TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

8 May 96

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

INTRODUCTION

Scope of Review

Action Item Status

Agenda

SCOPE OF REVIEW

CRITICAL DESIGN REVIEW (CDR) OF TELESCOPE READ-OUT

- **TRE Detector**
  - Electrical Design
    - Photo-diode sensor
    - Pre-amplifier
  - Packaging
    - Thermal Mount
    - Detector Package
- **TRE Forward Electronics**
  - Electrical Design
    - Charge-Locked Loop
    - Detector Support Functions
  - Cables
  - Interfaces
  - Enclosure

ACTION ITEM STATUS

TRE PDR: 35 Items

11 Closed
13 Recommend Closure

OPEN ITEMS (11 total):

1 Specification Items Still In Work
22) Scrub Total Weight In Front-End

2 Test Program Items Still In Work
19) Schedule EMI Test Milestones For Electronics Boxes
31) Define Test Chamber And Joint TRE/Telescope Test Plan

3 Simulation/Modeling Items
8) How Well Can We Calibrate Scale Factor On-Orbit With Rate Gyros
17) TRE Implications For Data Reduction
26) Generate A Detailed Error Analysis Of How Scale Factor, Bias, etc. Get To ATC System.

1 Thermal Item 14) Have Thermal Working Group Look At Probe Wires

4 System Engineering Items (# 18, 30, 32, 34)
Will be addressed by Stanford Systems Engineering

TRE IDR: 18 Items

7 Recommend Closure (#1, 4, 5, 7, 8, 10, 17)

OPEN ITEMS STILL IN WORK (11 total):

3 Specification Items Still In Work
2) Add Max. Field Of View Spec (Exclude HR5110 Companion)
3) PCB Change T002 And T003 Linearity - "Stable And Calibratable"
16) Estimate Thermal Gradient Values

3 Test Program Items Still In Work
13) Collect JFET Noise down to 0.1 Hz
15) Scheduling Tests To Verify Charge Trapping, etc.
18) Test Plan For Telescope System Tests

2 Simulation/Modeling Items
6) System model for Pointing Control Sim.
14) Det. Noise characteristics to be put into models

3 Miscellaneous
11) How to match Feedback Capacitors?
12) FET Guard ring?
9*) System Engineering Item (RF Interference From SE Asia)
(Will be addressed by SU Systems Engineering)

AGENDA

8:30	Introduction	
8:40	Functional Overview and Performance Issues	P. Ehrensberger
10:00	Detector Electrical Design	J. Goebel
10:50	Detector Mount Design	M. Sullivan
11:10	Detector QA and Parts Selection	F. Berkowitz
11:20	Detector to Telescope Integration	S. Wang
11:30	TRE Forward Electronics Design	R. Farley
12:15	Lunch	
12:45	Forward Electronics Enclosure	R. Ajitomi
1:00	TRE Manufacturing and Test Flow	G. Swart
1:10	Forward electronics QA and Parts Selection	G. Swart
1:20	Verification Plan and Test Matrix	Mark Tapley
1:40	Schedule	J. Burns
1:50	Development Tests	H. Demroff
2:05	Error Budget and Predicted Performance	K. Coleman
2:20	Wrap-up	P. Ehrensberger

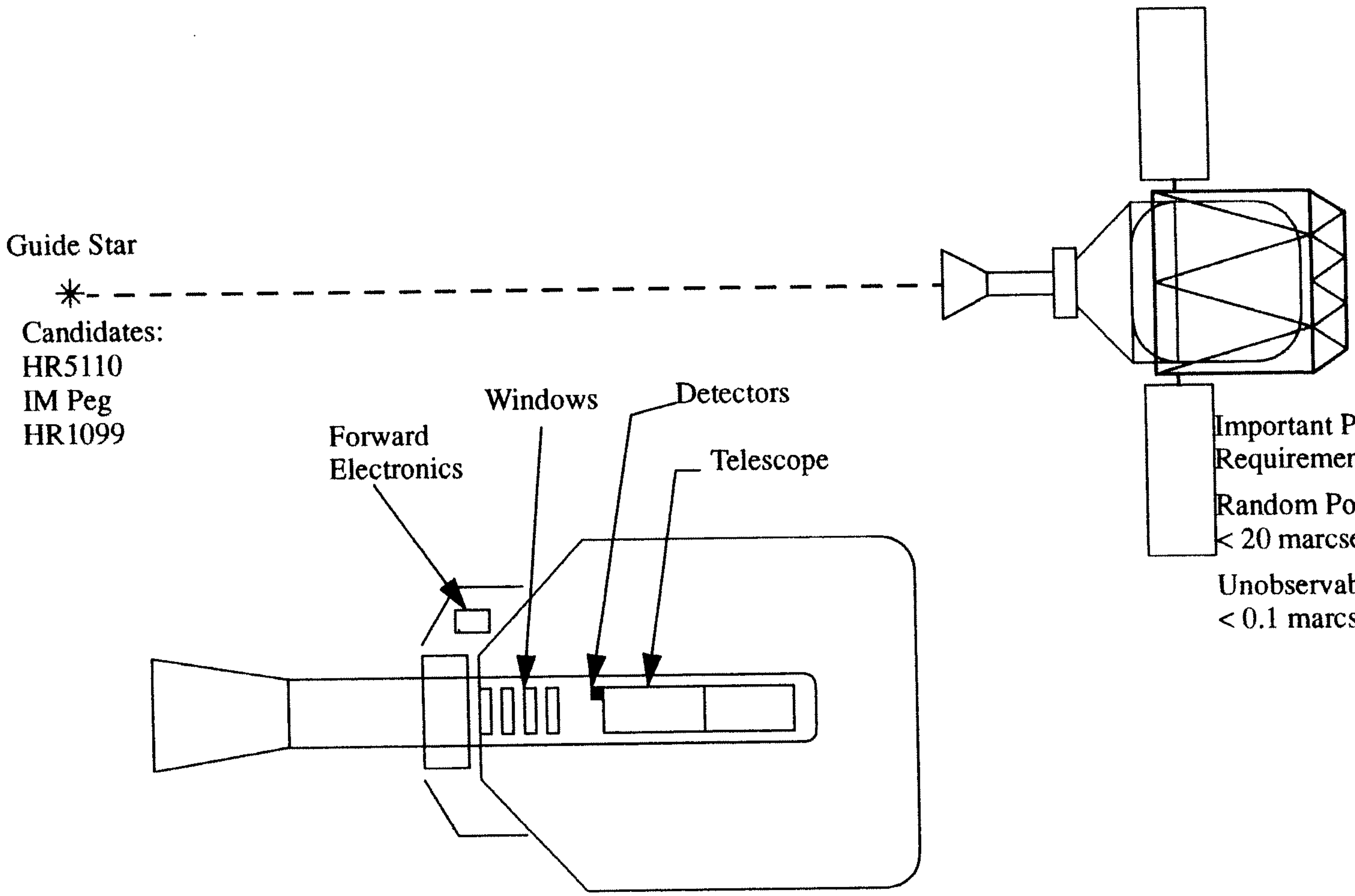
TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

