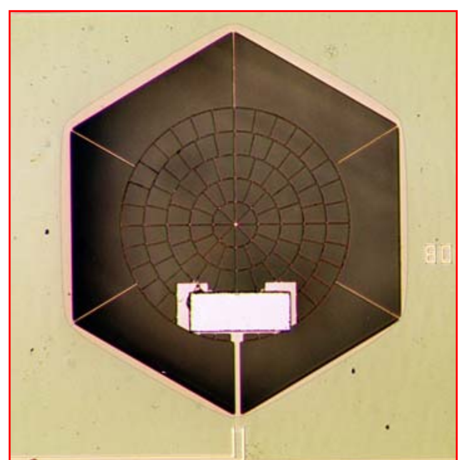
JPL

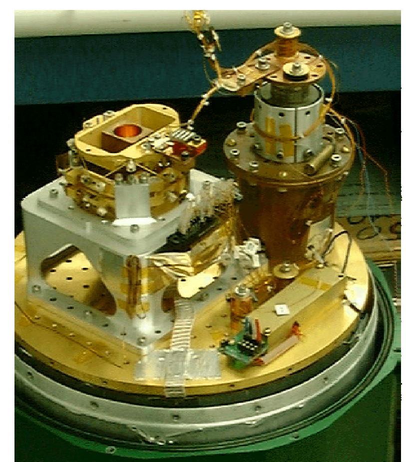
Bldg 233

Room 201A

Volume 2







Agenda July 31st

Start	End	Duration	Item	Presenter
8:00	8:20	20	8.0 Warm Electronics	Frederic Pinsard
8:20	8:50	30	9.0 Test program	Kalyani Sukhatme
			9.1 Overview	
			9.2 Verification Matrix	
			9.3 HRCR	
			9.4 Integration and Test Plan	
			9.5 EM Testing and Facilities	
8:50	9:05	15	10.0 Test facilities	Hien Nguyen
9:05	9:45	30	11.0 Mission Assurance	Gordon Barbay
9:45	10:00	15	12.0 Implementation Plan	Jerry
10:00	10:15	15	**-------Break-------**	
10:15	10:30	15	13.0 RFA Summary	James Bock
10:30	10:50	20	14.0 Summary/Objectives	Gerald Liliethal
10:50	11:50	60	**-------Board Report--------**	George Rieke

8.0
Warm Electronics
DCU Design

F.PINSARD

Service d'astrophysique CEA/DAPNIA

pinsard@cea.fr

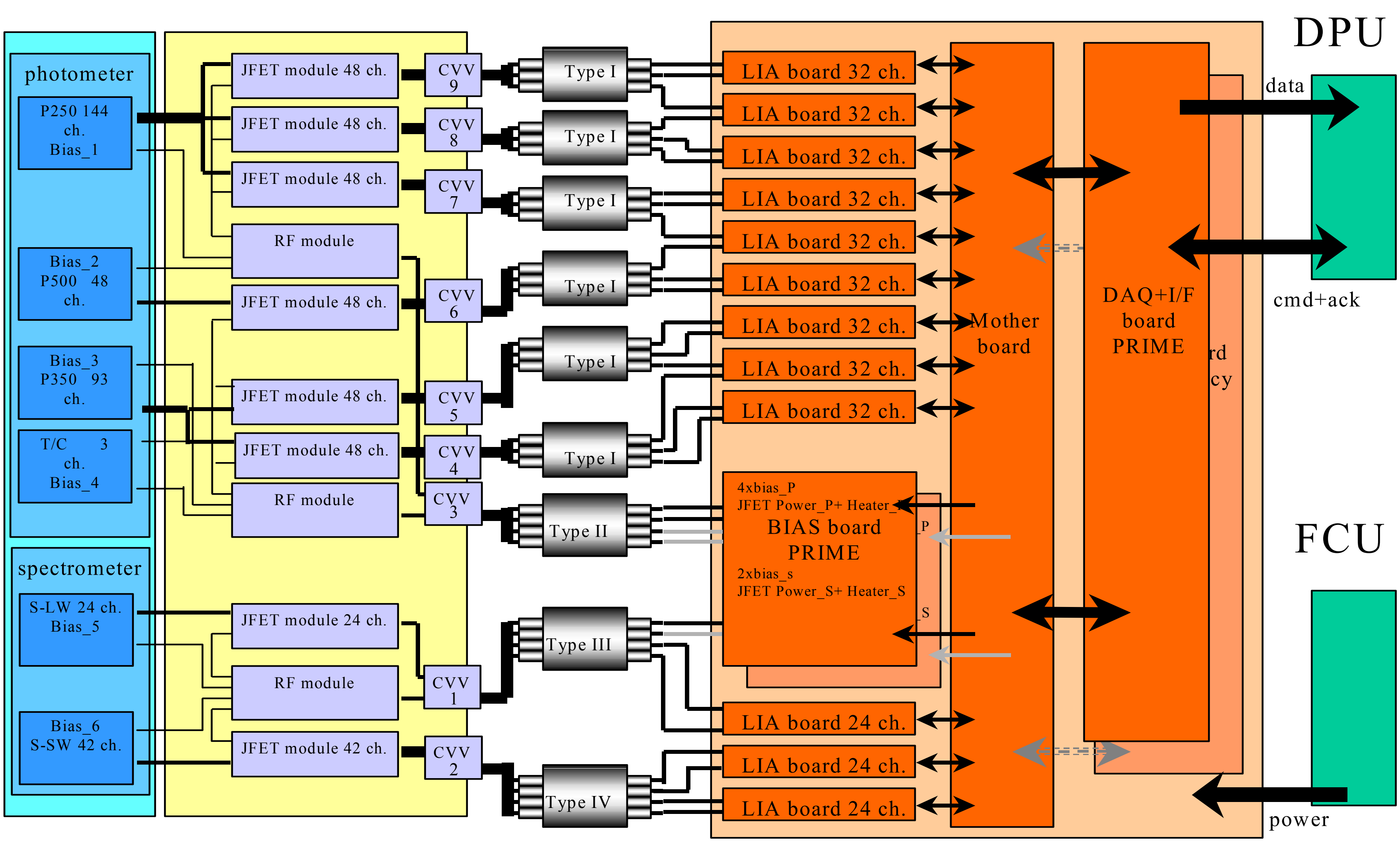
Overview (1)

- The DCU is a one box unit:
  - The Detector Control Unit comprises analog and digital electronics exclusively devoted to bolometers operation
  - In this box, 16 boards will be connect on a back plane printed circuit board
    - 9 LIA_P boards process the photometer analog signals
    - 3 LIA_S boards process the spectrometer analog signals
    - 2 BIAS boards (1 prime & 1 redundant)

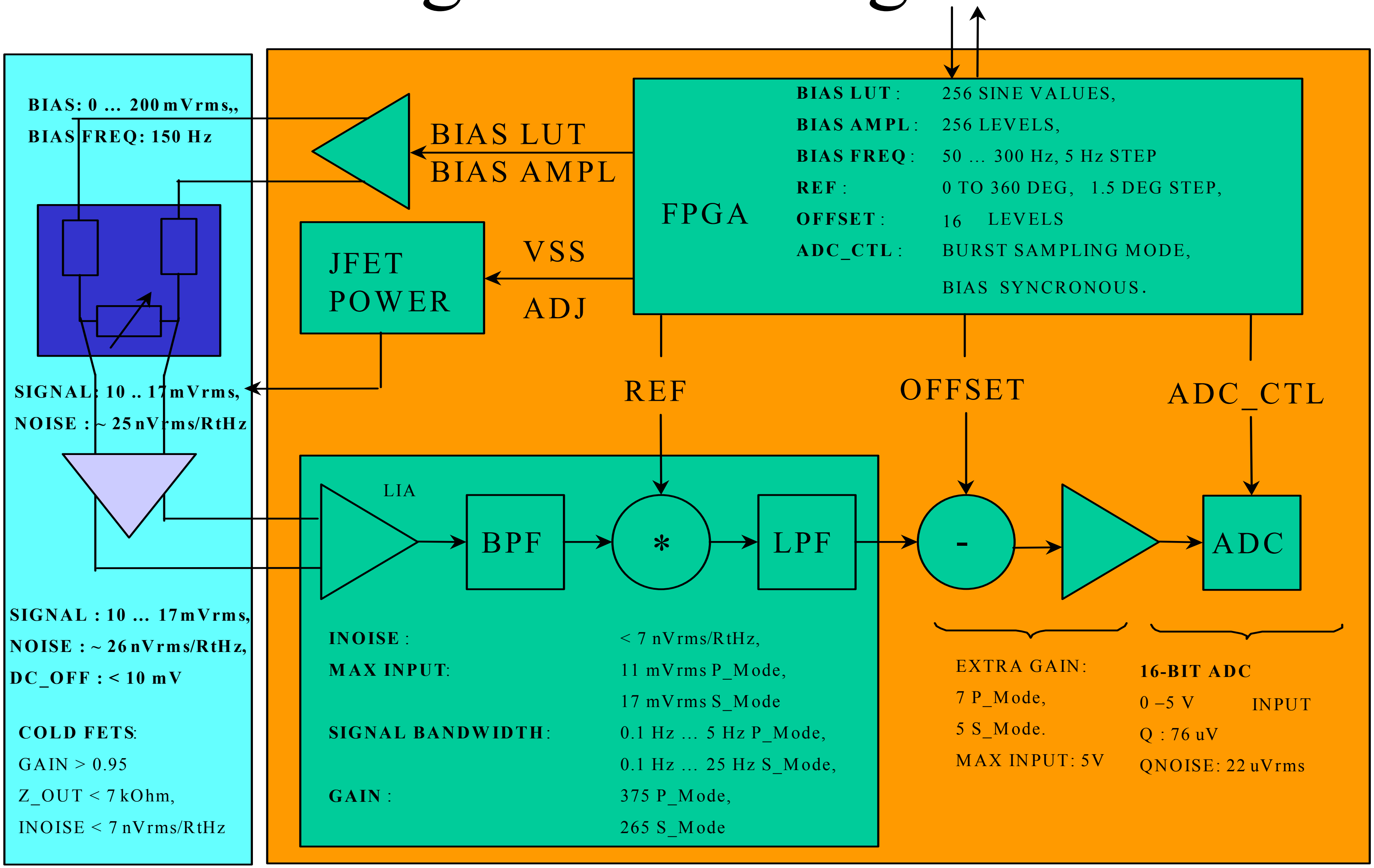
      distribute the bolometers bias and JFETs supply
    - 2 DAQ+IF boards (1 prime & 1 redundant)

      digitize signals, receive /decode commands

Overview (2)


FPU
DCU
DPU
FCU
photometer
P250 144 ch. Bias_1
Bias_2 P500 48 ch.
Bias_3 P350 93 ch.
T/C 3 ch. Bias_4
spectrometer
S-LW 24 ch. Bias_5
Bias_6 S-SW 42 ch.
JFET module 48 ch.
RF module
JFET module 24 ch.
JFET module 42 ch.
CVV 9
CVV 8
CVV 7
CVV 6
CVV 5
CVV 4
CVV 3
CVV 1
CVV 2
Type I
Type II
Type III
Type IV
LIA board 32 ch.
LIA board 24 ch.
4xbias_P
JFET Power_P+ Heater_P
BIAS board PRIME
2xbias_s
JFET Power_S+ Heater_S
Mother board
DAQ+I/F board PRIME
data
cmd+ack
power

Signal flow diagram



DCU Specification (1)

- ***Analog Processing channels***
  - Functions: receive, amplify, demodulate & filter bolometer signals
  - 336 total number : 288 for photometer + 66 for spectrometer
  - Specifications:
    - Gains:
      - Photometer: 375
      - Spectrometer: 265
    - Input signal bandwidth:
      - Photometer: 0.1 to 5Hz
      - Spectrometer: 0.1 to 25Hz
    - Input noise < 7nVrms/rt(Hz)

DCU Specification (2)

- ***Bias generators***

  – Functions: generate sine biases for bolometer and DC biases for JFETs and heaters
    - Adjustable sine biases:
      – Photometer : 1sine generator/ 4 channels with independent amplitudes
      – Spectrometer : 1sine generator/ 2 channels with independent amplitudes
    - Adjustable DC biases:
      – Photometer : 12 generators for JFET + 1 for heater
      – Spectrometer : 3 generators for JFET + 1 for heater

DCU Specification (3)

- ***Bias generators …***

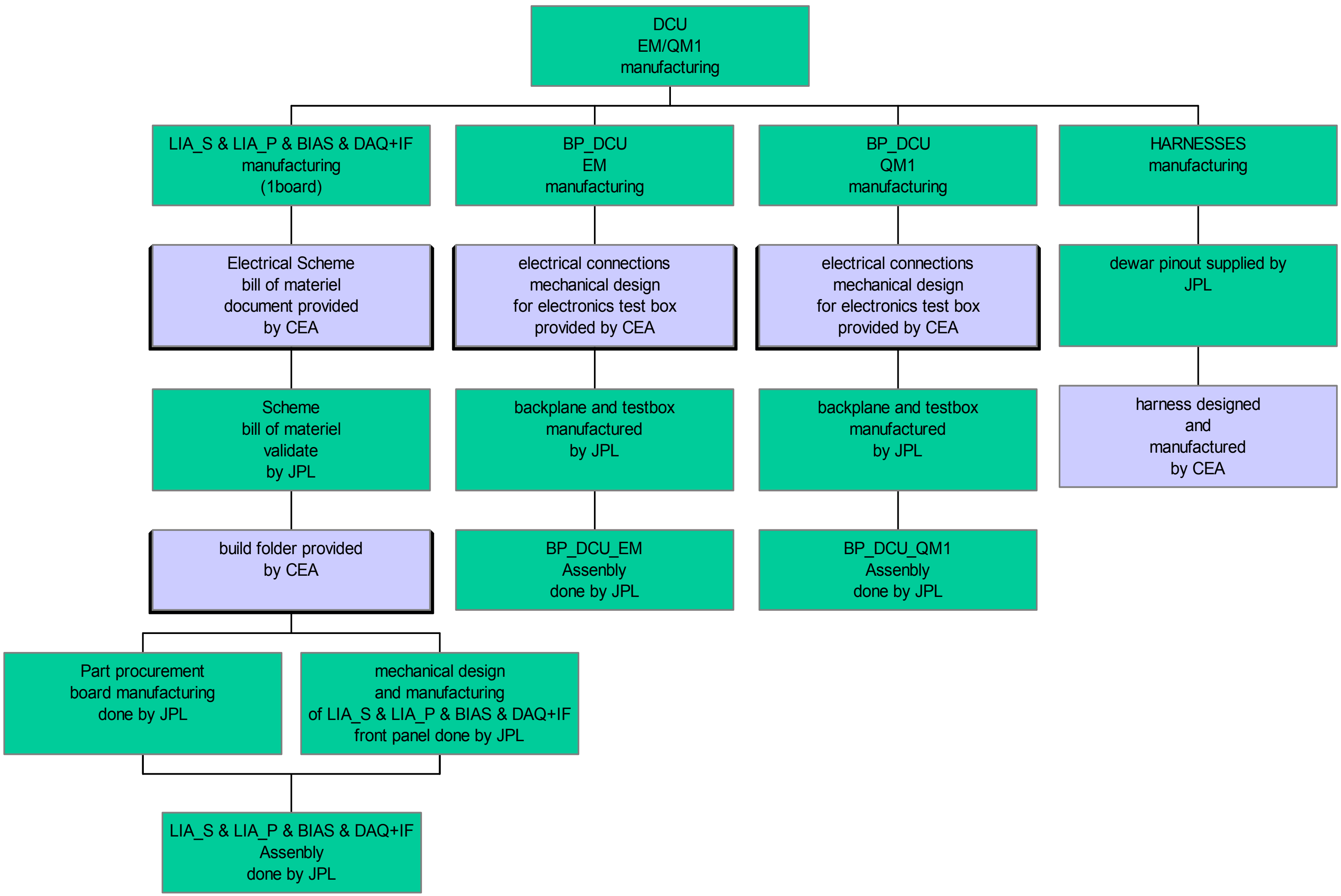
  – Specification:
  - Adjustable sine biases:
    – Voltage range: 0 to 200 mVrms for bolometers and
    0 to 500 mVrms for thermometers
    – Accuracy: 1mV (256 levels)
    – Frequency range: 50 to 300Hz
  - Adjustable DC biases:
    – Voltage range: 0 to –5V for JFETs (VSS)
    0 to –8V for heater
    – Output currents : 5mA max for JFETs
    25mA max for heater

DCU Specification (4)