TRE FUNCTIONAL OVERVIEW
AND
PERFORMANCE ISSUES

P. EHRENSBERGER

Specifications/Requirements
Detectors
Interface Between Detector and Fwd Electronics
Forward Electronics
Data Acquisition
Command, Telemetry, and Software
ATC Interface
Science Data Interface

GP-B SCIENCE TELESCOPE



Important Performance Requirements:

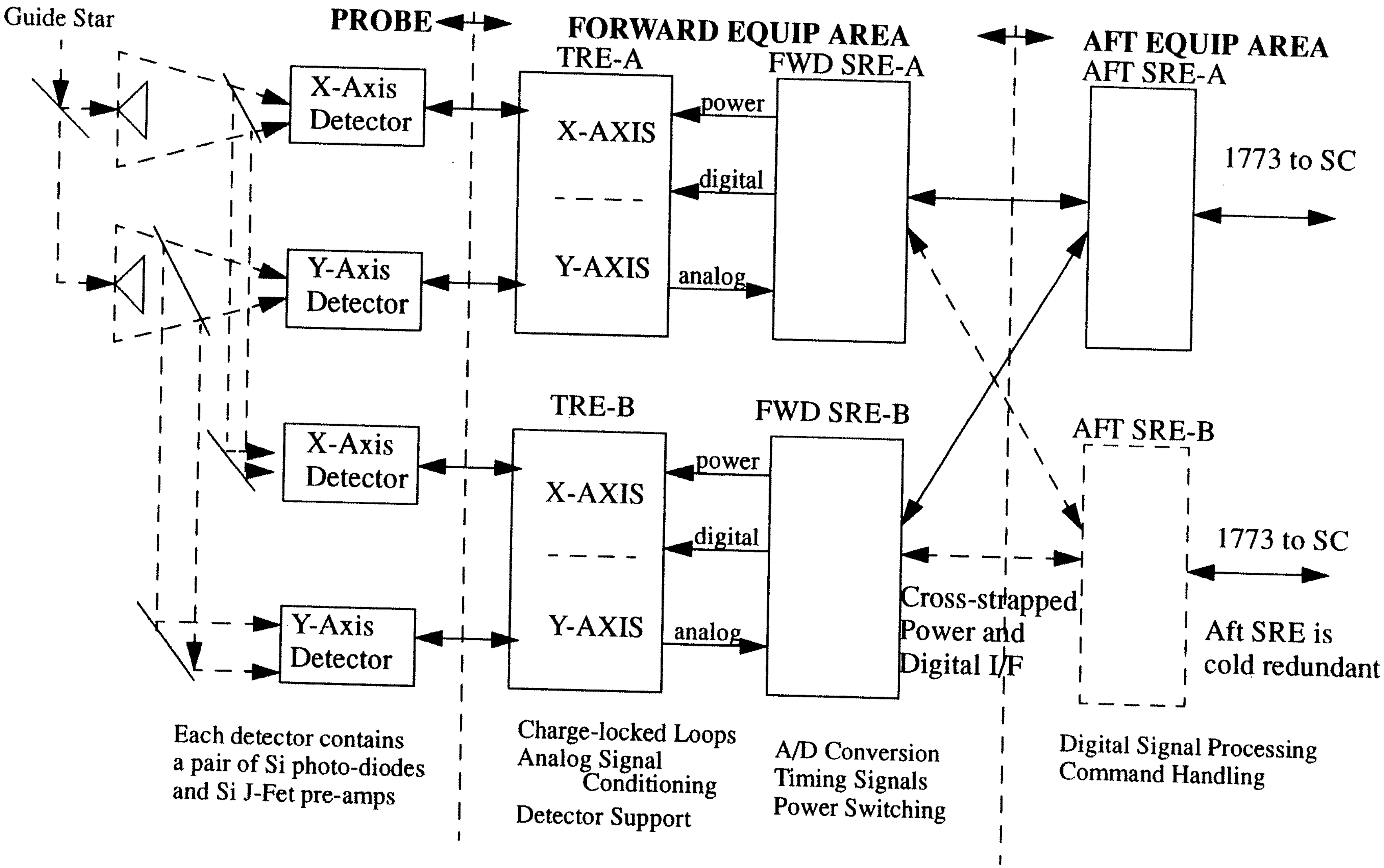
Random Pointing
< 20 marcsec RMS

Unobservable Pointing Bias
< 0.1 marcsec

SCIENCE TELESCOPE PROVIDES:

- POINTING REFERENCE FOR SPACECRAFT
- POINTING DATA FOR SCIENCE

OVERVIEW OF TELESCOPE READ-OUT ELECTRONICS



Each detector contains
a pair of Si photo-diodes
and Si J-Fet pre-amps

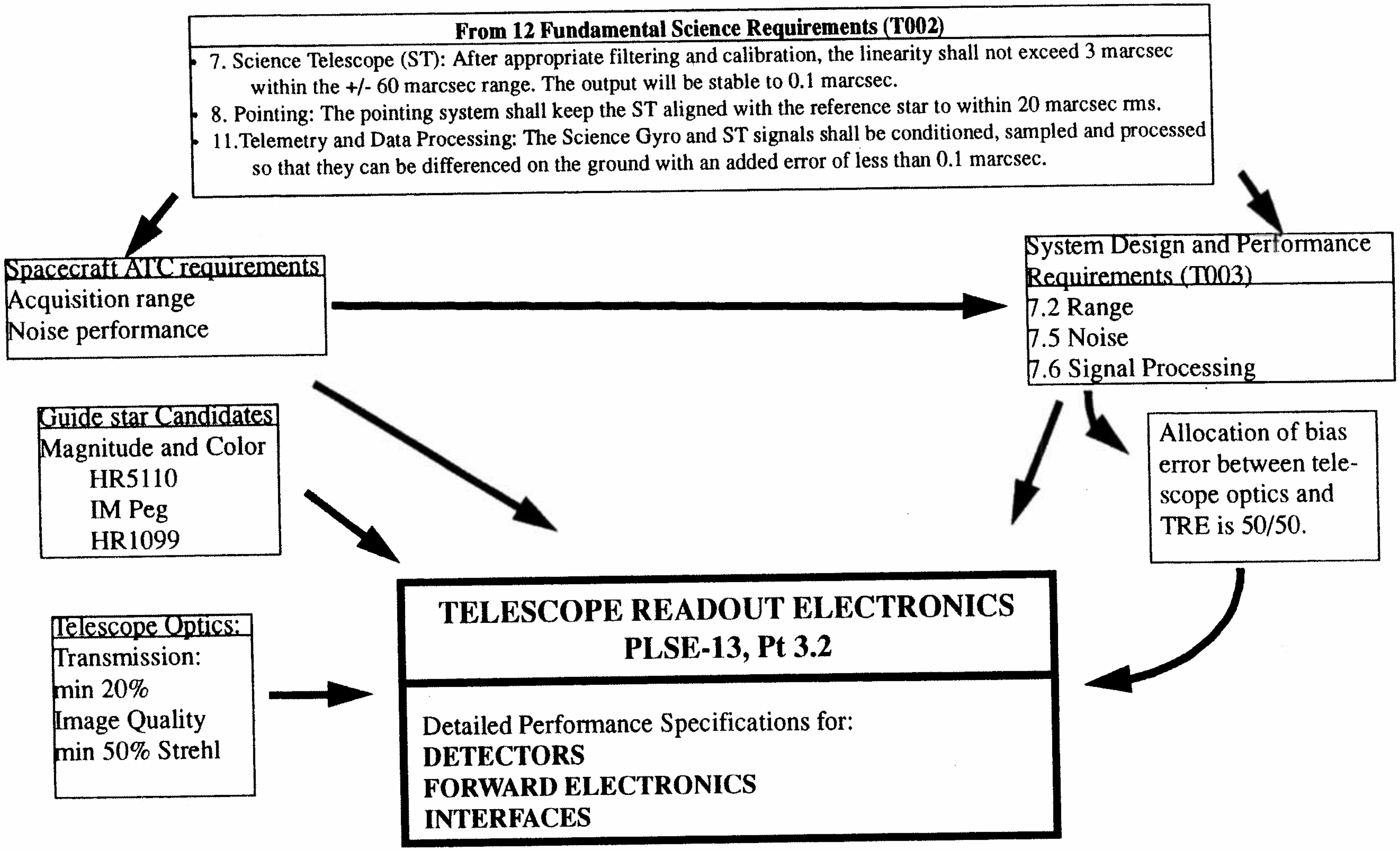
Charge-locked Loops
Analog Signal
Conditioning
Detector Support

A/D Conversion
Timing Signals
Power Switching

Digital Signal Processing
Command Handling

PRIMARY AND REDUNDANT TRE'S ARE OPERATED CONTINUOUSLY

FLOW DOWN FOR TRE SPECIFICATION



From 12 Fundamental Science Requirements (T002)

- 7. Science Telescope (ST): After appropriate filtering and calibration, the linearity shall not exceed 3 marcsec within the +/- 60 marcsec range. The output will be stable to 0.1 marcsec.
- 8. Pointing: The pointing system shall keep the ST aligned with the reference star to within 20 marcsec rms.
- 11. Telemetry and Data Processing: The Science Gyro and ST signals shall be conditioned, sampled and processed so that they can be differenced on the ground with an added error of less than 0.1 marcsec.

Spacecraft ATC requirements

Acquisition range
Noise performance

System Design and Performance Requirements (T003)

7.2 Range
7.5 Noise
7.6 Signal Processing

Guide star Candidates

Magnitude and Color
HR5110
IM Peg
HR1099

Allocation of bias error between telescope optics and TRE is 50/50.

Telescope Optics:

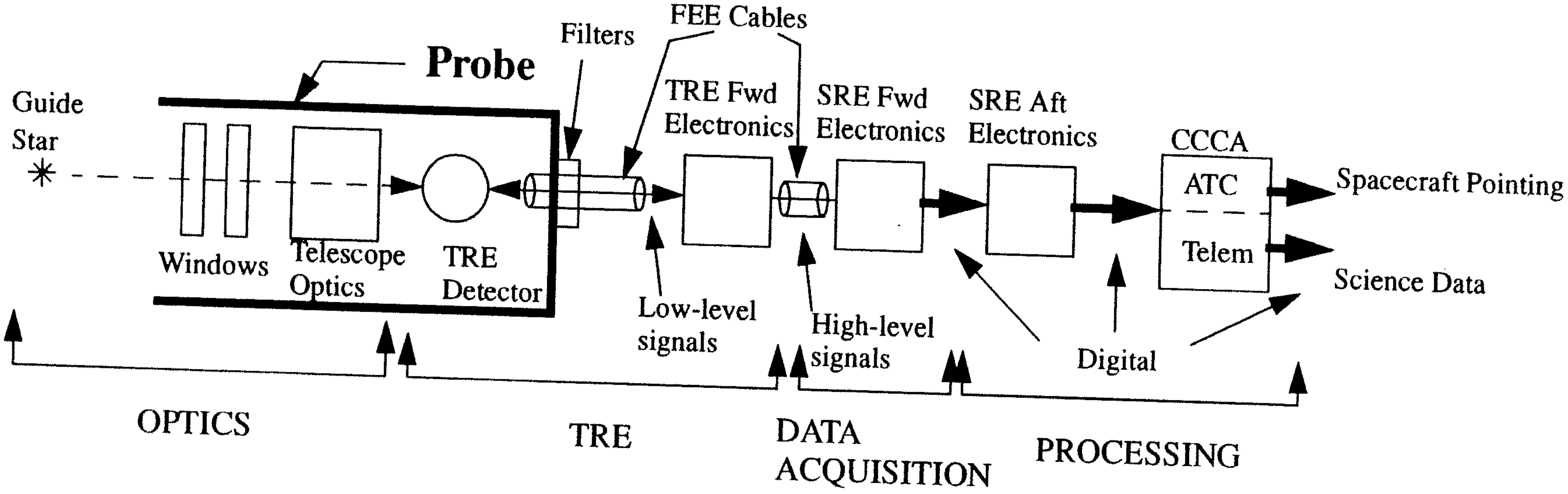
Transmission:
min 20%
Image Quality
min 50% Strehl

TELESCOPE READOUT ELECTRONICS
PLSE-13, Pt 3.2

Detailed Performance Specifications for:
DETECTORS
FORWARD ELECTRONICS
INTERFACES

TRE Specification is derived from worst case assumptions:
Guide Star - HR1099; Optics Transmission - 20%; and Strehl - 50%.