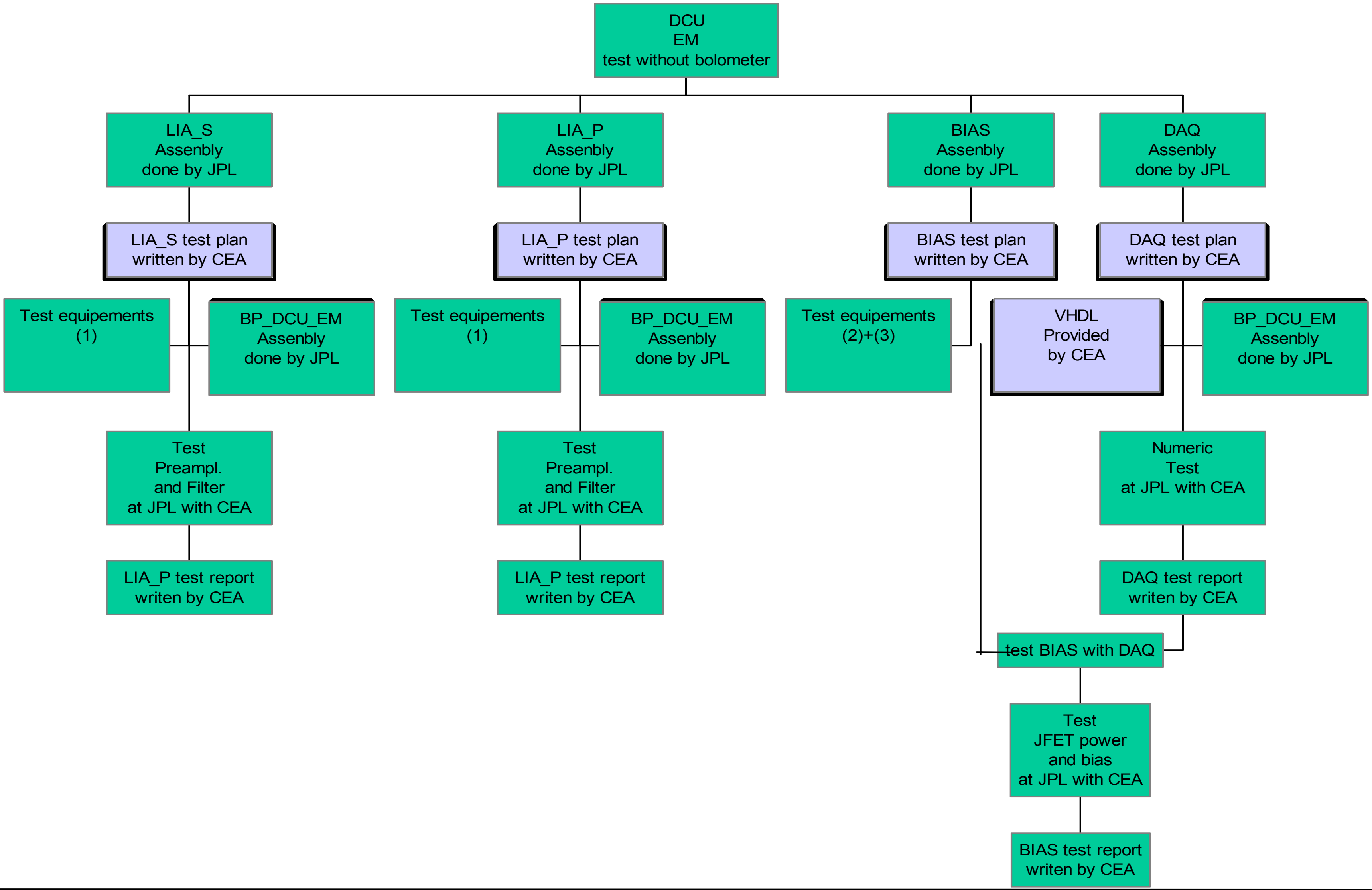
- ***Data acquisition & DPU interface***

  - Specification:
    - Digitizing resolution:19 bits (16-bit ADC + 4-bit offset)
    - Frame rate : 1/2 to 1/256 of sine bias frequency
    - Frame acquisition time < 3ms
    - Data formats and Command are defined in DRCU ICD
    - Electrical interface :RS422

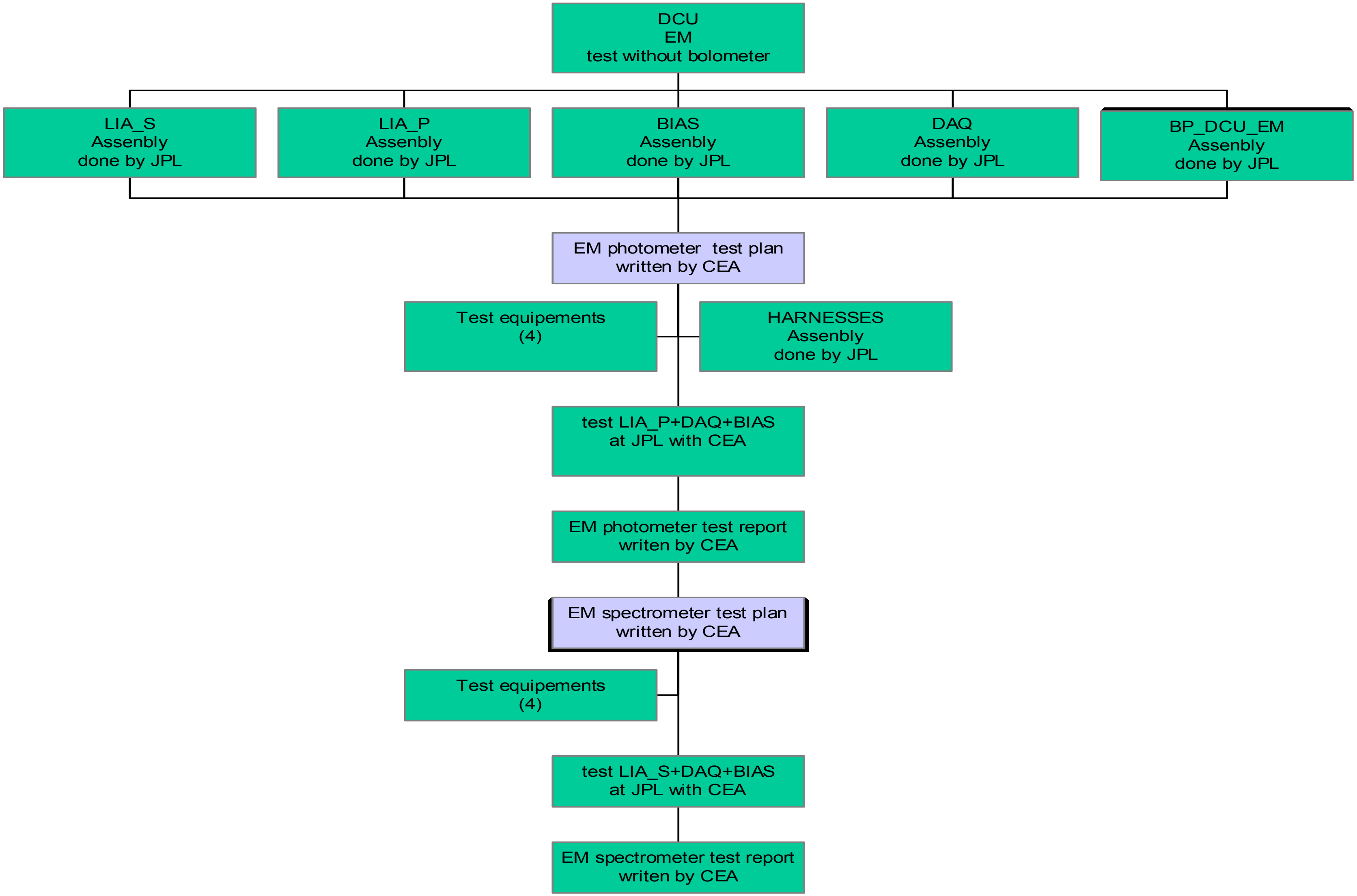
DCU EM/QM1 Development Tree (1)



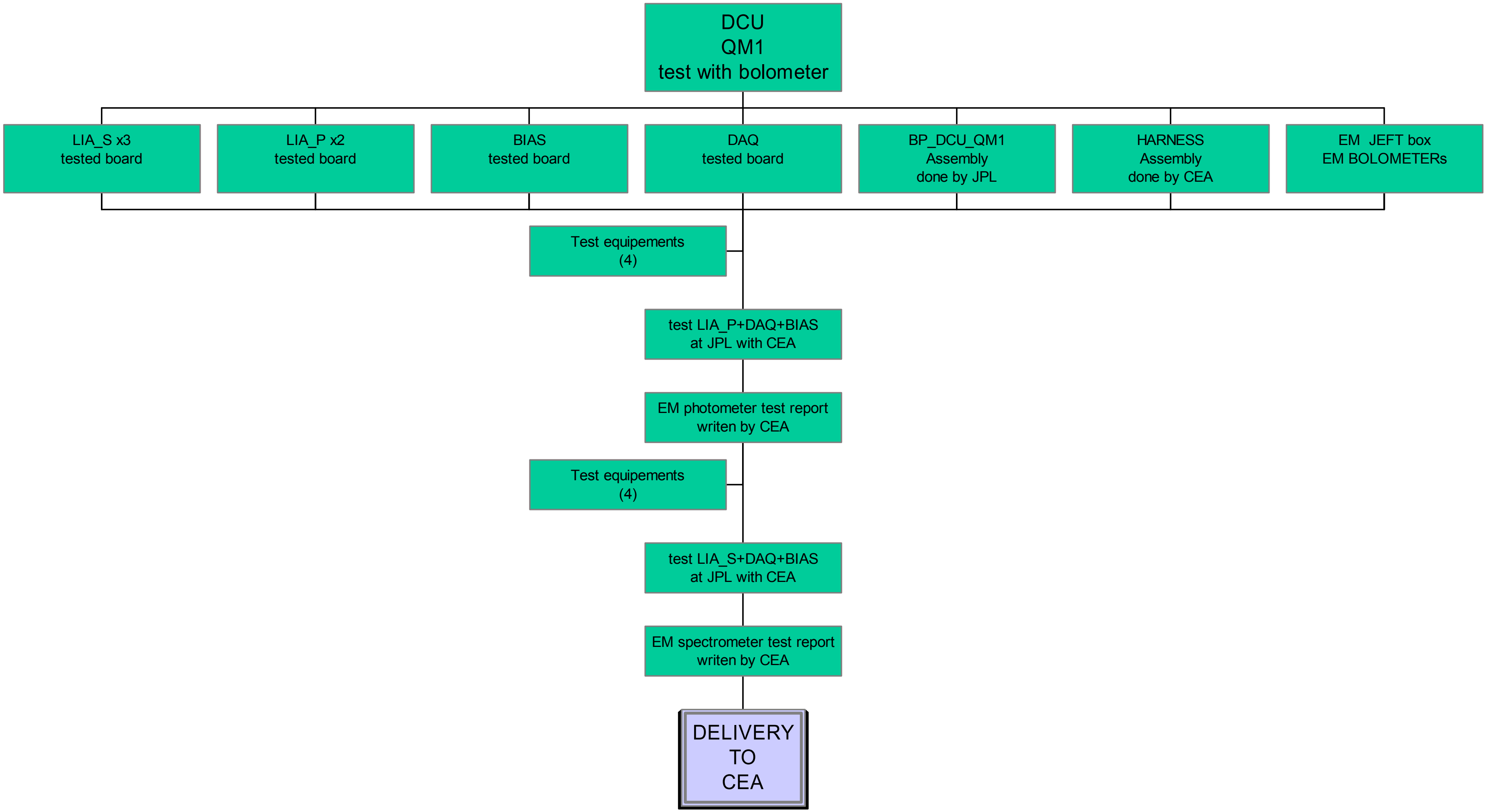
DCU EM Development Tree (2)



DCU EM Development tree (3)



DCU QM1 Development tree (4)



Design status (1)

- **Detector Control Unit**

  – QM1 development is divided into:
    - Phase 1: July 2000 to December 2000
      - Breadboard design & testing including 2 analog channels, 1 bias channel and 1data acquisition channel.
      - Goal : elementary functions & internal interfaces optimization
    - Phase 2: January 2001 to July
      - QM1 design including 4 complete analog boards (1 for photometer and 3 for spectrometer), 1 bias board and 1 data acquisition board.
      - Electrical schematics are done
      - Layout are done except for spectrometer analog board

Design status (2)

- **Detector Control Unit…**
  - Phase 3
    - Realization and test at JPL
  - Phase 4
    - Integration and test at SACLAY

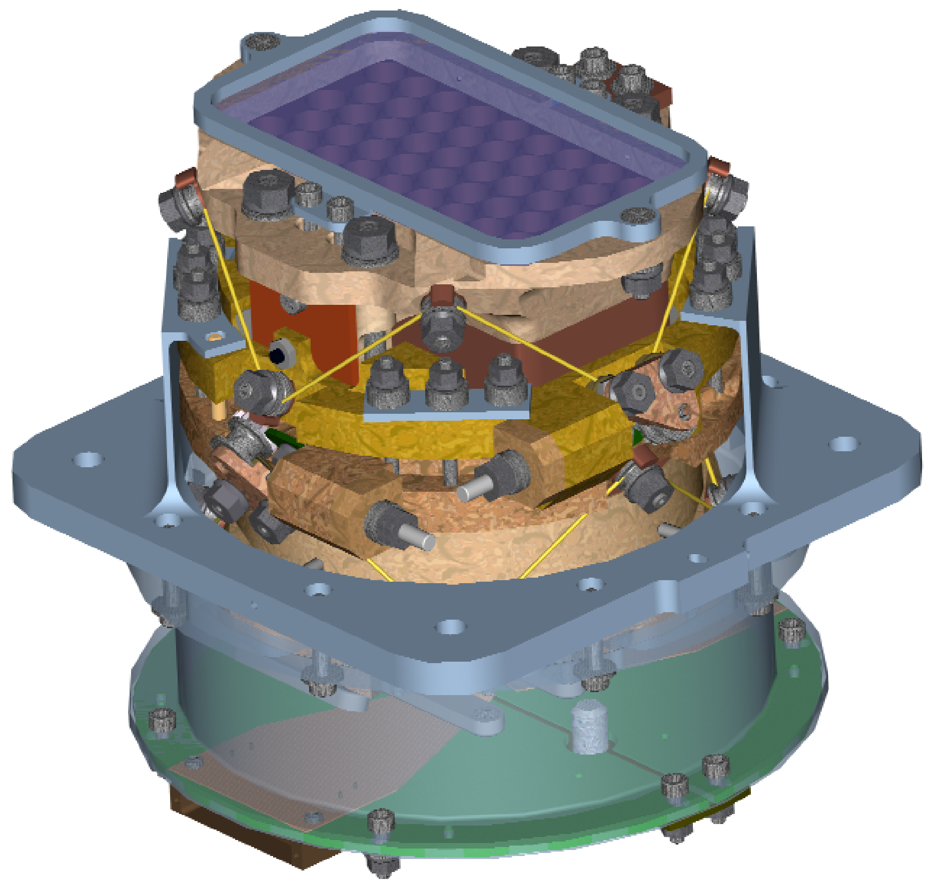
Phase 1 Conclusion

- **Breadboard**
  - For analog processing channels:
    - The chosen solution answers to the photometer noise and bandwidth requirements. For the spectrometer, the Low Pass Filter will have to be adjusted.
  - For bias generator :
    - The breadboard design is compliant with the bias requirements on the frequency and amplitude ranges and precision.
  - For acquisition :
    - The breadboard design must be improved to solve the ADC noise problem.

9.0 JPL HSO SPIRE Test Program

Presented by

Kalyani Sukhatme



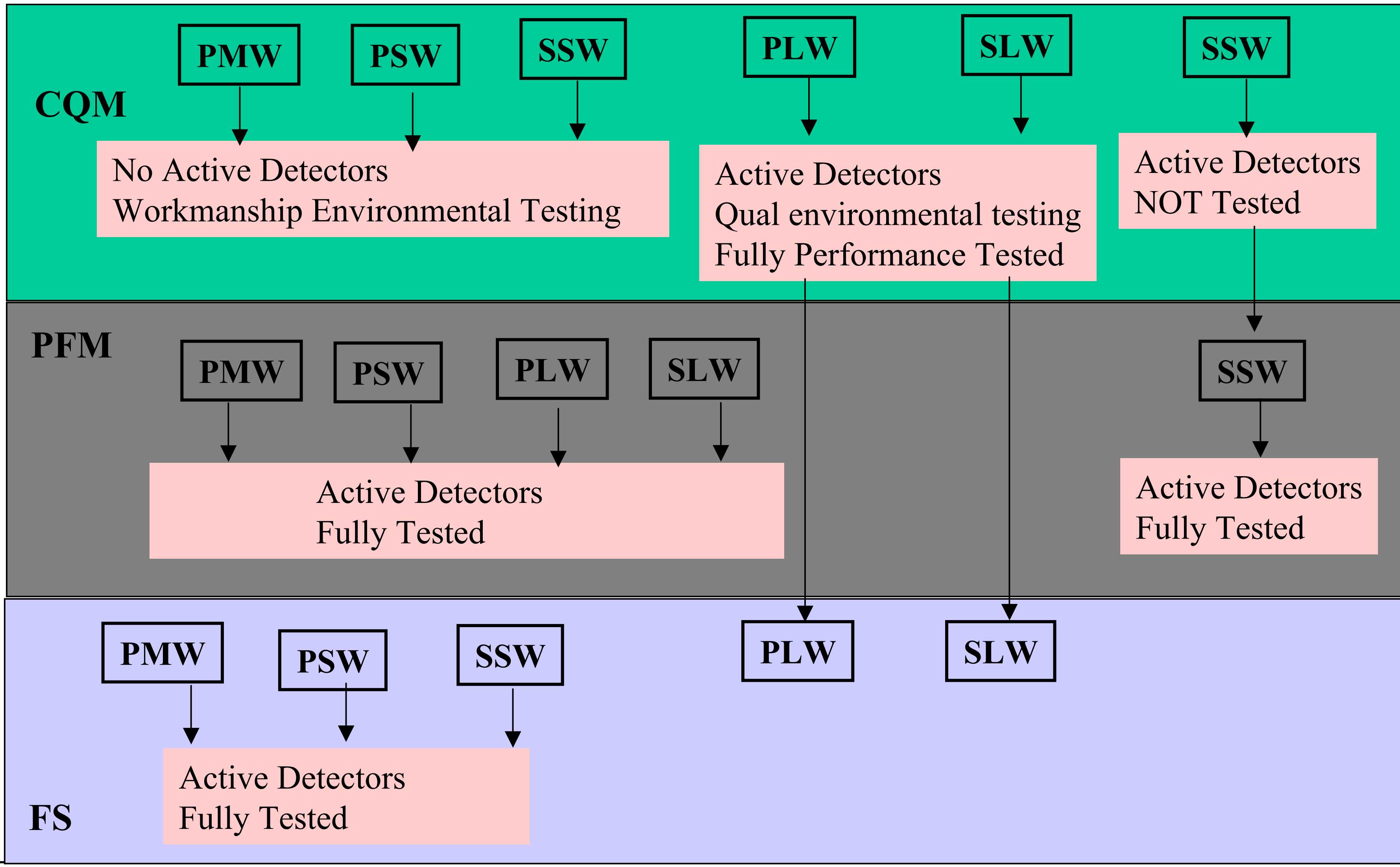
Agenda for Section

- Overview
- Verification Matrix
- HRCR
- Integration and Test Plan

Overview

- Deliverables
  - Bolometer Detector Array Assembly (BDA)
  - JFET Modules
  - RF filter modules
  - BDA to JFET Harness
- Test Program
  - Environmental Testing
  - Performance Characterization/Testing
- Testing Phase
  - EM Testing
  - CQM Testing
  - PFM/Spare Testing

BDA Units

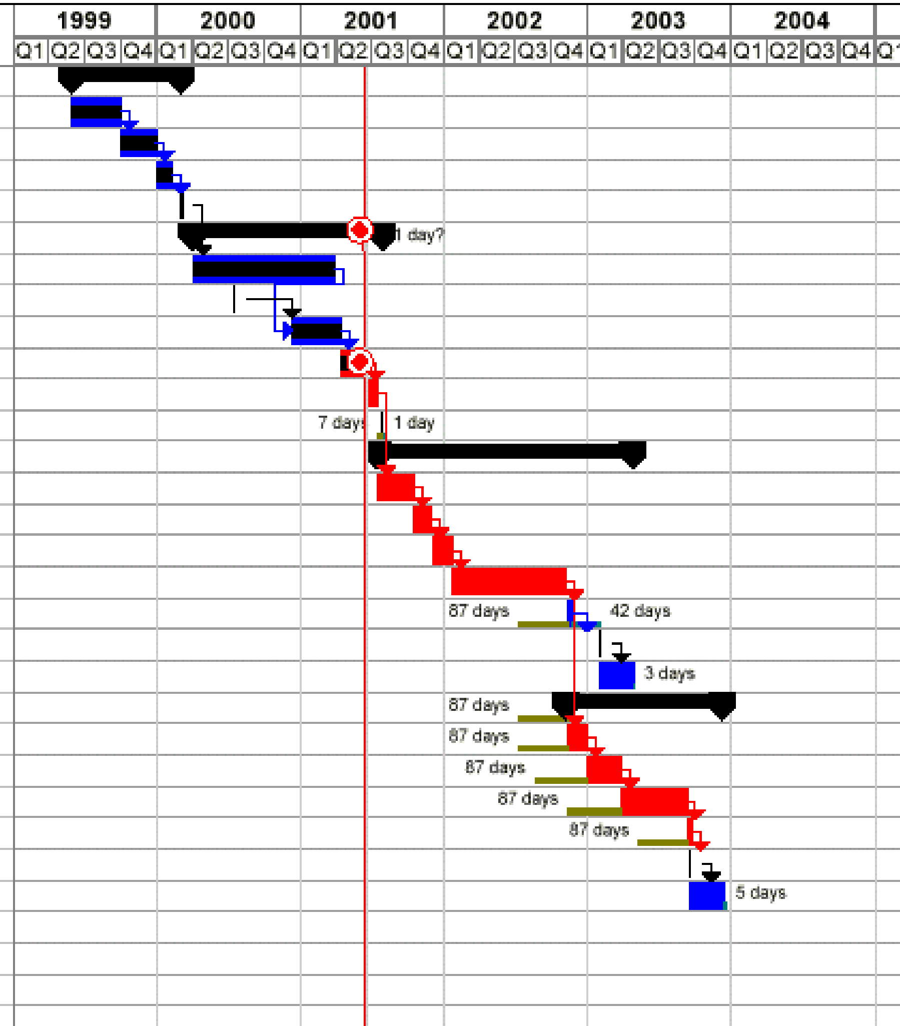

CQM
PMW
PSW
SSW
PLW
SLW
SSW
No Active Detectors
Workmanship Environmental Testing
Active Detectors
Qual environmental testing
Fully Performance Tested
Active Detectors
NOT Tested
PFM
PMW
PSW
PLW
SLW
SSW
Active Detectors
Fully Tested
Active Detectors
Fully Tested
FS
PMW
PSW
SSW
PLW
SLW
Active Detectors
Fully Tested

HSO/Planck Project

SPIRE Detector System

File: SPIRE 6-12-01

ID	Task Name
1	**Prototype Design and Testing Phase**
2	Design
3	Fabrication and Assembly
4	Testing and Data Reduction
5	Downselect Review
6	**Detail Design & EM Development Phase**
7	EM Design
8	PDR
9	EM Fabrication
10	EM Assembly
11	EM Testing & Data Reduction
12	CDR
13	**CQM Phase**
14	CQM/PFM/Spare Fabrication
15	CQM Assembly
16	CQM Environmental Testing & Data Reduction
17	CQM Performance Testing & Data Reduction
18	CQM HRCR & Shipment
19	CQM Required Date (Business Agreement)
20	CQM Integration Support
21	**PFM and Spare Phase**
22	PFM and Spare Assembly
23	PFM and Spare Environmental Testing and D.R.
24	PFM and Spare Performance Testing & D.R.
25	PFM and Spare HRCR and Shipment
26	PFM Required Date (Business Agreement)
27	PFM Integration Support
28	
29	
30	
31	



Page 1 of 23

Applicable Documents

- SPIRE Bolometer Detector Array Assembly Process and Test Qualification Plan
- SPIRE Bolometer Detector Array Performance Test Plan
- SPIRE JFET Module Process and Test Qualification Plan
- SPIRE JFET Module Performance Test Plan

- All four of the above will get incorporated into a Test Plan Package and will become an Agreed Document as per Business Agreement

Documents

Document Title	Number	Status		
		In Work	Complete	Released
BDA Process and Test Qual Plan	D-19152		100%	X
BDA Performance Test Plan	D-20549	X	75%	
JFET Module Process and Test Qual Plan	D-19153	X	75%	
SPIRE Vibration Test Plan	D-20550	X	75%	
Thermal Cycling Procedure	TP518518	X	25%	
BDA Performance Testing Procedure		-	-	
JFET And RF Filter Characterization Procedure		-	-	

BDA: EM Phase

Unit#1

Environmental Testing :
- Warm Vibration
- Thermal (LN_2) Cycling
- Cold (LN_2) Vibration

Baseline Test:
Tension and Metrology Tests before and after Each Environmental Test

Unit#2

Thermal Characterization

Install Bolometers in the BDA structure

Environmental Testing :
- Thermal Cycling
- Vibration Testing

Yield Testing :
- Warm Continuity Test
- Cold (300 mK) Continuity test

BDA: CQM/PFM/FS Phase

Environmental Testing :

Warm Vibration
(with Accelerometer)

Baseline Test:
Tension and Metrology
Tests performed
before and after
Each of the
Environmental Tests

Install Bolometers in the BDA structure

↓

Environmental Testing :

Thermal Cycling
Cold (LN_2)Vibration

Baseline Tests:
Warm Continuity Check.
And Cold Continuity Check
on ~20 channels during
Thermal Cycling

↓

Cold Alignment Test

↓

Performance Testing :

1) Dark Testing :

Load Curves
Noise Measurements

2) Optical Testing:

Load Curves, Noise Measurements
Optical Time Constant
Beam Mapping
Spectroscopy
Optical Efficiency, Optical Cross-talk

JFET Modules

Environmental Testing :

Thermal Cycling
Cold (LN_2)Vibration Testing

Baseline Test:
Measure Characteristic Offset Voltages
as a baseline test
before and after each environmental test

Performance Characterization:

Noise Measurements

RF Filter Modules

Environmental Testing :

Thermal Cycling
Vibration Testing

Baseline test :
Continuity Check
before and after each
environmental test

RF Characterization:

RF Attenuation Measurement
(on a few channels, warm)

Environmental Test Matrix for BDA and JFET Modules

Test:	CQM	PFM	FS
Vibration:	**Q**	**A**	**A**
Thermal cycle:	**D/Q**	**A**	**A**
Vacuum cycle	**D/Q**	**A**	**A**
Lifetime:	**D/X**	**-**	**-**
Soak/cycle:	**D**	**-**	**-**
Radiation tolerance:	**D**	**-**	**-**
Thermal range (Bakeout):	**D/X**	**-**	**-**
Thermal stability (Instrument Level):	**Q**	**A**	**A**
Microphonics (Instrument Level):	**Q**	**A**	**A**
Ionising radiation:	**D**	**-**	**-**
EMI (Instrument Level):	**Q**	**A**	**A**
EMC (Satellite Level):	**Q**	**A**	**A**

Q : test carried out at qualification level for qualification times;

A : test carried out at acceptance level;

D : qualification test carried out by design including unit-level testing and engineering analysis.

X : Will rely upon HFI test data on similar devices

BDA: Requirements Verification Matrix

Specification ID	Description	Verified By Test Or Measurement On				
		Prototype	EM	CQM	PFM	FS
BDA-FUN-04	The **positional repeatability** of the focal plane structure shall be < 125 um (TBC) orthogonal to the optical axis, and < 625 um (TBC) along the optical axis. The rotational repeatability around the optical axis shall be < 0.5 degrees (TBC).	X	X	X	X	X
BDA-TEC-03	The **BDA mass** will have a design value of 600 g (TBC) average over 5 detector arrays, including output connectors.	X	X	X	X	X
BDA-TEC-04	The **first resonant frequency** of the BDA will be > 200 Hz (TBC), with a goal of > 250 Hz.	X	X	X	X	X

BDA: Performance Characterization Matrix

Specification ID	Description	Verified By Test On				
		Prototype	EM	CQM	PFM	FS
BDA-PER-01	BDA detector yield.	X	X	X	X	X
BDA-PER-02	The ratio of photon NEP due to radiation absorbed at the detector and total NEP, given as (NEPphoton/NEPtotal)^2 NEP includes all sources of noise at 1 Hz, measured at 300 mK, assuming a total readout noise of 10 nV/rtHz and an operating impedance of 5 MOhm.	X		Y	Y	Y

Y: Noise tests are carried out under dark conditions. The detector noise model and optical efficiency will be used to predict detector noise under optical loading. The model can be confirmed under the optical testing with optical loads approximate to the loads encountered in flight.

BDA: Performance Characterization Matrix (Contd.)

Specification ID	Description	Verified By Test On				
		Prototype	**EM**	**CQM**	**PFM**	**FS**
BDA-PER-03	The optical efficiency of the FPU horn and bolometer assembly for the photometer arrays over the optical passband.	X	-	X	X	X
BDA-PER-04	The optical efficiency of the short wavelength spectrometer horn arrays and bolometer assembly over the optical passband.	-	-	-	X	X
BDA-PER-05	The optical efficiency of the long wavelength spectrometer horn arrays and bolometer assembly over 300-400 μm.	-	-	X	X	X
BDA-PER-06	The photometer detector time constant, assuming a maximum modulation frequency of 2 Hz.	X	**-**	**Z**	**Z**	**Z**
BDA-PER-07	The spectrometer detector time constant, assuming a maximum modulation frequency of 20 Hz.	-	-	Z	Z	Z

Z: The detector speed of response will be measured under optical loads approximate to the loads encountered in flight.

BDA: Performance Characterization Matrix (contd.)

Specification ID	Description	Verified By Test On				
		Prototype	EM	CQM	PFM	FS
BDA-PER-08	The uniformity of the calibrated responsivity.	-	-	YY	YY	YY
BDA-PER-09	Detector cross-talk.	ZZ	-	ZZ	ZZ	ZZ
BDA-PER-10	The 1/f knee frequency (total noise is sqrt(2) larger than white level).	Y	-	Y	Y	Y

YY: Responsivity calibrated by electrical load curves. Stability of responsivity derived from noise measurements.

ZZ: Optical cross-talk will be tested to the limits of our apparatus, on selected pixels, and from electrical cross-talk on resistor channels. Full cross-talk matrix acquired at instrument level.

Y: Noise tests are carried out under dark conditions. The detector noise model and optical efficiency will be used to predict detector noise under optical loading. The model can be confirmed under the optical testing with optical loads approximate to the loads encountered in flight.

JFET: Verification Matrix

Specification ID	Description	Verified By Test Or Measurement On				
		Prototype	EM	CQM	PFM	FS
JFET-FUN-02	The RF filters will operate without power dissipation	-	-	-	-	-
JFET-FUN-03	The JFET modules must be capable of functioning, without meeting noise specifications, over a temperature range from 4 K to 300 K	-	X	X	X	X
JFET-FUN-04	The JFET module and RF filters will operate from a base temperature between 4 – 20 K.	-	X	X	X	X

JFET: Verification Matrix (Contd.)

Specification ID	Description	Verified By Test Or Measurement On				
		Prototype	EM	CQM	PFM	FS
JFET-TEC-01	The JFET modules will have a mass less than 305 g.	-	X	X	X	X
JFET-TEC-03	The RF filters are to provide –40 dB attenuation from 500 MHz to 3 GHz (TBC, minimum), -60 dB attenuation from 500 MHz to 10 GHz (TBC, goal).	-	X	AA	AA	AA
JFET-TEC-05	The on-state power dissipation of a JFET module is to be < 11 mW (minimum performance); < 5.5 mW (TBC) (design value). This results in a photometer power dissipation < 66 (33) mW, a spectrometer power dissipation < 22 (11) mW, and an average dissipation < 44 (22) mW assuming 50 % operation of the photometer and 50 % operation of the spectrometer. NB: A 50% margin will be held on the design values to reflect the uncertainty in achieving the low thermal dissipation.	X	X	X	X	X

AA: On selected channels

JFET: Performance Characterization Matrix

Specification ID	Description	Verified By Test On				
		Prototype	EM	CQM	PFM	FS
JFET-PER-01	Median noise of JFET module over 100 – 300 Hz.	X	X	X	X	X

HRCR

- List of Documents Available for Delivery with the Hardware
  - Design Documentation (Includes released drawings)
  - Environmental Test Plans and Results
  - Performance Characteristics/ Measurements
  - Handling Specifications
  - Manufacturing or Build Documentation
    - AIDS and IR
    - Verification of ESD requirements and Contamination control
  - Problem Failure Reports (List of all the PFRs and copies of any open PFRs)
  - Materials Review Board Documentation (If Necessary to resolve any discrepancies between the Cog-E and QA)
  - Final Inspection Report

Integration And Test Plan

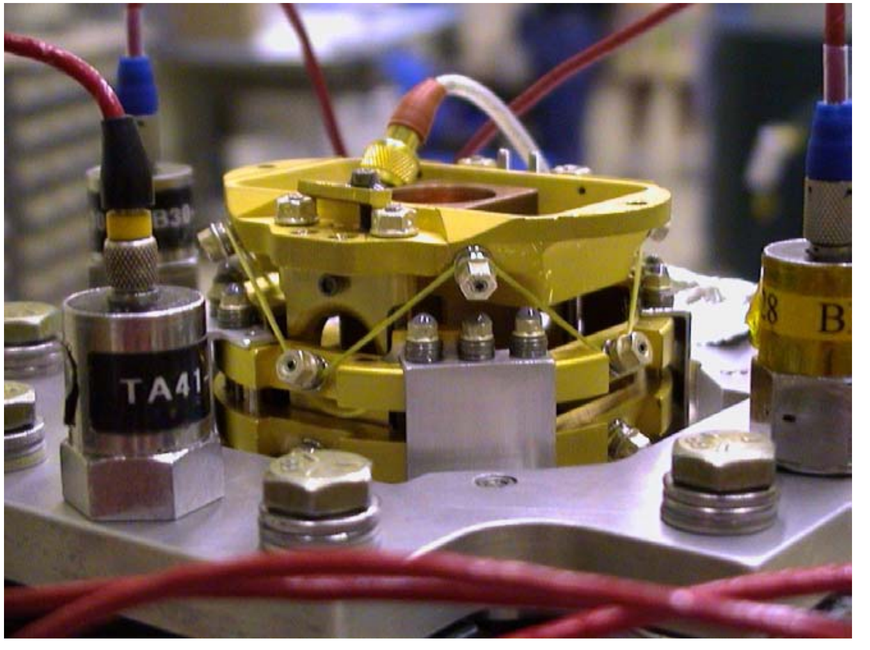
- Documentation
  - Details of the JPL deliverable hardware integration in Europe
  - Details of the test plan in Europe
- Support for Integration and Testing in Europe
  - Cryoharness Testing Support at RAL
  - Representatives from RAL and Cardiff will visit during JPL Testing Phase
  - Integration support for all JPL deliverables