ELEMENTS OF TELESCOPE PERFORMANCE



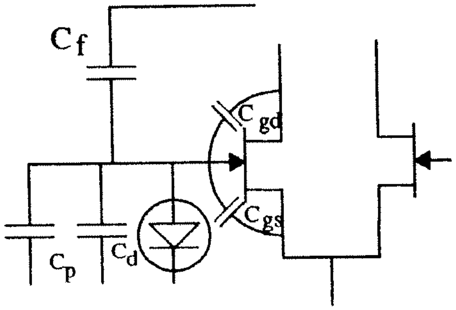
TRE SPECIFICATION STATUS

- Held Spec Sign-off Meeting: Most specs in data base
    - PCB 227: Change leakage current specs in probe cables.
    - PCB 234: TRE spec update (includes ATC interface specs, and other previously unsigned pages).
    - PCB 231: Change Probe TRE pin-outs.
    - PCB 233: Add capability to switch between primary and redundant channels for SC pointing.
- Software for Science Data and ATC are covered in SE-15 and -16
- Data Acquisition and SRE interface is covered in TRE Specification.
- Filters covered in Filter Specification (#5833851)
- FEE Cables in separate FEE Cable Specification
- Probe Cables are covered in SIA Specification

The most difficult performance specifications are random noise and bias stability.

TRE RANDOM NOISE

Requirement: < 10 marcsec/rtHz single-sided (Goal is to achieve photon-limit)
Influence on SC random-pointing error - especially important for back-up Mode.



Noise is dominated by first stage of detector preamp.

Important elements for noise:

- detector capacitance - driven by size to accommodate alignment and acquisition range
- transistor capacitance
- parasitic capacitance
- transistor input-referred voltage noise

Demonstrated performance to date (based on 10 second acquisition time):
Standard deviation of 100 mS estimates is 26 marcsec => **8.2 marcsec/rtHz** average over DC to 5 Hz.

For reference photon noise implies:
Standard deviation of estimates 7.9 marcsec => **2.48 marcsec/rtHz**

REQUIREMENT WILL BE MET

Development continues to achieve the photon-limit goal.

TRE Bias Stability

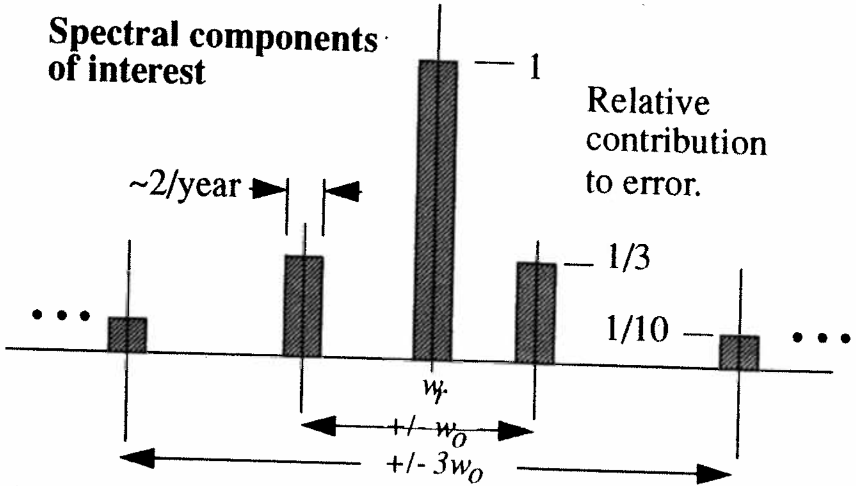
T003 Requirement 7.6.2.1:

$$\frac{1}{T_a}\int_{GV} z(t)\,\frac{t}{T_a}\begin{bmatrix}\cos(w_r t)\\ \sin(w_r t)\end{bmatrix} d(t) < 0.1 \text{ marcsec}$$

Modified by 50% allocation and change to absolute stability rather than "change over year"

TRE Requirement:

$$\frac{1}{T_a}\int_{GV} z(t)\begin{bmatrix}\cos(w_r t)\\ \sin(w_r t)\end{bmatrix} d(t) < 0.05 \text{ marcsec}$$


Spectral components of interest

w_r is roll (1 to 10 min period), SQUID Calibration, or dither(20 sec to 45 min period).
w_o is orbital frequency and T_a is annual period.

Error contributions dominated by temperature changes. This then bounds the temperature coefficients of the TRE.

Additional requirements (T003 7.6.2.2 and.3) bound the bias errors at w_r modulated by annual and orbital frequencies. These are easily meet by requiring that the temperature coefficients never exceed the values required to meet the previous requirements over the temperature ranges at orbital and annual.