9.5
EM Vibration Status and Facilities

Kalyani Sukhatme

EM BDA Environmental Testing

- EM Unit #1
- Kevlar Preload = 30 lb
- List of Tests
  - Warm Vibration
  - Thermal Cycling
  - Warm Vibration with Force Transducers
  - Cold Vibration
- Metrology before and after each test

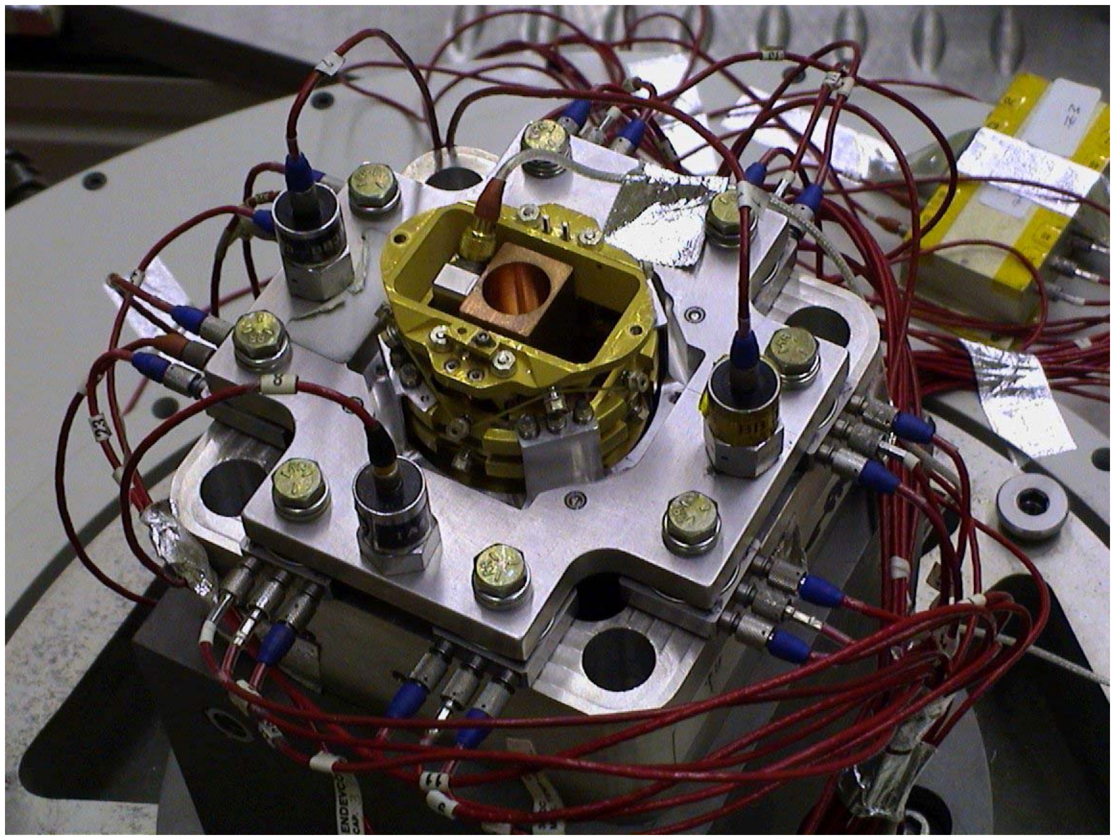


EM Vibration Levels

Axis	Frequency (Hz)	Level
Long/Lat	20-100 Hz	+6 dB/Oct
Long/Lat	100-300 Hz	0.05 g^2/Hz
Long/Lat	300-1000 Hz	-6 db/Oct
Long/Lat	Grms	5.27

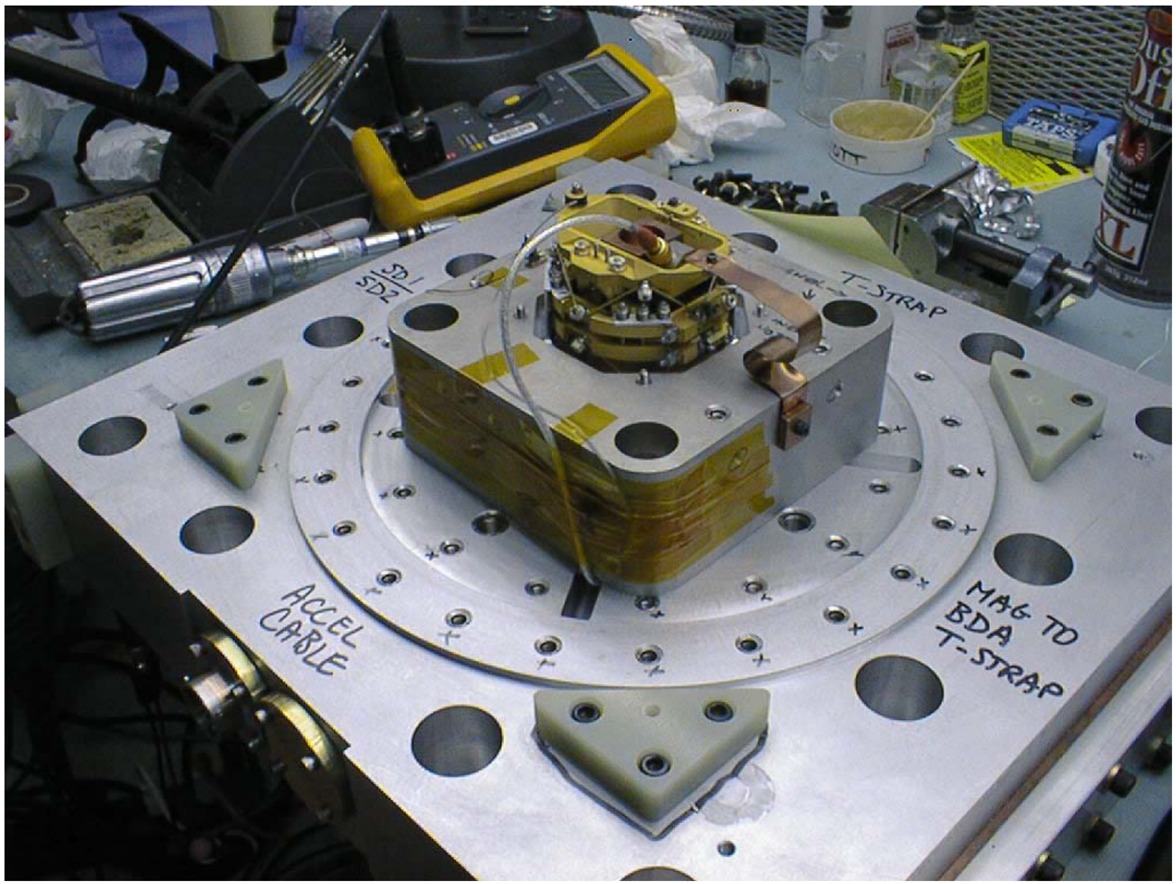
EM BDA Testing

- BDA Warm Vibration with Force Transducers

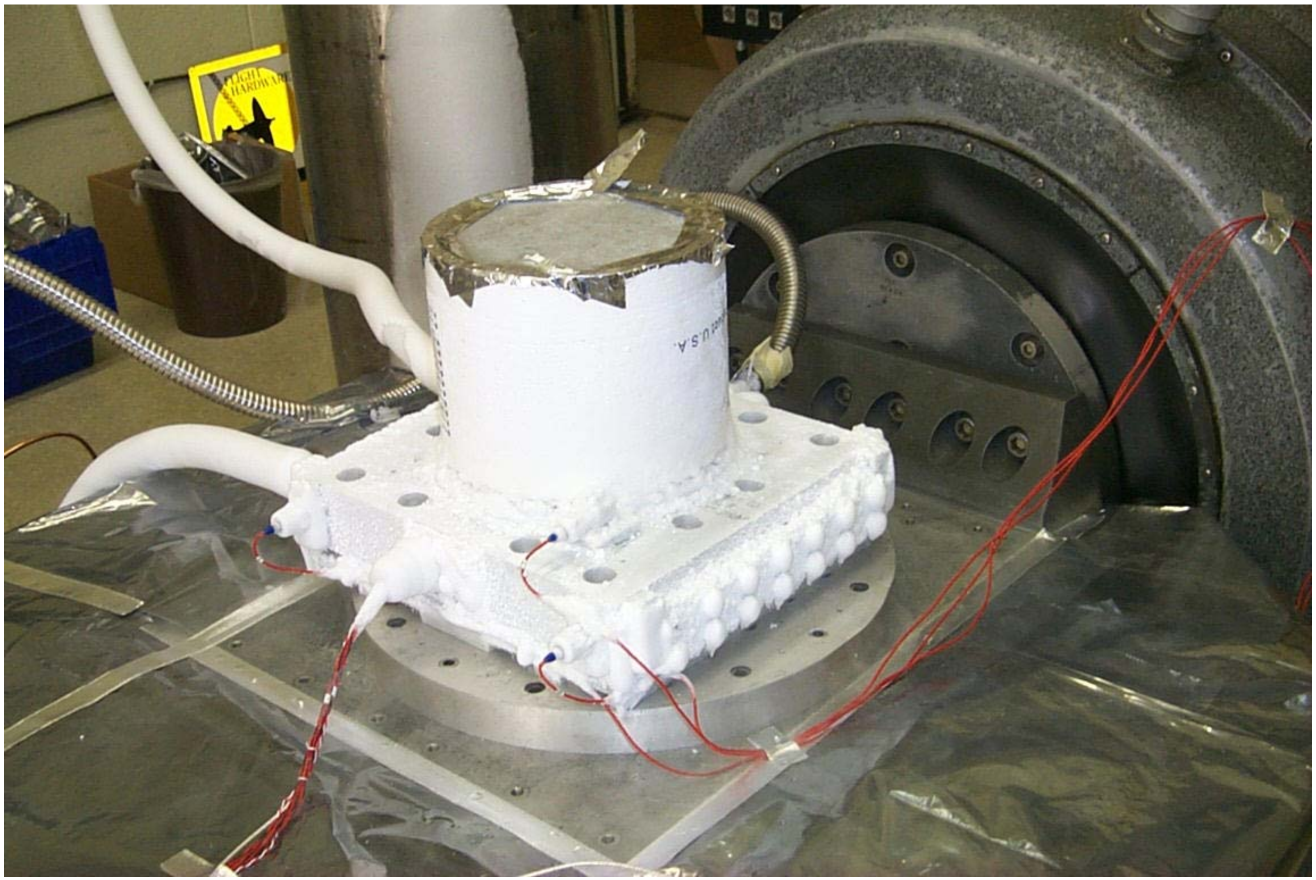


EM BDA Testing

- Cold Vibration Fixture



Cold Vibration



Metrology

Displacement along the z-axis (Optical Axis)
(mm)

Test	pnt17	pnt18	pnt19	pnt20
	0	0	0	0
After Warm Vibration	0.052	0.057	-0.061	-0.064
Install Thermometer	0.057	0.06	-0.064	-0.065
After Thermal Cycling	0.061	0.064	-0.053	-0.051
After Installing Accelerometer	0.053	0.058	-0.052	-0.057
After Warm Vibration with force transducers	0.095	0.108	-0.095	-0.106
After Cold Vibration	0.049	-0.02	-0.017	-0.01

Positional Repeatability Requirement Along z-axis = 0.625 mm

10.0
TEST FACILITIES

Hien Nguyen

Flight Laboratory

- Flight certifiable Lab established in 183-215
  - Contamination Control certification (D-19156) in process
  - ESD certification is in process
  - Safety certification is in process
  - Personnel training is completed
- Test equipment
  - Two laminar flow benches
  - Thermal Characterization/Electronic Interface Dewar
  - JFET Testing Dewar
  - Thermal Cycle Dewar
  - Cold Vibe Fixture
  - BoDAC's, Bolometric Detector Assembly Cryostat
  - Data Acquisition System
  - General Electronics
  - Beam Mapper
  - Spectrometer
- Laboratory is planned to be certified by Nov 01

Thermal Characterization/Electronic Interface Dewar

Also known as Green Dewar

Purpose

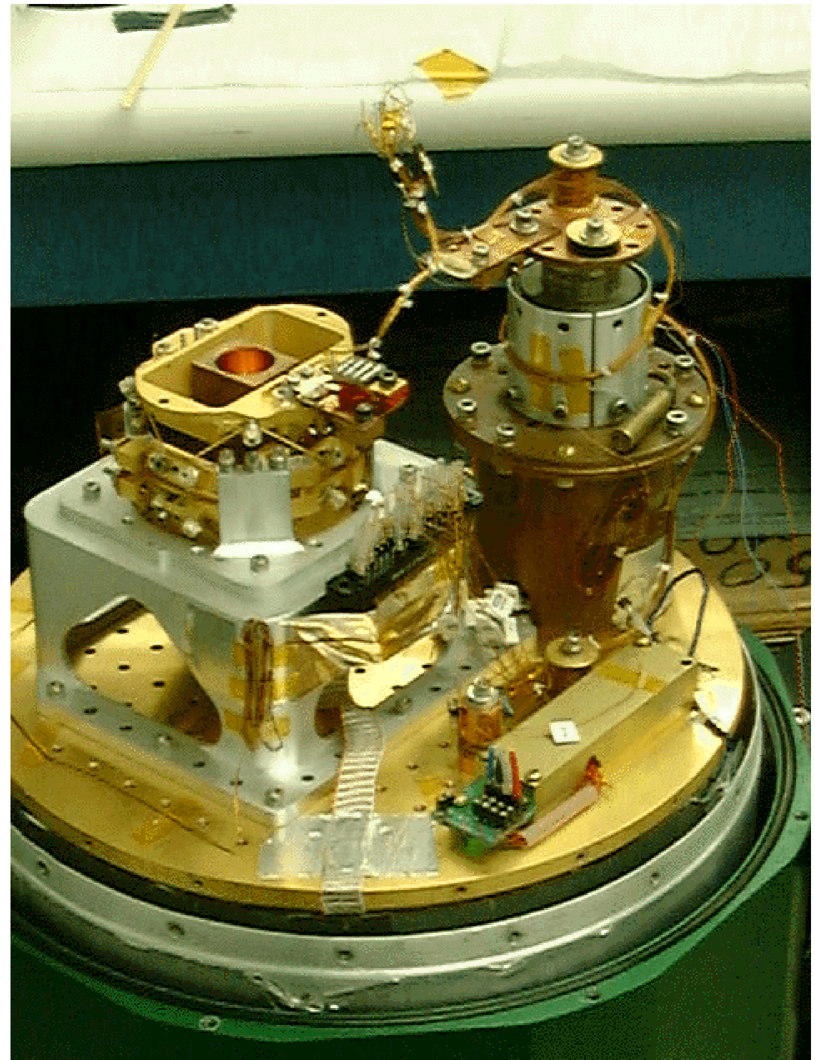
The Green Dewar is to be used for thermal characterization of the BDA. Later it will be used for electronic testing by CEA Team

Status

Functional
Only for EM Testing
Handling Procedure needed for CEA users

Peripherals

Wirings and cables: Completed
^{3}He Fridge: Installed and working



JFET Testing Dewar

Also known as The Blue Dewar

Purpose

To Characterize JFET Performance

Description

Small IR LAB Helium Cryostat

Status

Functional

Procedure and Certification needed

Peripherals

Preamp: Completed

Internal Wiring: Completed

Warm Cable: 80% Completed

Insert Picture Here

Thermal Cycle Dewar

- Cool Down to 77 K in approximately two hours
- Automated
  - Closed Cycle Cryostat (Cryogen Free)
- Optical window for the Optical Alignment Test
- Vacuum Electrical Feed-throughs
  - For thermal housekeeping
  - For measuring detector arrays
- Vendor: Cryomech Inc.
- Delivery: November 2001
- Procedure and Certification needed

Pulse Tube Cooler:

The PT405 PulseTube Cryorefrigerator produces cryogenic temperatures below 2.8 K without the use of displacers. Because there are no displacers, there are no displacer seals, no moving cold parts,and almost no vibration.