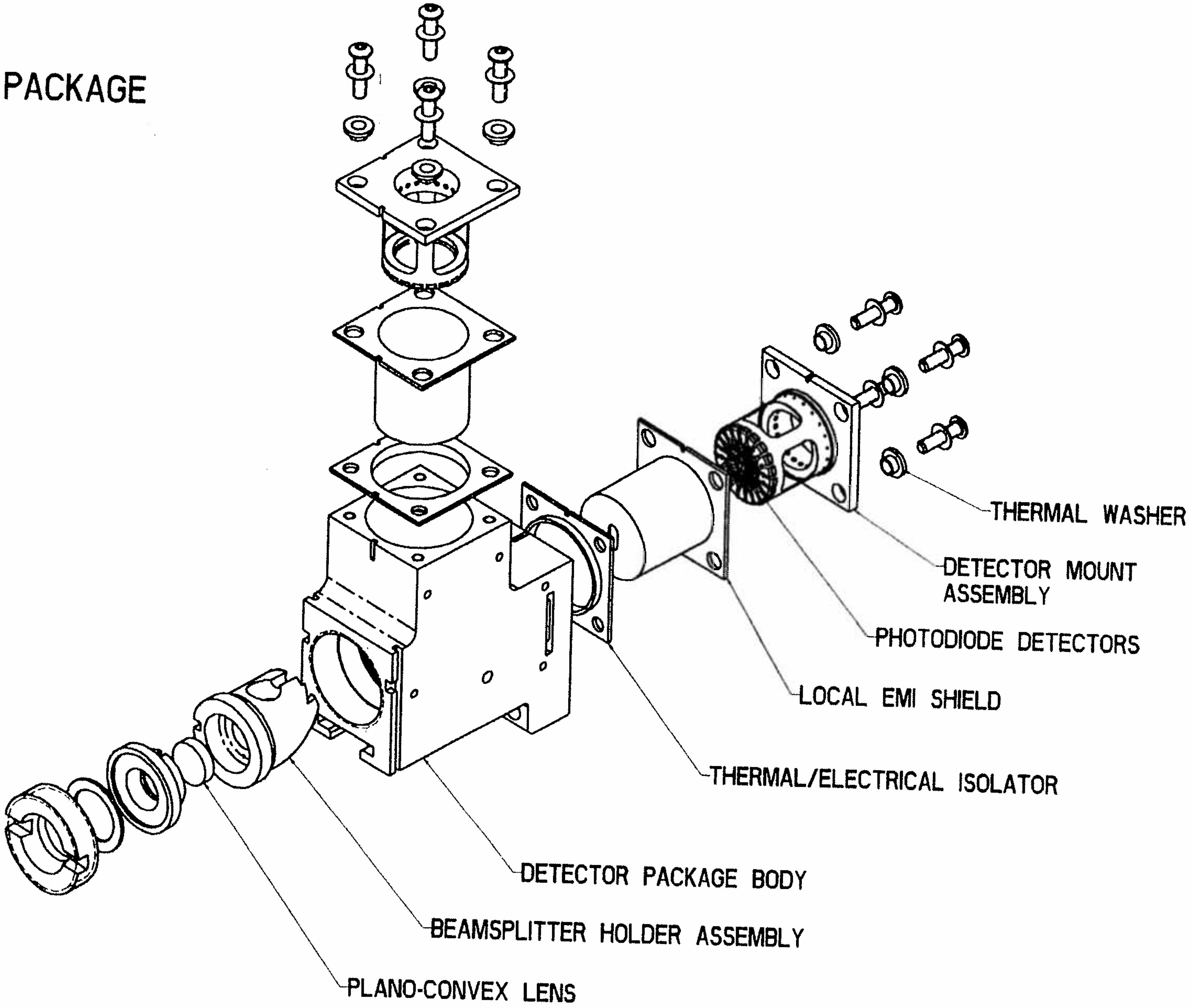
TRE TEMPERATURE COEFFICIENTS WILL MEET THIS REQUIREMENT

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

TRE DETECTORS

Design Overview
Photo-diodes and Alignment
Optical Signal Level
Ionizing Radiation
Thermal Interface to SIA

TELESCOPE DETECTOR PACKAGE ASSEMBLY



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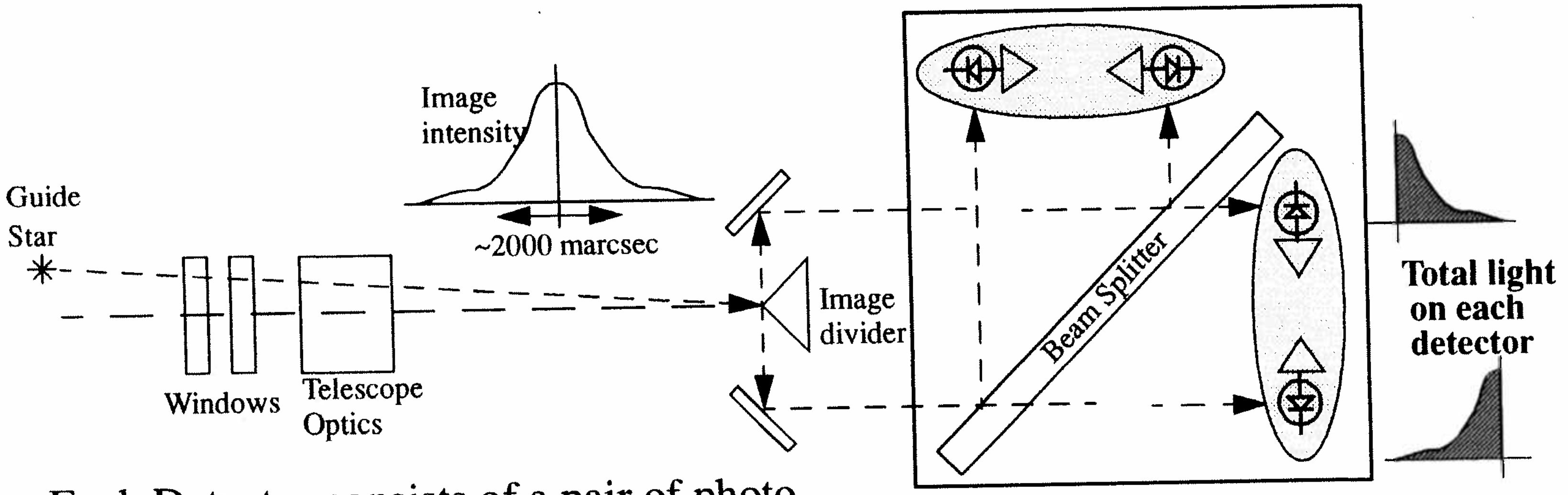
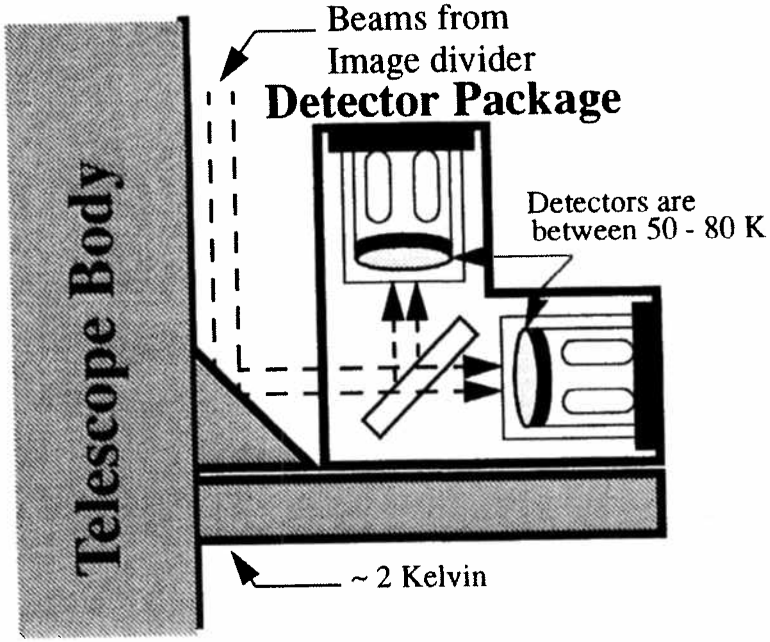
DESIGN OVERVIEW