Cold Vibe Facility

Purpose

Interface Fixture For The BDA
(Both Warm and Cold (LN2))

Description

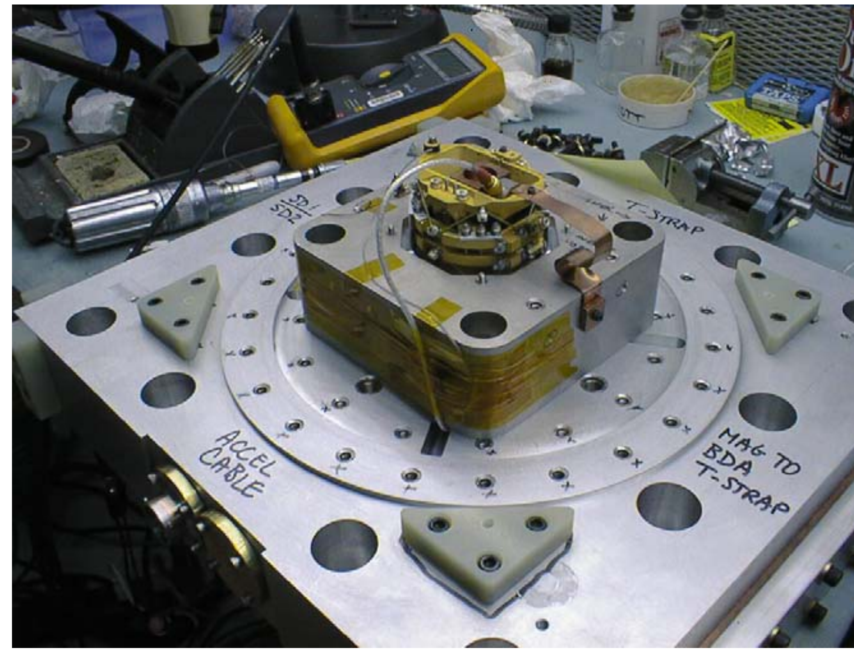
Compatible with BDA and JFET

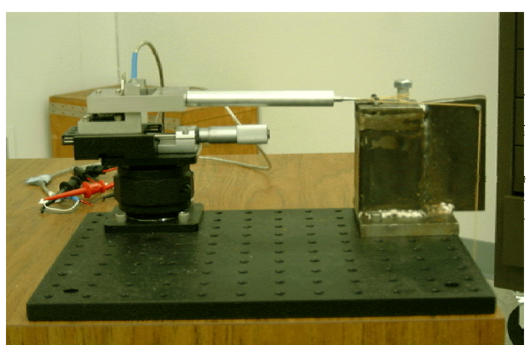
Status

Functional
Approved by Safety
Procedure and Certification needed

Peripherals

Tensionometer and metrology





The BoDAC's

Purpose

To Characterize Bolometer Performance

Description

Internal Optics and Filters
Cryogenics JFET/RF
3He/4He Closed cycle fridge
Warm Electronics
Lockin Amplifier
DAS

Status

Cryogenically Functional
3He/4He fridge operational
Optics and filters provided by Cardiff University, UK
JFET/RF and warm electronics in fabrication
Procedure and Certification needed

Beam Mapper

Purpose

To map the beam profile of the horns

Status

Design Phase

Picture avail. By CDR

Spectrometer

Purpose

To measure the spectral response of BoDAC

Description

Bruker IFS 120 HR Far IR Spectrometer

Operate from 10 to 4800 cm^{-1}

Continuous scanning

Status

On Loan to Glenn's Group in University of Colorado

Setup completed and ready for feedhorn testing

Picture available
by CDR

Documentation Schedule

Item	Document	% Complete	Completion Due Date
LN2 Vibration Test	Procedure	75%	Aug-01
	Certification	In Process	Sep-01
Thermal Cycling	Procedure	25%	Sep-01
	Certification	-	Dec-01
JFET Performance Testing	Procedure	-	Oct-01
	Certification	-	Nov-01
Bolometer Performance Testing	Procedure	25%	Oct-01
	Certification	In Process	Jan-02
Environmental Test Readiness Review	N/A	N/A	Nov-01
Performance Test Readiness Review	N/A	N/A	Jan-02

Hardware Schedule

Item	% Complete	Date Needed
BoDAC #1	100	Jul-01
3He/4He Fridge	75	Sep-01
Optics	80	Sep-01
Detector Mount	25	Oct-01
Cryocabling	50	Oct-01
JFETs	40	Oct-01
RF Filters	40	Oct-01
IR Filters	0	Sep-01
Warm electronics	60	Dec-01
Lockin amplifiers	90	Aug-01
Data Acquisition System	20	Dec-01
Software	0	Jan-01
Spectrometer	90	Nov-01
Beam Mapper	40	Sep-01
BDA and JFET simulators	10	Nov-01

Open Issues

- Schedule seems to have less slack than we would like for our test program

11.0
Mission Assurance Management

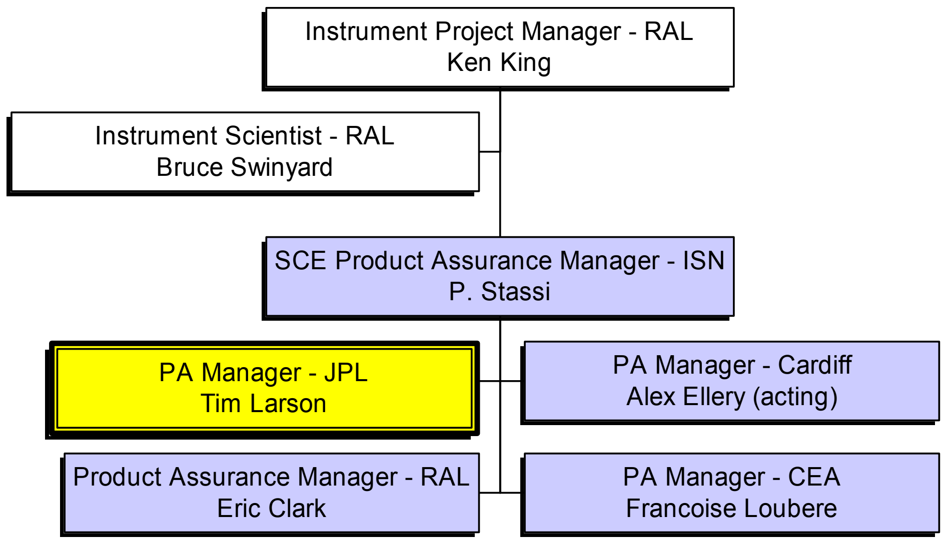
Gordon Barbay

Outline

- SPIRE Product Assurance Organizations
- JPL Mission Assurance Drivers
- Risk Management & Policy
- Mission Assurance Team
- Models & Implementation
- Mission Assurance Design Principles
- Mission Assurance Requirements & Documentation
- Mission Assurance Execution:
  - Systems Safety
  - Quality Assurance
  - Parts, Materials, Processes
  - Reliability Engineering
  - Environmental Engineering
  - Contamination Control
  - Problem/Failure Reporting
  - Configuration Management & Waivers

PA Organizational Interfaces

SPIRE PA Organization



Yellow = JPL Mission Assurance

Blue = JPL MA Interfaces

JPL Mission Assurance Drivers

- New, enabling technologies
  - New parts, materials, and processes
- Establishing "custom" reliability tests
  - Non-standard materials, processes
  - Cryogenic test & operating temperatures
- Multiple organizational interfaces
- Variations from European partners in established nomenclature (models, documentation)
- Transitions of technology development to flight hardware development

Risk Management

- The JPL Herschel/PLANCK project will:
    - 1. Plan and implement a disciplined approach to risk management throughout the project life cycle
    - 2. Support management decision-making by providing integrated risk assessments
    - 3. Communicate risk status to all project and appropriate NASA, JPL, and European Partners' management personnel
- The project risk policy is designed to first minimize risk (See Risk Policy).
- Mission Assurance program targets areas of risk for technologies and processes
    - – Table identifies the SPIRE areas of risk and implications for mission assurance program at JPL.

Risk Policy

Herschel/Planck Project Risk Policy

Programmatic Objectives and Constraints

As a junior partner in a collaboration with Europe on the Herschel and Planck missions, JPL's objectives are to provide the European Space Agency (ESA) and the relevant instrument Principal Investigators (PIs) with specific contributions that benefit the overall science value of both missions and allow U.S. scientific participation in the resultant research efforts. The JPL effort is constrained by a funding profile determined by NASA headquarters. Within the risk policy and budget profile, JPL's goal is to maximize the performance contribution to both missions.

The Herschel and Planck missions are major scientific endeavors for ESA. Although both Herschel and Planck will be validating new technologies, they are not considered to be technology validation missions where significant risk-taking would be acceptable. Both missions must succeed in meeting their required science objectives.

Herschel/Planck Risk Policy

Minimizing risk to the overall mission is the highest priority. It is the goal of the Herschel/Planck project to eliminate the possibility that any single-point failure causes mission failure. This means that all items that are mission critical will have built-in redundancy, where this is possible (ex., Planck cryocooler). Where this is not possible (ex., Herschel telescope) special risk avoidance measures will be taken to minimize mission risk. Plans and status of this risk avoidance will be an important part of project reviews. Minimizing risk to mission performance is a second priority which will be addressed within schedule and budget limitations.

Risk Avoidance/ Risk Acceptance/ Risk Taking

When possible within the project constraints and the performance goals of the project, the emphasis shall be on risk avoidance rather than risk acceptance. When faced with a trade-off between risk acceptance and performance, risk acceptance can be considered as an acceptable alternative only when the risk being considered avoids placing the entire mission at significant risk as stated in the risk policy. Therefore some risks may be accepted with mitigation and justification. Such decisions will be made in collaboration with the appropriate European PI.

The JPL Herschel/Planck Project emphasizes risk avoidance by minimizing risk through:

- analysis and redesign
- alternative developments
- parallel developments
- appropriate margins

Where the JPL Herschel/Planck Project decides to accept risks, risk will be minimized by:

- developing contingency plans and margin management criteria
- exercising those plans
- allowing descope/reduction in mission return to trade against cost, schedule, and other resources

Some performance reduction options were exercised in Phase B, and any new options need to be identified and agreed upon (and will be listed on prioritization of performance list). Herschel/Planck may move risk from cost risk to performance risk, remaining within the performance requirements and agreements with ESA and the instrument PIs.

SPIRE Risk Management

Project Element	Technology/Process	Target Area	MA Actions
SPIRE	Bolometer Array technology	• Definition & implementation of qualification, assembly, test	• Qualification Plan D-19152 "SPIRE Bolometer Qualification Plan"
SPIRE	BDA thermal isolation/mechanical design	• Qualification	• Verification of thermal requirements & performance on Qual Model
SPIRE	JFET Module (Differential Amplifier Circuitry)	• Qualification	• Qualification Plan D-19153 "SPIRE JFET Module Qualification Plan"

JPL Mission Assurance Team

Mission Assurance Manager	Tim Larson
Quality Assurance	Donna Markley
System Safety	Karan L'Heureux
Reliability	Gordon Barbay
Environments:	Gordon Barbay with Peter Barrett
Dynamics	Peter Barrett, Terry Scharton, Dennis Kern
EMC	Al Whittlesey, Tom Larter
Thermal	Jim Fu, Henry Abakians
Space Radiation Environments	Martin Ratliff
Electronic Parts Engineering	Ed Erginsoy
Materials & Processes	Mike Knopp
Configuration Management	Charles Davis
Contamination Control	Glenn Aveni

Model Summary

	EBB	QM	PFM/FM	FS
HIFI		X	X	X
SPIRE		X	X	X
Sorption Cryocooler	X		X	
HFI		X	X	X

SPIRE has 5 qualification models, two of which will be flight spares

<u>Key (see D-19155, section 2):</u>

EBB = "Elegant" Breadboard (Fidelity between traditional Breadboard and Engineering Model)

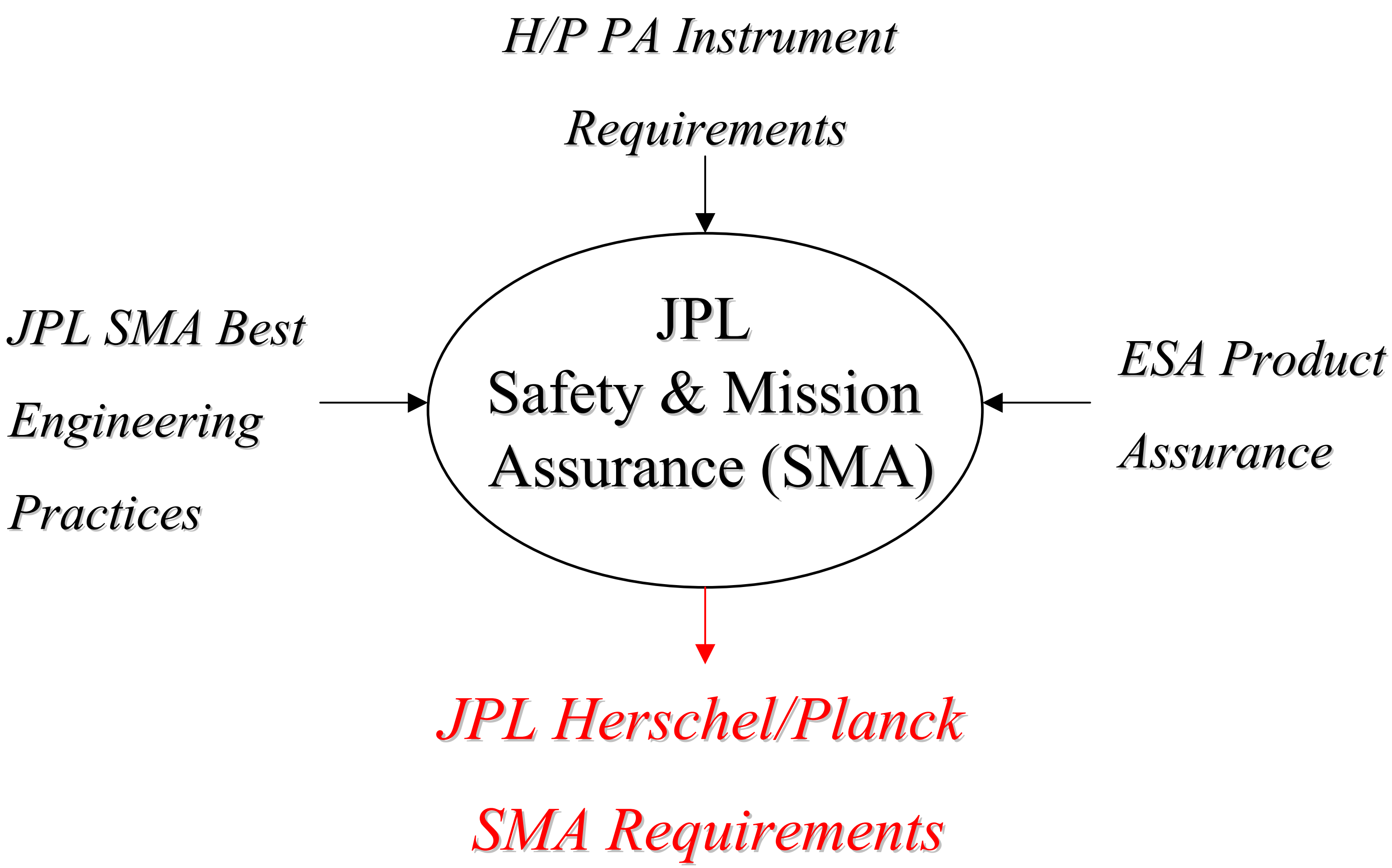
QM = Qualification Model

PFM = Protoflight Model (Flight hardware for which there is no previous qualification heritage)

FM = Flight Model

FS = Flight Spare

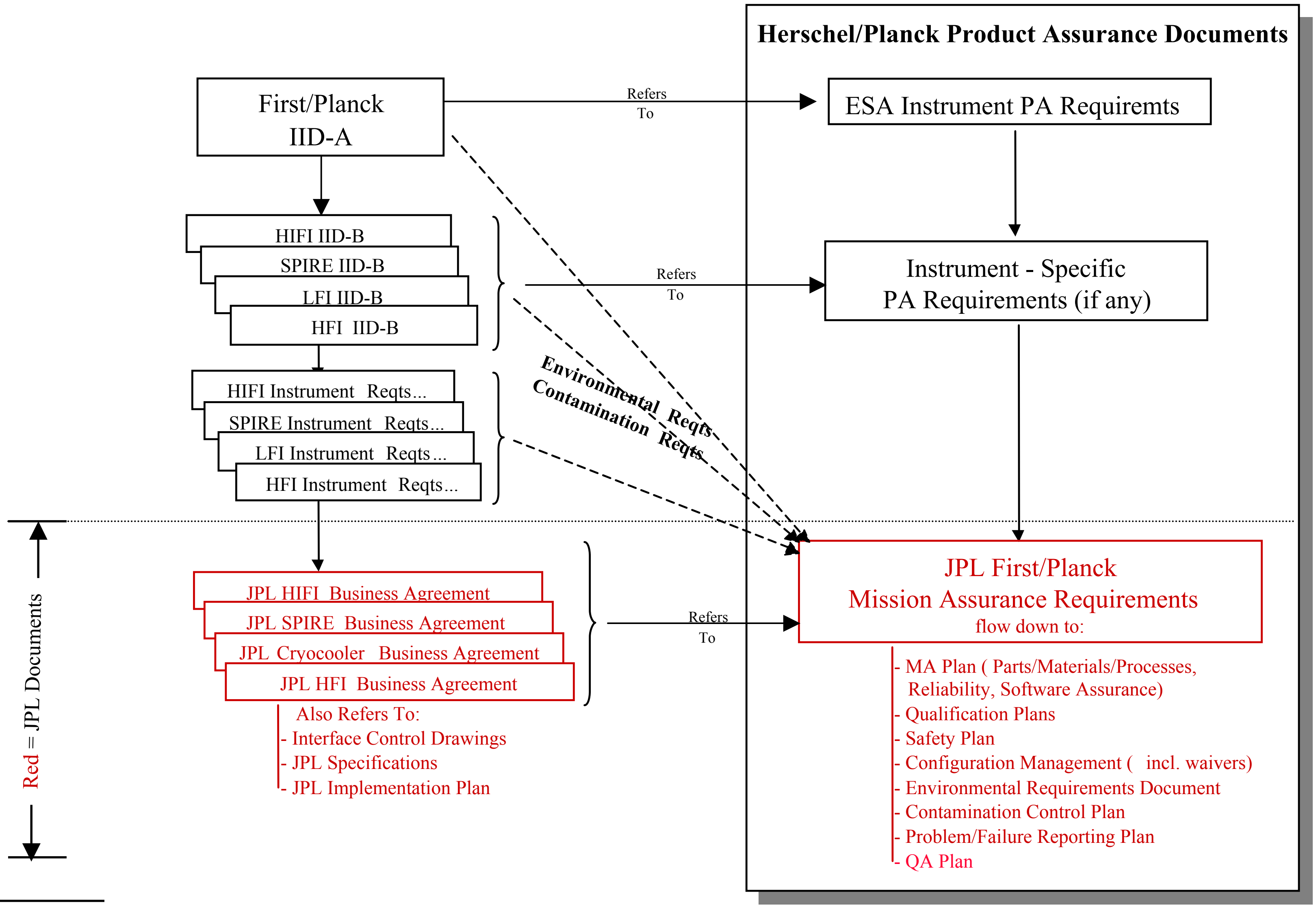
Mission Assurance Requirements Flow



Mission Assurance Design Principles

- Response to D-17868 “Design, V&V, and Ops Principles for Flight Systems” February 2001
  - Filtered for Mission Assurance-related principles
  - Each item dispositioned. See attachments.
  - No exceptions at this time (for Mission Assurance)

Product Assurance Documents



MA Documentation

Mission Assurance Requirements for the Herschel/Planck Mission	D-16642	RELEASED 1/01
Herschel/Planck Mission Assurance Plan (includes Parts/Materials/ Processes, Quality Assurance, Reliability)	D-16874	RELEASED 4/01
FIRST/Planck Safety Plan	D-16875	RELEASED 12/00
FIRST/Planck Risk Management Plan	D-16857	RELEASED 11/00
Herschel/Planck Configuration Management Plan (includes Waivers)	D-16873	RELEASED 1/01
FIRST/Planck Problem/Failure Reporting Plan	D-19151	RELEASED 10/00
Herschel/Planck Contamination Control Plan	D-19156	RELEASED 4/01
Herschel/Planck Quality Assurance Plan	D-19173	TBR August 2001
Herschel/Planck Environmental Requirements Document	D-19155	RELEASED 2/01
SPIRE Product Assurance Requirements Map	D-19164	TBR September 2001
SPIRE Bolometer Detector Assembly Qualification Plan	D-19152	RELEASED 7/01
SPIRE JFET Module Qualification Plan	D-19153	TBR August 2001

System Safety (1 of 2)

- Requirements & Implementation: Herschel/Planck Safety Plan (D-16875)
  - Meets requirements of:
    - JPL D-560 “JPL Standard for Systems Safety” applicable to hardware developed, integrated, or tested at JPL
    - RS-CSG-Ed.5 (0) Vol. 1 “CSG Safety Regulations (Payload Design)”
    - RS-CSG Ed. 5 (0) Vol. 2 “CSG Safety Regulations (Payload Preparation)”
  - Responsive to:
    - “Ariane 5 Users Manual” Issue 3, Rev 0
    - MSFC-HDBK-527
    - JSC 09604 “Materials Selection List for Space Hardware Systems”
    - NASA Technical Standards, where applicable
    - NFPA Regulations
    - National Electrical Code
    - Federal OSHA Regulations
    - Environmental Protection Agency Regulations

System Safety (2 of 2)

- Safety Challenges:
  - Cryogenics
  - Pressurized Tanks
  - No pyrotechnic devices, no ionizing radiation devices, no batteries, no propellants, no hazardous materials, no power during launch
- Safety Compliance Documentation: Hazard Analysis
- Preliminary Safety Survey of 183-215 Lab Complete
  - No issues, waiting for final equipment delivery & installation
- Certification of Qualification tests (Cold Vibration Test)

Quality Assurance (1 of 2)

- Requirements & Implementation:
  - Mission Assurance Requirements for Herschel/Planck (D-16642)
  - Quality Assurance Plan (D-19173)

- Scope:
  - Facilities Certification
  - Procurement Control
  - Manufacturing and Assembly control
  - Integration and Test control
  - Handling, Storage, Packaging, Marking, Labeling, Transportation Control
  - Acceptance and Delivery

Quality Assurance (2 of 2)

- MDL: Flight build preparations for detector arrays are near completion
  - Processes are documented (evaluated by J. Bock)
  - Procedures completed, in approval cycle and in PDMS
  - Process traveler completed and approved
  - Fabrication AIDS are approved
  - Facilities are certified
  - Personnel are certified and trained
- Fabrication and Test (Building 103):
  - QA is ready to support integration of detector array into BDA in Bldg. 103
    - Generation fabrication procedures and AIDS
    - Qualification units fabrication ______

Parts, Materials, Processes (1 of 5)

- Requirements & Implementation:
  - Mission Assurance Requirements for Herschel/Planck (D-16642)
  - Mission Assurance Plan for Herschel/Planck (D-16874)
- Requirements/Scope:
  - Approvals of required Parts, Materials, Processes
    - Review of M&P accomplished through Material Identification & Usage Lists (MIUL)
    - Review of electronic parts accomplished through approved parts lists
  - Prohibited materials, Alerts
  - Electronic parts MIL-STD-975M Grade 1 or 2 parts or equivalent
  - Derating per JPL Derating Guidelines (D-8545) for electronics
  - Radiation TID 20 Krad (includes RDM = 2), SEU LET = 37 MeV/cm^2, SEL LET = 75 MeV/cm^2
  - Lot Acceptance Test & Screen
  - Requirements flow down to suppliers

Parts, Materials, Processes (2 of 5)

- Requirements/Scope (continued):
  - Qualification Plans:
    - Qual Plans for new part types/high risk non-standard parts include manufacturer surveys, design & construction analysis, in-process inspection & test samples, lot qualification, destructive physical analysis, testing (performance, environmental, life), screening
    - Qual Plans for materials/processes not previously qualified for application include thermal vacuum, thermal cycling, radiation, stress corrosion, fracture mechanics

Parts, Materials, Processes (3 of 5)

- Safety & Mission Assurance working with PEMs concurrently for approval of parts, materials, processes
- Activities:
  - Preliminary MIUL for BDAs
    - Not all materials and processes identified
    - Final PMP lists expected by ________
  - Parts/Materials Selection
  - Qualification support
  - Procurement/procurement support
  - Stores, Radiation Test Facilities, Electronic Parts Evaluation Laboratory, Failure Analysis Laboratory

Parts, Materials, Processes (4 of 5)

PMP Status

- **M&P**
  - **Preliminary MIUL for BDA Complete**
    - **Working to identify remaining materials and processes**

- **EEE Parts - Two parts identified**
  - **U401 JFET – JPL approved part, being procured**
  - **Murata EMI chip filter – JPL unapproved part, going through element evaluation to class K**

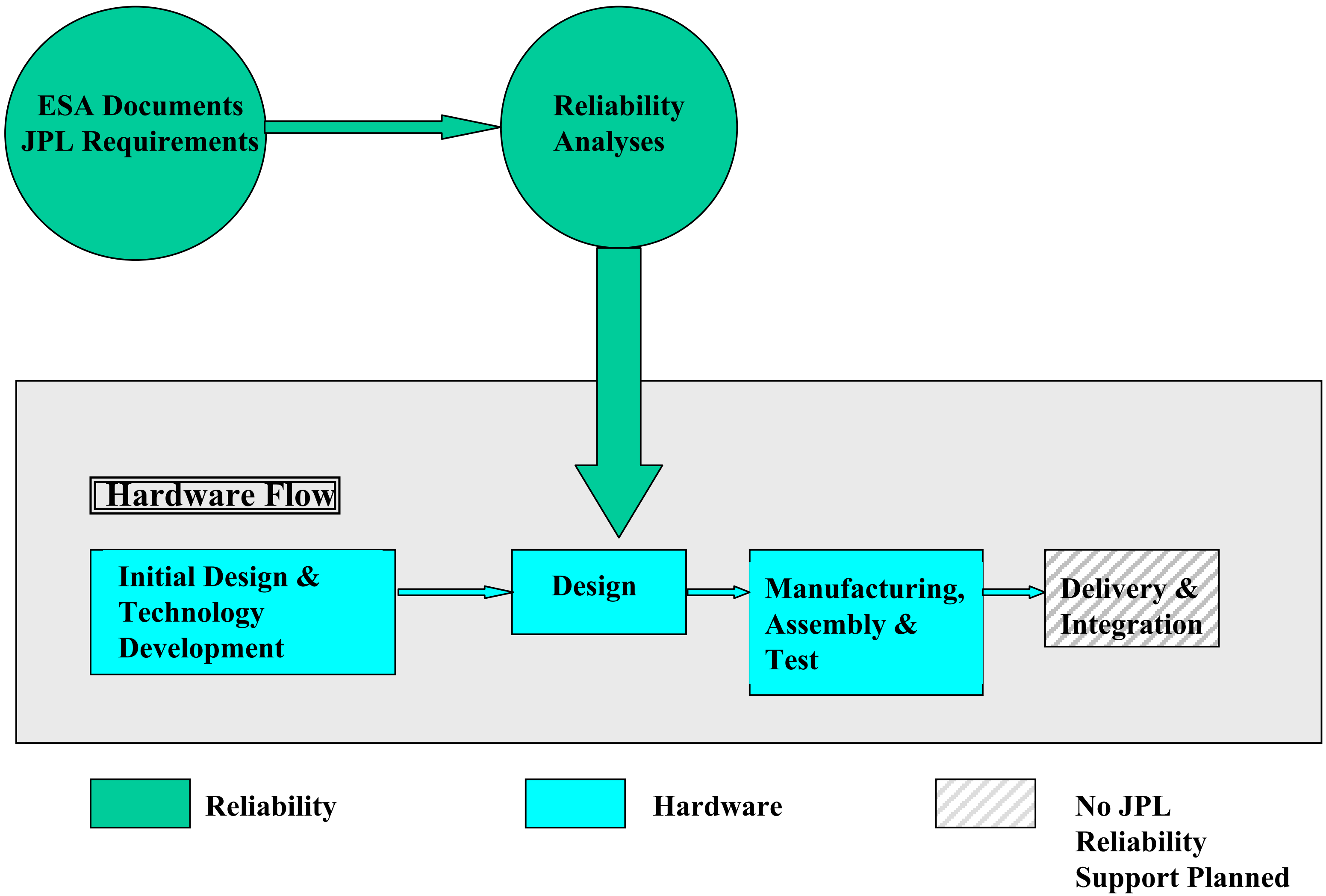
Parts, Materials, Processes (5 of 5)

- Specific Support - The Cognizant Engineer ensures the appropriate participation, including drawing approval, of engineering specialists:

Discipline	Contact
Cabling Engineering	Mark Hetzel (ASI), Mick Tickner
Contamination	Glenn Aveni
Electronic Packaging Engineering	Roy Packard, Charlie Kaczinski
Fabrication Engineering	Randy Fayner
Fasteners	Don Lewis
Materials & Processes	Mike Knopp
Mechanical Components	Mike Knopp
Structures & Dynamic Analysis	Mike O'Connell, Michelle Coleman, Peter Barrett
Temperature Control	Jim Fu, Henry Abakians
Radiation Control	Al Hoffman, Martin Ratliff
Electronic Parts	Ed Erginsoy, Parts Specialists
Connectors	Pat Dillon
PDMS (Drawing Control)	Charles Davis, Mike Stefanini
Shipping Containers	Mick Tickner

Reliability Engineering (1 of 5)

Reliability Analysis Requirements



Reliability Engineering (2 of 5)

Reliability Analyses Matrix

ITEM	FIRST/Planck JPL Hardware - Reliability Analysis						
	Parts Stress Analysis (PSA)	Worst Case Analysis (WCA)	Power Supply Transient Analysis	Sneak Circuit Analysis (SCA)	Failure Modes, Effects and Criticality Analysis (FMECA)	Fault Tree Analysis (FTA)	Ground Support Equipment (GSE) FMECA
Herschel							
HIFI	A	A	N	N	A	A	A
SPIRE	A	A	N	N	A	N	A

N = Analysis Not Required

A = Analysis Required

WCA, PSA FMECA completed July 2001

GSE FMECA TBD by September 2001

Reliability Engineering (3 of 5)

- Requirements & Implementation:
  - Mission Assurance Requirements for Herschel/Planck (D-16642)
- Detailed Requirements:
  - Assure flight hardware operation within specification over expected environments and conditions (including design margins)
  - During design process, perform:
    - Fault Tree Analysis and Failure Modes, Effects & Criticality Analysis
    - Parts Stress Analysis and Worst Case Analysis
    - Identification of single point failures and critical items
    - Infusion of Lessons Learned (preventive action) http://llis.nasa.gov

Reliability Engineering (4 of 5)

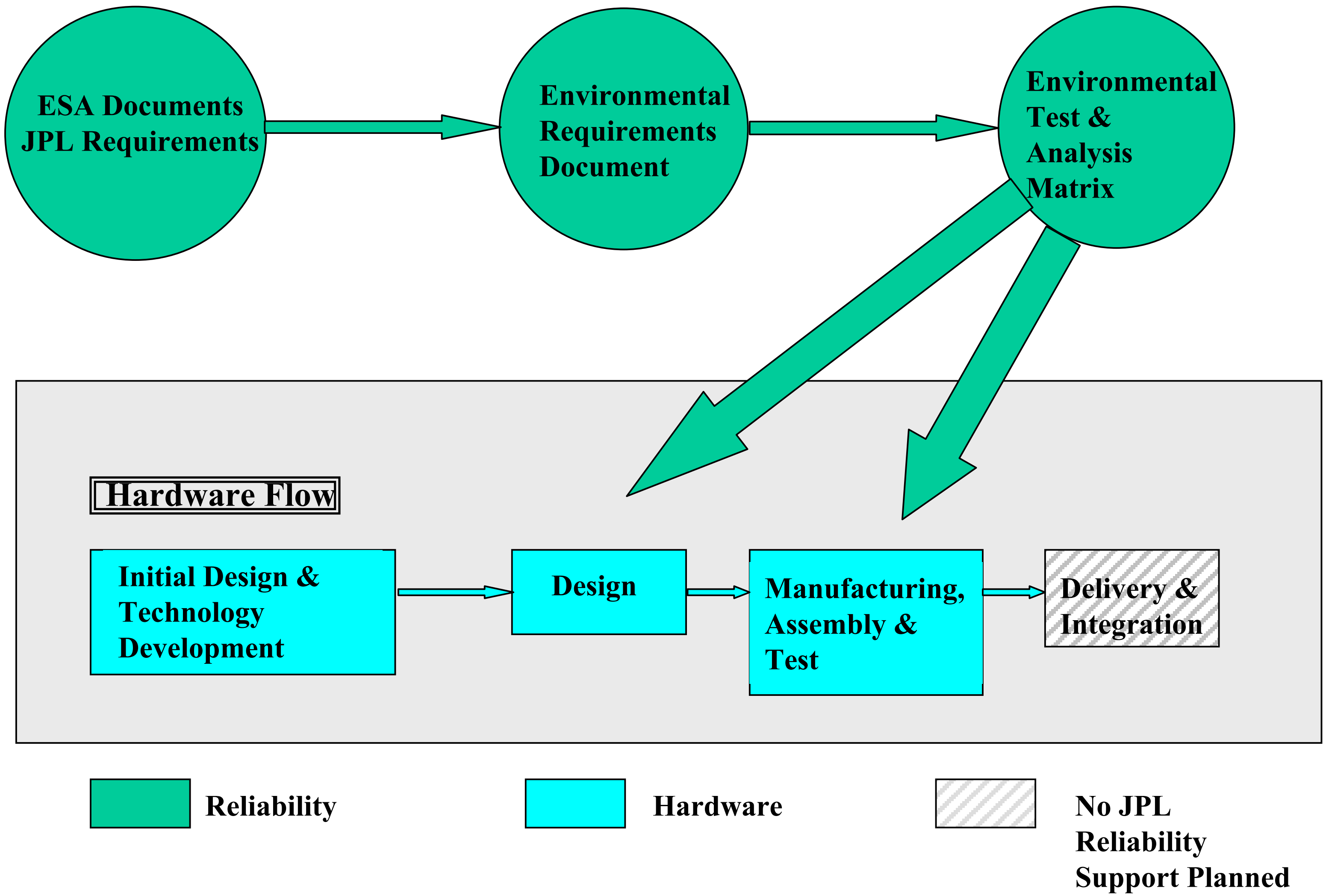
- Flight Electronics Operating Hours
  - Design Principles:
    - Unit Level prior to spacecraft integration minimum of 200 hours
    - System Level prior to launch minimum:
      - 1000 hours single string
      - 500 hours each side of redundant (with goal of 1000 hours)
  - Operating time measured by "youngest" replacement part
  - Requirement needs to be specified in Herschel/Planck MA requirements document (No ESA requirement at this time)