- Each Detector consists of a pair of photo-diodes and pre-amps (a "bi-cell" for one axis)
- Each Detector Package includes a primary and redundant detector.
- Full complement is two detector packages
- Thermal mount provides standoff between 2 K ambient and 50-80 K detector.

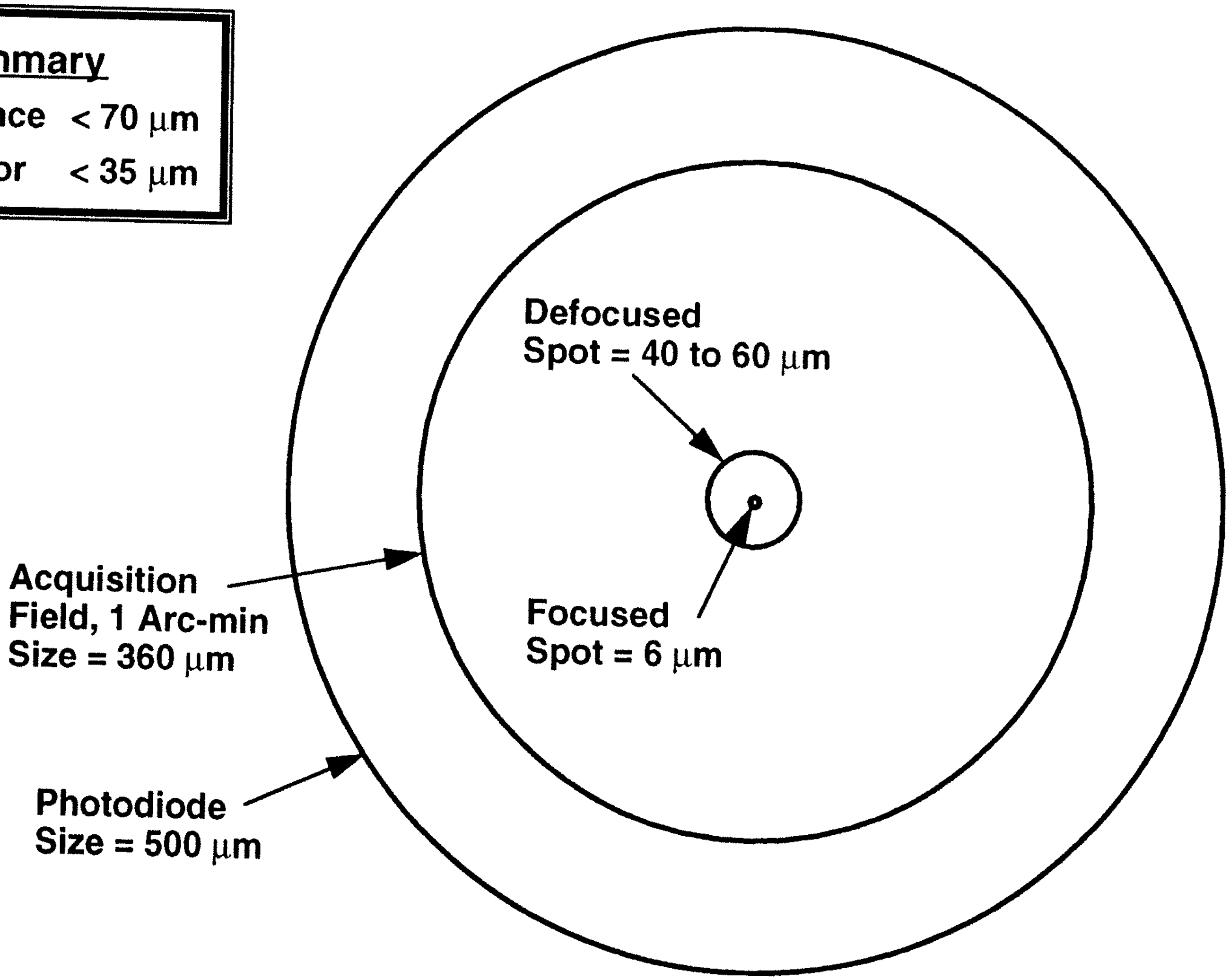
This design minimizes thermal differentials that lead to bias variation