Reliability Engineering (5 of 5)

- Reliability Analyses Results:
  - Parts Stress & Worst Case Analysis
    - Insufficient data to assure EOM success
    - Plans to close issue
      - Acquire historical data
      - Explore feasibility of testing
      - Other avenues
  - FMECA Analysis
    - No discrepancies found
    - Possible shorts between cable harness wires issue
      - Add to FMECA analysis, if needed (August 2001)

Environmental Engineering (1 of 9)

Environmental Analyses and Test Requirements



Environmental Engineering (2 of 9)

Environmental Analyses Drivers

- **Dynamics**
  - **Ariane 5 Launch Vehicle**
- **Thermal**
  - **Multiple Thermal Environments**
- **EMC/EMI**
- **Natural Space Environment**
  - **Using Standard Environments for L2 Orbit**

Environmental Engineering (3 of 9)

Environmental Test and Analysis Matrix - Part 1

			Static Load		Earth Handling			Dynamics			
	HARDWARE ITEM	Test Program Type	Static Loads	Quasi-static acceleration	Package Drop & Trans Vibration	Humidity	Explosive Atmosphere	Acoustic	Vibration - sine	Vibration - Random	Pyro. Shock/Simulated Drop Shock
	SPIRE (Jerry Lilienthal)										
	Qual Cold Electronics JFET Module	Q	A	A	Z	Z	Z	N	X	X	SD
	Proto Flt Cold Electronics JFET Module	PF	A	A	Z	Z	Z	N	X	X	N
	Flt Spare Cold Electronics JFET Module	FA	A	A	Z	Z	Z	N	X	X	N
	Qual Photometer Assembly	Q	A	A	Z	Z	Z	N	X	X	SD
	Flt Spare Photometer Assembly	PF	A	A	Z	Z	Z	N	X	X	N
	Proto Flt Photometer Assembly	FA	A	A	Z	Z	Z	N	X	X	N
	Qual Spectrometer Assembly	Q	A	A	Z	Z	Z	N	X	X	SD
	Proto Flt Spectrometer Assembly	PF	A	A	Z	Z	Z	N	X	X	N
	Flt Spare Spectrometer Assembly	FA	A	A	Z	Z	Z	N	X	X	N

SD = Simulated Drop Shock
C = Cold Vibration Test (4 deg K)
Z = No Test or Analysis Required if Approved Procedures are Followed and Acceptable Environmental Conditions are Maintained
N = Neither Test or Analysis Required
H = Test or Analysis Req at the Higher Level of Assembly or One Analysis Performed for The Group
X = Test Required
A = Analysis Required

Environmental Engineering (4 of 9)

Environmental Test and Analysis Matrix - Part 2

		Thermal						Natural Space						
HARDWARE ITEM	Test Program Type	Contamination	Temp. ground handling	Thermal Shock	Launch Press Profile	Temp./ Atmosphere	Thermal Vac.	Ionizing Dose	Displacement Damage	Low Dose Rate	EUV	Single Event Effects	Solid Particles	Orbital Debris Generation
SPIRE (Jerry Lilienthal)			A	A	A			A	A	A	A	A	A	A
Qual Cold Electronics JFET Module	Q	Z	H	H	H	N	X	H	H	H	H	H	H	H
Proto Flt Cold Electronics JFET Module	PF	Z	H	H	H	N	X	H	H	H	H	H	H	H
Flt Spare Cold Electronics JFET Module	FA	Z	H	H	H	N	X	H	H	H	H	H	H	H
Qual Photometer Assembly	Q	Z	H	H	H	N	X	H	H	H	H	H	H	H
Flt Spare Photometer Assembly	PF	Z	H	H	H	N	X	H	H	H	H	H	H	H
Proto Flt Photometer Assembly	FA	Z	H	H	H	N	X	H	H	H	H	H	H	H
Qual Spectrometer Assembly	Q	Z	H	H	H	N	X	H	H	H	H	H	H	H
Proto Flt Spectrometer Assembly	PF	Z	H	H	H	N	X	H	H	H	H	H	H	H
Flt Spare Spectrometer Assembly	FA	Z	H	H	H	N	X	H	H	H	H	H	H	H

Environmental Engineering (5 of 9)

Environmental Test and Analysis Matrix - Part 3

	EMC						
HARDWARE ITEM	EMC Conducted susc. Note 3	EMC Radiared susc.	EMC Cond Emissions	EMC Radiated Emission	ESD Susceptibility	Magnetic	EMC Isolation
SPIRE (Jerry Lilienthal)							
Qual Cold Electronics JFET Module	H	H	H	H	H	H	X
Proto Flt Cold Electronics JFET Module	H	H	H	H	H	H	X
Flt Spare Cold Electronics JFET Module	H	H	H	H	H	H	X
Qual Photometer Assembly	H	H	H	H	H	H	X
Flt Spare Photometer Assembly	H	H	H	H	H	H	X
Proto Flt Photometer Assembly	H	H	H	H	H	H	X
Qual Spectrometer Assembly	H	H	H	H	H	H	X
Proto Flt Spectrometer Assembly	H	H	H	H	H	H	X
Flt Spare Spectrometer Assembly	H	H	H	H	H	H	X

Environmental Engineering (6 of 9)

- Requirements & Implementation:
  - Herschel/Planck Environmental Requirements Document (D-19155)
    - **JPL Requirement/Analysis Used Where No "flowdown" Requirement Specified**
    - **Resolution of variant requirements addressed as they are identified to JPL by the Instrument**
    - **Approach: Meet ERD requirements and assess hardware capability**

Environmental Engineering (7 of 9)
Environmental Testing

- Environmental Test Authorization & Summary (ETAS) Forms Document Tests on Flight Hardware
  - Documents Configuration, Specs, Approved Deviations, As-Tested Levels, & Results
  - Approved and Tracked by Environmental Requirements Engineer (ERE)
  - Used to Provide Documentation for Reviews
- Test Failures Reported and Tracked via P/FRs
- Any Re-testing Based on Need
  - Type and Levels Determined by CogE and ERE

Environmental Engineering (8 of 9)
ERD/ESA Specification Differences

- **ESA requirements derived from IIDA or IIDB**
- **No ESA Radiation Requirement (Environment Only)**
  - **ERD has JPL Derived Requirements**
- **Low Level Sine Sweep: ESA - .5g vs JPL - .25g**
  - **ESA Level Could Cause Excessive Response**
- **ESA High Level Sine Sweep Levels**
  - **Cause Excessive Shaker Displacement (5-20 Hz)**
  - **Potentially Damaging to Hardware (20-100 Hz)**
- **ESA Random Vibration Levels Below JPL Standard Workmanship Levels**

- **Working with European partners to resolve differences**

Environmental Engineering (9 of 9)
Vibration Test

- Vibration Test
  - Warm & Cold Test Performed on BDA EM
  - Warm test on JFET module in work
- Test Results
  - BDA Test Successful

Contamination Control

- Requirements & Implementation:
  - Herschel/Planck Contamination Control Plan (D-19156)
- Detailed Requirements:
  - Assembly, Handling, Test Facilities
    - Class 100,000 (ISO 14644-1 Class 8) cleanroom
    - Class 10 Microdevices Fabrication
- Certification of 183-215 Lab Awaiting Clean Bench Delivery
  - Delivery expected August 2001

Problem/Failure Reporting (1 of 2)

- Requirements & Implementation:
  - Mission Assurance Requirements for Herschel/Planck (D-16642)
  - FIRST/Planck Problem/Failure Reporting (D-19151)
- Non-conforming materials in-process dispositioned on Inspection Report, Non-conforming Materials Report, Destructive Physical Analysis Report
- Problems/unexpected behavior/anomalies reported in P/FR System
- If determined to have impact on European interface, can create NCR
- P/FR system is set up and ready to go

Problem/Failure Reporting (2 of 2)

Begin problem reporting at:

Hardware/ Software	Ground Support Equipment (GSE)	EBB/QM	Flight
Hardware	At GSE Acceptance Test before interface with qualification or flight hardware.	System Electronics: First application of power for performance test prior to assembly level qualification.	System Electronics: First application of power for performance test prior to assembly level flight H/W protoflight testing.
		Mechanical Devices: Starting with assembly level qualification.	Mechanical Devices: Starting with assembly level protoflight testing.
Software	At GSE Acceptance Test before interface with qualification or flight hardware.	Prior to integration.	Prior to integration.

Configuration Management (1 of 3)

- Requirements & Implementation:
  - Mission Assurance Requirements for Herschel/Planck (D-16642)
  - Herschel/Planck Configuration Management Plan (D-16873)
- Baselines, changes, controlled change decision-making process
- Scope includes, but not limited to:
  - Engineering data
  - Proposal data
  - Requirement data
  - Specification data
  - Design data
  - Fabrication or assembly data
  - Test or inspection data
  - Repair or rework data
  - Change or modification data
  - Configuration lists
  - Parts lists and Bills of Material
  - Documentation and drawing lists
  - Problem, failure or anomaly reports
  - Plans
  - Work Package Agreements
  - Interface Agreements/Commitments
  - Project/Programmatic Documentation

Configuration Management (2 of 3)

- Configuration Control Begins:
  - Documents/Drawings/Plans: First release
    - "Pre-release" control for drawings
  - QM and Flight Hardware: complete traceability
    - Lot traceability on procured items
    - Serial number traceability on built items
- Configuration Control Services
  - Project Data Management System: Drawings, Waivers, Engineering Change Requests, Project Documents, Master Control Document List, Project Archive
  - Project Library: Work Areas, Reviews, Presentations
  - PFOC: Problem/Failure Reporting System
  - QA: QA Records
  - DMIE: JPL Institutional Documents

Configuration Management (3 of 3)

- Waivers
  - ESA "Request for Waiver" for ESA-approved Requirements
  - JPL Waiver Form for JPL-approved requirements that do not impact post-delivery I&T, launch, operations

Backup Charts: Attachments

- Mission Assurance Design Principles Conformance Matrix

Mission Assurance Design Principles (1 of 8)

1.10	4	During development a list of potential credible single point failures shall be developed, maintained and reported at PMSR, PDR, CDR, ATLO START and Launch.	Will Comply. Will be documented during design analysis on "Critical Items and Single Point Failures" form.
1.10	5	The list of accepted potential single point failures shall be communicated to the flight operations team. Particular attention shall be given to those items where the risk mitigation plan requires flight operational actions.	Will Comply. Inputs will be to Instrument Teams for HIFI, HFI, SPIRE, to Spacecraft Systems/Ops Team for Telescope, and to both ? for Sorption Cryocooler.
1.12	1	The project shall plan early in the formulation phase for adequate safety and mission assurance activity, and shall identify the responsibilities of the participating organizations in tailored Safety and Mission Assurance plans. These plans shall define	Comply.
1.13	1a	- Mission Assurance and Independent Assessment	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1b	- System Safety	See D-16875 "FIRST/Planck Safety Plan"
1.13	1c	- Reviews	See Project Implementation Plan (PIP) section on Reviews.
1.13	1d	- Reliability Engineering	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1e	- Quality Assurance	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1f	- Electronic Parts Engineering	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1g	- Risk Management	See D-16857 "FIRST/Planck Risk Management Plan"
1.13	2	Assurance engineering shall be integrated and concurrent with the design activity throughout the project life cycle.	Comply. Started late due to technology development (appropriately) not including assurance engineering processes. Progressing at an acceptable rate. Still "catching up" on HFI and SPIRE.

Mission Assurance Design Principles (2 of 8)

No.	Item	Requirement	Disposition
1.13	1	The project shall plan early in the formulation phase for adequate safety and mission assurance activity, and shall identify the responsibilities of the participating organizations in tailored Safety and Mission Assurance plans. These plans shall define	Comply.
1.13	1a	- Mission Assurance and Independent Assessment	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1b	- System Safety	See D-16875 "FIRST/Planck Safety Plan"
1.13	1c	- Reviews	See Project Implementation Plan (PIP) section on Reviews.
1.13	1d	- Reliability Engineering	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1e	- Quality Assurance	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1f	- Electronic Parts Engineering	See D-16874 "FIRST/Planck Mission Assurance Plan"
1.13	1g	- Risk Management	See D-16857 "FIRST/Planck Risk Management Plan"
1.13	2	Assurance engineering shall be integrated and concurrent with the design activity throughout the project life cycle.	Comply. Started late due to technology development (appropriately) not including assurance engineering processes. Progressing at an acceptable rate. Still "catching up" on HFI and SPIRE.
1.13	3	Project quality assurance provisions shall be flowed down to all project acquisitions.	Will Comply. Telescope and HIFI LO contracts, and parts/ materials/processes procurements will include QA provisions.
1.13	3R	*Rationale: Proposals should reflect S&MA approach to customer, and assurance engineering can be involved in the earliest design decisions. Avoids redesign resulting from after-the-fact MA review, and resolves product quality issues as they arise. Commu*	(Rationale)
1.16	1	The design shall be reviewed early in the formulation process, and at appropriate points in the life-cycle, by the engineering team against the JPL/ NASA Lessons Learned data base, NASA/JPL Alerts, etc. Each item of potential applicability to the project	Will Comply. There are 805 Lessons Learned. Need to consolidate into what is applicable (some are). Make or Get LL to provide a selectable, dispositionable list. Alerts will be reviewed during parts/materials/processes approvals.
1.16	1R	*Rationale: Important "lessons" can be drawn from past events which have applicability beyond the original event, which can preclude recurrence of faults/failures, and enable early and cost-effective changes. Some examples of past troublesome areas are:*	(Rationale)

Mission Assurance Design Principles (3 of 8)

No.	Item	Requirement	Disposition
1.18	1	The project shall perform, with appropriate independent assessment support, a total mission risk assessment at inception of project, and as defined for reviews.	Will Comply As Applicable, at Project-Element Level and at Project Level. Peer Reviews and PDR are independent inputs to this assessment. Define GPMC's role in this.
1.18	1R	*Rationale : To ensure JPL and customers are informed of risk to program/project success, and to provide independent assessment back to project to enable possible mitigation approaches outside the project's sphere of influence.*	(Rationale)
1.18	2	These assessments shall specifically identify and address risks to project and program objectives.	Will Comply. Determine how documented.
1.18	3	Risk assessments shall specifically include margin assessment as one of the risk metrics.	Will Comply As Applicable.
1.19	3	Particular attention should be given to Red Flag PFRs/unverified failures and ISAs. (new)	Will Comply.
1.19	3R	*Rationale: Identifies incompatibilities between previous usage and current mission requirements.*	(Rationale)
1.19	1	A tailored closed loop problem failure reporting (PFR) system shall be implemented. Strategy, specific approach, and timing for instituting PFRs shall be documented. The JPL electronic problem log/PFR System shall be used.	Will Comply. Need to coordinate with COI.
1.19	1R	*Rationale: Uniformity of describing and reporting problems, and consistent reference capability enables cross-project understanding of risks and implications of the issues.*	(Rationale)
1.19	2	A process that utilizes a concurrent cognizant project team (Project Manager for Red Flag PFRs) shall be established to close problems in a timely and confident manner. Red Flag PFRs or unverified failures shall be compiled and forwarded to the flight op	Will Comply.
1.19	2R	*Rationale: To make the flight team aware of those pre-launch problems that may be a significant threat to flight operations activities. (new)*	(Rationale)
1.27	3	To enable use of engineering or prototype models as flight spares, appropriate actions shall be taken to ensure hardware safety, reliability, and functionality.	Will Comply.