Photodiode Image Location And Alignment Tolerance

Alignment Error Summary

Total alignment error tolerance	< 70 μm
Expected rms alignment error	< 35 μm



Defocused Spot = 40 to 60 μm

Acquisition Field, 1 Arc-min Size = 360 μm

Focused Spot = 6 μm

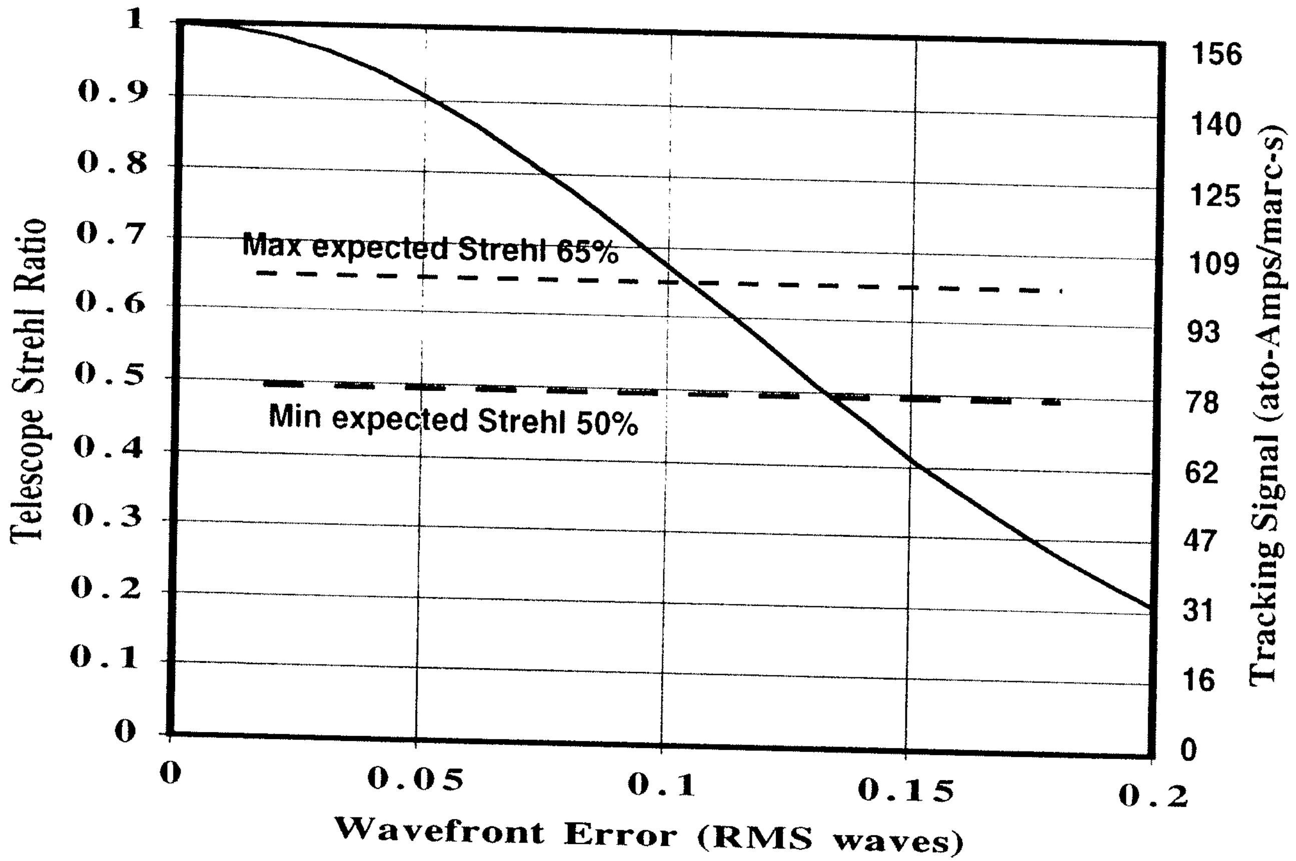
Photodiode Size = 500 μm

Telescope Through-Put & Tracking Performance Estimate

Parameter / Guide Star Name	HR 5110	HR 1099	IM Peg
Ecliptic Latitude (deg)	43.00	-18.30	22.10
Star Temperature (K)	6700	4490	4500
Companion Temperature (K)	4800	5733	0
Visual Magnitude	4.98	5.71	5.64
Star/Companion Flux Density Ratio	0.233	0.396	0
Incident Photons/sec (400 nm to 1000 nm)	6,834,710	4,289,492	4,841,490
Detected Photo-electrons for 1 Itek Window	4,865,493	3,080,146	3,481,800
Detected Photo-electrons for 2 Itek Windows	4,326,539	2,738,879	3,095,362
Telescope High Transmission Efficiency (%)	53.36	53.36	53.36
Telescope Low Transmission Efficiency (%)	21.63	21.63	21.63
High Single Detector Signal (fA)	**51.92**	**32.87**	**37.16**
Low Single Detector Signal (fA)	**18.72**	**11.85**	**13.39**
Telescope High Strehl Ratio	0.65	0.65	0.65
Telescope Low Strehl Ratio	0.5	0.5	0.5
High Tracking Signal (aA/marc-s)	**101.25**	**64.10**	**72.46**
Low Tracking Signal (aA/marc-s)	**28.07**	**17.77**	**20.08**

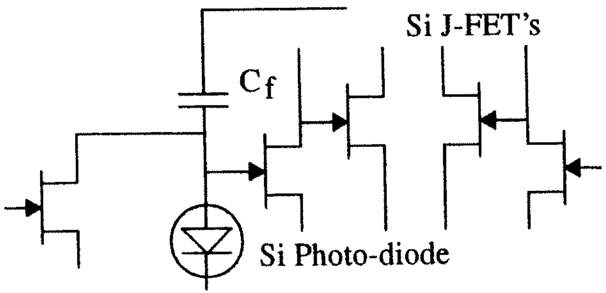
- **Thermal spectrum used for guide star and companion.**
- **Star data obtained from Lange, GP-B TR S0225, 2-4-'94.**
- **Multi-spectral star image used to calculate detector and tracking signal.**

Telescope Wavefront Quality Effect on Tracking Signal



- Wavefront errors degrade telescope Strehl ratio and tracking signal together.
- Change shape of focused spot but detector signal unchanged.

DETECTOR RESPONSE TO IONIZING RADIATION



Sensitive Elements:

- Photo-diode
- Feedback Capacitor
- Transistors

TRANSIENT EFFECTS

Short-term transients (i.e. "cosmic-ray hits") can blind telescope.

"Hit-rate" is less than 10 per hour (per photo-diode) outside SAA.

Software "sanity check" will detect and veto events.

Resets effectively limit persistence of transient on subsequent measurements.

Guide-star Invalid mode will be used during SAA transit.

Long-term relaxation effects (from passing through SAA or magnetic poles) could cause bias variation.

Expected to be small. Will not to occur at sensitive frequencies.

INTEGRAL EFFECTS

Total dose is low. No problem wrt device damage.

"Charge-trapping" not expected to be a problem.