Mission Assurance Design Principles (4 of 8)

No.	Item	Requirement	Disposition
1.31	1	Orbital debris safety considerations shall be addressed during the project formulation phase and during the implementation phase.	Will Comply.
1.31	2	Orbital debris from launch vehicles, spacecraft, instruments or components thereof (e.g., launch vehicle 2nd or 3rd stage, instrument covers) shall be limited, as much as practical, by employing prudent design and flight operations techniques, as appropri	Comply.
1.31	3	The design and flight operations shall employ debris-limiting options (e.g., propellant depletion burns, cover release inhibits) considering normal and off-normal operations, and certain anomalous events (e.g., explosions, breakups, or collision with othe	Not Applicable. Ask Peter Barrett how to document this.
1.31	4	Identification of orbital debris sources, potential hazards and a debris-limiting assessment shall be presented at the SRR. Functional design implementation shall be reviewed at the PDR and finalized at the CDR. (new)	Not Applicable. JPL hardware has no orbital debris sources.
1.31	4R	*Rationale: Limit the proliferation of debris that may be a safety threat to personnel or space vehicles (current and future) generated by orbital debris. (new)*	(Rationale)
			-
2.8B	5	The design shall keep piece-part silicon junction temperatures less than 110°C (assuming a mounting surface temperature of 70°C) for the planned circuit design and packaging scheme. Higher junction temperatures may be considered where risk is shown to be	Will Comply via worst-case analyses.
2.8B	7	Optics, detectors and other unique hardware shall be designed for allowable flight temperature limits extended by -15°C and +20°C and margins may be tailored to specific application based on required operating temperature ranges of sensitive elements.	Will Comply. See D- 19155 "FIRST/Planck Environmental Requirements Document"
2.8C	8	Electronic hardware design shall be capable of surviving power on-off temperature cycling and/or solar exposure cycling of three times the number of worst-case expected mission cycles with worst-case flight temperature excursions. Prior to having a missi	Will Comply As Applicable. Ask Brad's team do we address this in ERD (how).
2.8C	9	Mechanical hardware design thermal cycling profile shall be tailored for the specific application.	Will Comply.
2.8C	10	Flight hardware thermal cycling shall be minimized to preclude the risk of damage.	Will Comply.
2.8C	10R	*Rationale: Thermal cycling has been implicated as a major contributor to faults/problems.*	(Rationale)

Mission Assurance Design Principles (5 of 8)

No.	Item	Requirement	Disposition
2.21	2	The Design shall be assessed for robustness through a program of analyses tailored from the Reliability Analysis Handbook Guidelines (JPL D-5703) or Contractor/Partners equivalent, including Part Parameter Data from available databases, and Derating Guide	Will Comply. Need to determine if this should be in MA Plan (Reliability Section) or in Qual Plans (to be written).
2.21	2	- Worst-case circuit analysis or Voltage-Temperature- Frequency margin testing - to demonstrate performance margin.	-
2.21	2	- Failure mode effects functional analysis (FMEA) at the system/subsystem functional block diagram and interface levels - identifies potential critical single failure points.	-
2.21	2	- System interface circuit, functional, and fault analyses (mechanical, thermal, etc.) - demonstrate that faults in one subsystem/system will not propagate or functionally degrade other subsystems.	-
2.21	2	- Failure Modes Effects/ Criticality Analyses (FMECAs) are generally applied to electronics and electronic functional interfaces, and Fault Tree Analyses (FTAs) to devices and mechanisms).	-
2.21	2	- Parts stress analyses - verify margins.	-

Mission Assurance Design Principles (6 of 8)

No.	Item	Requirement	Disposition
2.22A	0	General	-
2.22A	1	Appropriate derating of parts shall be incorporated in electronics design.	Will Comply. Qualification Plans? need to identify derating approach for custom devices.
2.22A	2	The availability and cost/risk effectiveness of grade-one parts shall be considered before COTS parts become the design baseline.	Will Comply.
2.22A	3	An early design parts list review shall be performed against documented requirements to:	Will Comply. "Catching up" with HFI and SPIRE.
2.22A	3a	- identify long-lead time parts.	-
2.22A	3b	- assess radiation dose, latch up and Single Event Effects (SEE) capability/compatibility.	-
2.22A	3c	- minimize the number of different part types.	-
2.22A	3d	- provide parts vendor assessment information.	-
2.22A	3e	- assure all known parts issues are identified and closed early.	-
2.22A	3f	- benefit from Parts Engineering/independent assessments and knowledge from other missions.	-
2.22A	3g	- provide data to project risk data base.	-
2.22A	3h	- cost-effective match between design and parts capabilities.	-
2.22A	4	The root cause of electronic parts failures shall be determined.	Will Comply.
2.22A	4R	*Rationale: Avoids repeating same or related failure, and develops effective and efficient corrective action that addresses underlying cause.*	(Rationale)

Mission Assurance Design Principles (7 of 8)

No.	Item	Requirement	Disposition
2.25	1	System Safety analyses, inspections and tests, and required reports, shall be performed according to the guidelines and requirements of JPL Standard for System Safety (D-560). These include:	Will Comply.
2.25	1a	- A preliminary hazard analysis- in support of preparation of System Safety Plan	-
2.25	1b	- A Safety Compliance Data Package	-
2.25	1c	- Safety tests and/or inspections, and Facility and operational Safety Surveys	-
2.26	1	Environmental design assessments and verification tests shall be performed to verify the design against the specified environment. These shall be performed at the unit, and system level, considering the requirements and guidelines of JPL D-14040, “Proces	Will Comply As Applicable. See D-19155 "FIRST/Planck Environmental Requirements Document"
2.26	1a	Analyses - Single Event Effects (SEE), micrometeoroid, pressure profile, magnetic fields, etc.	-
2.26	1b	Unit-level Qual random vibration, pyro, thermal, EMC, and Acceptance random vibration and thermal	-
2.26	1c	System-level/ Protoflight random vibration and/or acoustic, pyro shock, thermal vacuum, EMC	-
2.27	1	A minimum power-on operating time shall be established for all electronics as follows:	See below.
2.27	2	Unit Level prior to spacecraft integration minimum of 200 hours	Will Comply. Current requirement states 100 hours pre-delivery, plus 500 hours pre-launch. Need to re-word requirement for clarity, and application to deliveries (assembly versus subsystem).
2.27	3	System Level prior to launch minimum of 300 hours (Goal 1000 hours)	TBD. Does ESA have op hrs reqt?

Mission Assurance Design Principles (8 of 8)

No.	Item	Requirement	Disposition
2.28	1	JPL source QA provisions shall be provided for critical processes/products and strategically applied to high risk suppliers.	Will Comply.
2.28	2	Analyses, inspections, and/or tests shall be performed to ensure that the as-built product is consistent with the as-designed Baseline Configuration.	Will Comply.
2.28	3	Quality assurance provisions, as defined in the Project QA Plan, shall be implemented throughout the ATLO process. Such provisions may include:	Will Comply. Applicable to the extent of JPL ATLO responsibilities.
2.28	3a	- Work proactively in the safety and contamination control activity to ensure hardware integrity.	Note: assure shipping/handling documents include these.
2.28	3b	- Provide configuration support for test and flight software.	-
2.28	3c	- Assure that project documentation requirements are met.	-
2.28	3d	- Conduct a physical verification of all hardware - to ensure that it meets the workmanship, CM and other project requirements.	-
2.28	3e	- Witness Critical operations.	-
2.28	3f	- Maintain spacecraft/instrument configuration log.	-
2.28	3g	- Remain an integral part of the SRCR/HRCR process.	Note: need to assure HRCRs are in Reviews Plan (PIP).
PLES			-
3.3	1	First-time, in-flight events/activities, particularly mission critical or irreversible events shall receive special development attention (e.g., analyzing what ifs, reviewing Red Flag PFRs, unverified failures/ISAs, identifying need for additional testing	Will Comply.

12.0
Implementation Plan

Gerald Lilienthal

Implementation Plan

BDA Structure

- Parallel implementation for CQM hardware
  - If CQM design acceptable (0.12 g^2/Hz TBD) then:
    - Fabricate STM
    - EM modification to accommodate higher loads
    - Test new EM while CQM hardware is on order
  - If a higher level is required (>0.12 g^2/Hz TBD) then:
    - Fabricate STM
    - EM modification to accommodate higher loads
    - Test with higher denier kevlar
    - Negotiate new system resources
    - Fabricate CQM hardware
    - Negotiate schedule and budget revisions

Implementation Plan

BDA Components

- Bolometers – Go ahead with fabrication
- Kapton Cable
  - Complete and test EM2 cable, then fabricate CQM
- Load Resistors and Backshorts – Go ahead with fabrication
- Horns – Go ahead with delivery of photometer horns; await data and then start fab of spectrometer horns
- Packaging process
  - EM BDA to be packaged and tested with EM hardware
  - Process review to take place prior to CQM build

JFET Assemblies

- Complete and test EM JFET membranes for performance
- Begin fabrication of STM and CQM hardware
- Qualify assembly processes on EM modules and EM membranes

RF Filters

- Await tests on the EM JFET modules prior to fabrication

Cables

- Harness definition document is nearly complete
- Routing design of cables has not started at MSSL
- Fabricate and qualify cables at manufacturer prior to drop shipment to RAL – Delivery could be negotiated if there are budget or schedule problems

Testing Program

- Design of test facilities is completed
- Definition of test program completed
  - Qual Plan signed off
  - Test Plan nearly complete
  - Test procedures to be written
- Test Readiness Review scheduled prior to CQM testing

13.0
RFA Summary

Jamie Bock

Responses to 2000 Peer Review

Programmatic and technical comments from last year’s review were presented and responded to at the Confirmation Readiness Review (7/2000) as follows

We collected 36 technical RFAs from the review panel

25 Accepted
11 were taken on an Advisory basis
0 Rejected

We continue to value your input

Programmatic Replies to Peer Review

1. Documentation of requirements, interfaces, deliverables.
Action: Completion of business agreement.

2. Bound scope of technology development.
Action: Current performance levels are adopted as specifications; design values incorporate margin.

3. Better define testing interfaces with European partners.
Action: a. JPL delivers directly to RAL, 3 months later. QMW personnel participate in detector testing at JPL.
b. JPL verifies performance of CEA warm electronics.

4. Better define interface of JFET modules.
Action: JFET enclosure fabricated in Europe, resulting in simple ICD.

5. Tailor schedule and deliverables to match budget profile.
Action: CQM deliverables limited to 2 array assemblies.

6. Workforce limitations.
Action: Increasing workforce, first at MDL.

SPIRE REVIEW BOARD RFAs (1)

#	Description	Disp.	Response
1	Develop understanding of Kevlar stress as a function of temperature and creep as a function of time. (HM)	Accept	Unit was designed based on published contraction and creep data.
2	Negotiate reduction in deliverables from 15 units to 10. (GS)	Accept	Baseline is 2 CQM BDA units, 5 PFM units and 3 new FSM units, refurbished from CQM units.
3	Increase 500 g mass allocation for Bolometer Assemblies to ~600g with mass margin. (GS)	Accept	Done.
4	Assess number of total JFET modules available vs. cost, mitigated against risk of possible failures during integration. (GS)	Accept	Baseline is FSM JFET units are the CQM JFET units.
5	Get hard numbers for limits on required max heat loads at all stages; try to increase power budget for the arrays from 10 microwatts to 20 microwatts. (MD)	Advisory	Impact of additional heat load raises operating temp. Dissipation spec defined as 15 uW pending systems study.

SPIRE REVIEW BOARD RFAs (2)

#	Description	Disp.	Response
6	Is there a well understood definition of time constant? What about the 2-T model applied to spiders? Which definition holds? (MD)	Accept.	Time constant is defined as drop in optical response by 0.7.
7	Is there a spec on the Beam Asymetry and the Width Scatter across the plane? Get these into the agreements. (MD)	Advisory.	Specification on feedhorn beams (BDA-FUN-10, 11 single-mode/multi mode). This is a specification on optics.
8	Get a better definition of final requirements for FPA motion and internal resonances. (MD)	Accept.	Done. Requirement reflected in BDA-TEC-04, BDA-FUN-04
9	Define responsibilities for light leaks into the focal plane. (PR)	Accept.	MSSL is responsible for baffling of 2-K and 4-K boxes.
10	Develop a spec on the RF attenuation of the 2K heat strap penetration.	Accept	Spec to be less than BDA-STR-03.

SPIRE REVIEW BOARD RFAs (3)

#	Description	Disp.	Response
11	Improve the feedhorn efficiency testing by making a cryogenic black body the same diameter as the Lyot Stop. (PR)	Advisory.	We measure total efficiency and beam patterns.
12	Consider use of weak spring in place of PTFE and multiple turns on pulleys in place of glue. (PR)	Advisory.	Determine need based on test of EM unit, but can be accommodated.
13	Investigate the issues of heat dissipation in Kevlar during shake, temperature stability of Kevlar and the issue of fatigue. Utilize quantitative measurements of resonance damping. (PR)	Advisory.	Address kevlar fatigue via vibration tests on prototype unit. Unit has already survived preliminary vibration test.
14	Investigate the issue of focal plane shift during shake; first with full tension, then with reduced tension strands. (PR)	Accept.	Will implement.
15	Design for minimum number of interfaces to reduce effects of uncertainty in boundary resistance. Consider use of distributed one dimensional heat flow single pole filter of a suitable magnetic alloy as used on Benoit refrigerator. (PR)	Accept.	Will reduce number of interfaces. Investigating passive filtering. Will measure temperature gradients in array assembly.

SPIRE REVIEW BOARD RFAs (4)

#	Description	Disp.	Response
16	Establish a more structured approach and document the deliverables (in addition to the hardware) between organizations. (SK)	Accept.	Defined in business agreement.
17	Document the contamination requirements and investigate the suitability of thermal grease for their application. (SK)	Accept.	Any application of grease must be consistent with contamination specifications.
18	Investigate an applicable specification (similar to MIL-461) for EMC/EMI requirements and discuss with SPIRE Instrument Scientist (SK) Make part of BA. (GR)	Accept.	Specifications are listed in sub-systems specification document. Levels are still TBD.
19	Establish and document the qualification plan to address all aspects of performance, test, radiation, manufacturing, process, etc. (SK)	Accept.	All test and assembly procedures will be written and documented prior to CQM testing.
20	Investigate the effects of radiation on the JFETs and document the results to meet environmental requirements. Utilize resident expertise at JPL for radiation effects.	Accept.	We concur.

SPIRE REVIEW BOARD RFAs (5)

#	Description	Disp.	Response
21	Develop a complete qualification plan to verify mission life and radiation performance. (SK)	Accept.	We concur.
22	Consider doing away with corrugations due to their limited efficiency improvement. Determine if multi-mode smooth bands are adequate using HFSS and a larger entrance hole. (GR)	Accept.	We concur.
23	Use electronic parts acceptable for flight to ESA/CEA. Prepare a list of critical parts and negotiate selections. (GR)	Accept.	Readout prototype developed at CIT will use ESA qualifiable parts.
24	Define the whole train and quantify how the alignment of optics contributes to offsets. (GR)	Advisory.	Optical tolerance budget defined in optics SSSD (document #) and optical alignment plan (document #).
25	Conduct a literature search of thermal conductivity of greases and joints. Look at Kittel paper. (MD)	Advisory.	Design needs to minimize effects of interfaces.

SPIRE REVIEW BOARD RFAs (6)

#	Description	Disp.	Response
26	Use Cobalt 60 source to simulate cosmic ray hits and to calibrate time constant of detectors instead of taking photometer to an accelerator. (MD)	Advisory.	We take this under advisement.
27	Investigate the use of stacked washers for the corrugated feeds. Look at Dragone's work at Bell Labs and Paul Goldsmith's book. (MD)	Advisory.	We take this under advisement.
28	Simulate, with HFSS, the use of a choke at the bolometer/horn interface to stop leakage out the sides of the cavity. (MD)	Advisory.	We take this under advisement.
29	Determine if the 25 micron alignment requirement can be reduced, given the pixel size. (RR)	Accept.	Specification reduced to 125 um.
30	Run a launch vibration test with before and after alignment measurements. (RR)	Accept.	We concur. In process.

SPIRE REVIEW BOARD RFAs (7)

#	Description	Disp.	Response
31	Carefully analyze the tension cord design for slipping past the rollers, its damping, heating and alignment performance. (RR)	Accept.	We agree and are conducting vibration tests on prototype.
32	Try to converge quickly on the development of all key requirements needed for important decisions. (RR)	Accept.	Developed in business agreement and sub-system specification.
33	Test Kevlar straps early and often at LN and room temperature. Test to destruction to determine margins. Develop cheap metrology for tests. (PR)	Accept.	We agree and are conducting vibration tests on prototype.
34	Corrugated horns, although enthusiastically endorsed in the UK, are high risk, higher cost, and more difficult to inspect than smooth horns. They are unlikely to approach theoretical performance as closely as smooth horns. Consider their use only where there is a substantial >10% theoretical advantage. (PR)	Accept.	We concur.
35	Establish a spec on the fridge. Determine what your (Delta T)/T temperature attenuation requirement will be. Is the thermal shunt better?	Accept.	Specification on fridge in BDA-HCO 01, 02, and 03. Investigating passive solutions.

SPIRE REVIEW BOARD RFAs (8)

#	Description	Disp.	Response
36	Fabricate test blocks of horns with both corrugated and smooth feeds to save time. (MD)	Advisory.	Prototyping of horns will be completed before CQM delivery.
37			
38			
39			
40			

14.0 Summary/Objectives

Gerald Lilienthal

Charter

- Evaluate the readiness of the SPIRE Detector Subsystem to proceed into CQM fabrication, assembly and test
  - Previous concerns and deficiencies considered and resolved
  - Requirements flowdown from instrument
    - Requirements traceability and compliance matrix
    - Documentation of requirements and interfaces
  - Detailed design is adequate stable and well documented
    - Detailed design responds to requirements
    - Tradeoffs understood
    - Demonstration of technology
    - Configuration control
    - Implementation documentation is adequate (AIDS, Process Sheets, Travellers)
    - Manufacturing process design
    - GSE design and certification of test equipment
    - Integration and test plans
    - Reliability analysis and qualification plans
    - Delivery, handling and shipping plans
  - Product assurance plans are adequate
  - Risks understood and plans exist for managing them

Success Criteria

- Designs and processes meet requirements and are sufficiently defined and documented to proceed with development within the risk policy of the project
- Plans for resolving remaining problems are consistent with available resources and risk policy
- Test approach and test product status is thorough and acceptable with verifying compliance with the requirements
- Technology has been demonstrated by test and correlated to the analyses

Recommendations

- All interfaces should be frozen by September, 2001 (ICD's should be signed off)
- Vibration levels for the BDAs should be set to the BDA capability or the instrument must accept the risk
- Comment on the benefit of coordination between IPAC and the SPIRE instrument team
- Comment on potential descopes to our program if they are necessary