INTEGRAL AND TRANSIENT EFFECTS WILL BE CONFIRMED IN RADIATION TEST PROGRAM

VERY-LOW ENERGY SCATTERED RADIATION

Bias error from very-low energy scattered radiation is possible. Judged very unlikely.

Analysis must be made to confirm.

SAA Effects on Telescope Detectors - I

STANFORD
Lockheed

- **Overview of SAA Effects on Telescope Detectors**
  - GP-B will pass through SAA several times every 12 hours; Maximum duration in SAA ~16 min
  - Minimum shielding at location of Telescope Detectors is 5.7 g/cm^2
  - Proton flux at Telescope Detectors during SAA passage will be approximately 10^3 / cm^2 / s
  - Latchup is not a problem: no structures susceptible to latchup are used
  - Because of their large area, the Detector Diodes dominate the Telescope Detector response to the SAA
  - Total Detector Diode area is 40 x 10^{-3} cm^2: Therefore, the estimated hit rate on the Telescoope Detector Diodes in the SAA is 40 / s
  - We must assume that the Science Telescope will be effectively blind in the SAA
- **Resulting Effect on ATC System:**
  - Not a problem: Use Guide Star Invalid pointing mode
  - Proton Detector data, sanity checks on Telescope data, and Ephemeris data are used to know when to disregard the Telescope data
- **Resulting Effect on Science Data:**
  - Not a problem: 95% of the total Science Data which would be available were it not for the SAA will still be available despite the SAA
  - Proton Detector data, sanity checks on Telescope data, and Ephemeris data are used to know when to disregard the Telescope data

THERMAL INTERFACE BETWEEN SIA AND TRE DETECTOR

- **Detector power dissipation**
  1 mW max per detector (4 mW total)
    0.75 mW allocated to circuit and 0.25 mW to heater
- **SIA Temperatures**
  QBS temperatures: QBS fingers 2.45 K; Spider 2.49 K
    Meets requirement.
- **Temperature Stability**
  The mount base temp bounded to 3.5 mK peak to peak @ roll via static analysis.
    Detector electronics temp change at least 20 times less (< 0.2 mK).
    Error budget performed using 2mK variation.

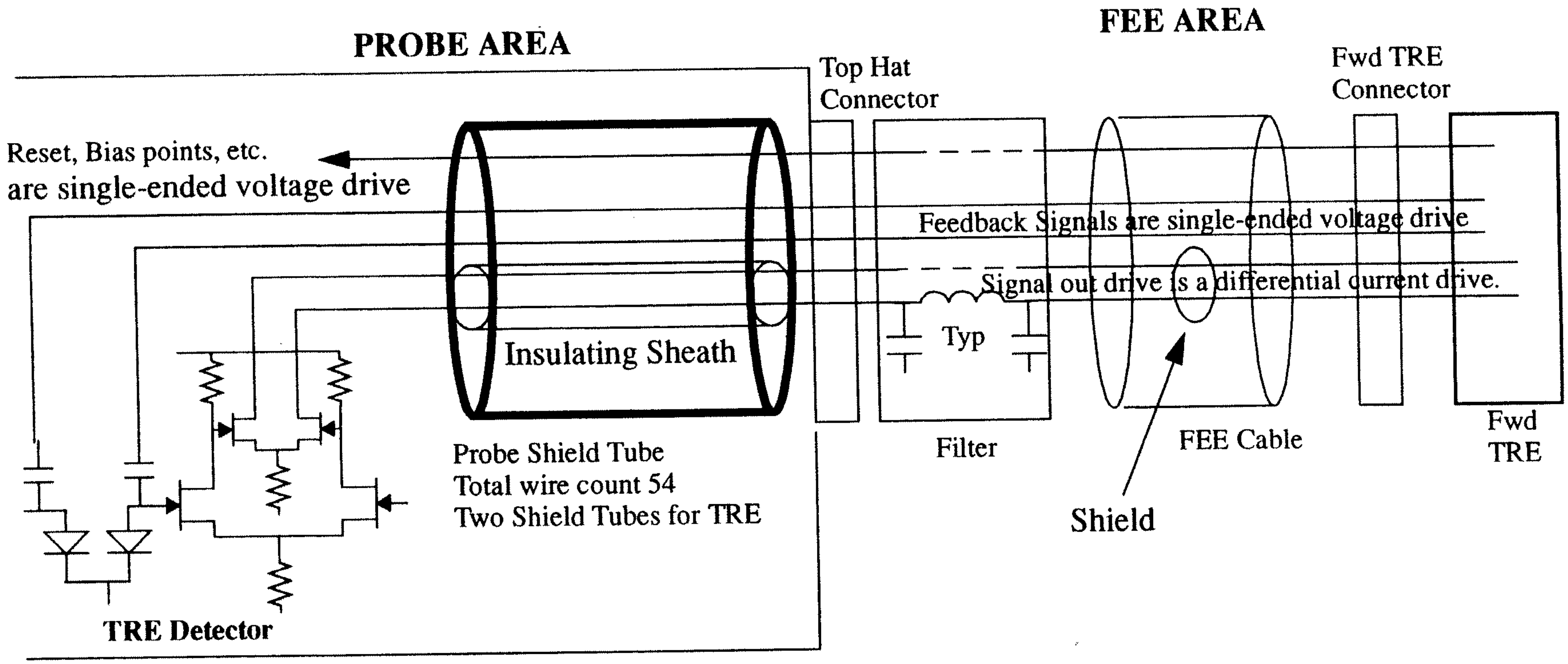
BASE-LINE IS TO USE OPEN-LOOP TEMP CONTROL OF DETECTOR
CLOSED-LOOP OPTION IS AVAILABLE.

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

INTERFACE BETWEEN
DETECTOR AND FWD ELECTRONICS

Signal Transmission Methods
Signal Levels

ELECTRICAL INTERFACE BETWEEN DETECTOR AND FORWARD ELECTRONICS



PROBE AREA

FEE AREA

Reset, Bias points, etc.
are single-ended voltage drive

Top Hat
Connector

Fwd TRE
Connector

Feedback Signals are single-ended voltage drive

Signal out drive is a differential current drive.

Insulating Sheath

Typ

Probe Shield Tube
Total wire count 54
Two Shield Tubes for TRE

Filter

FEE Cable

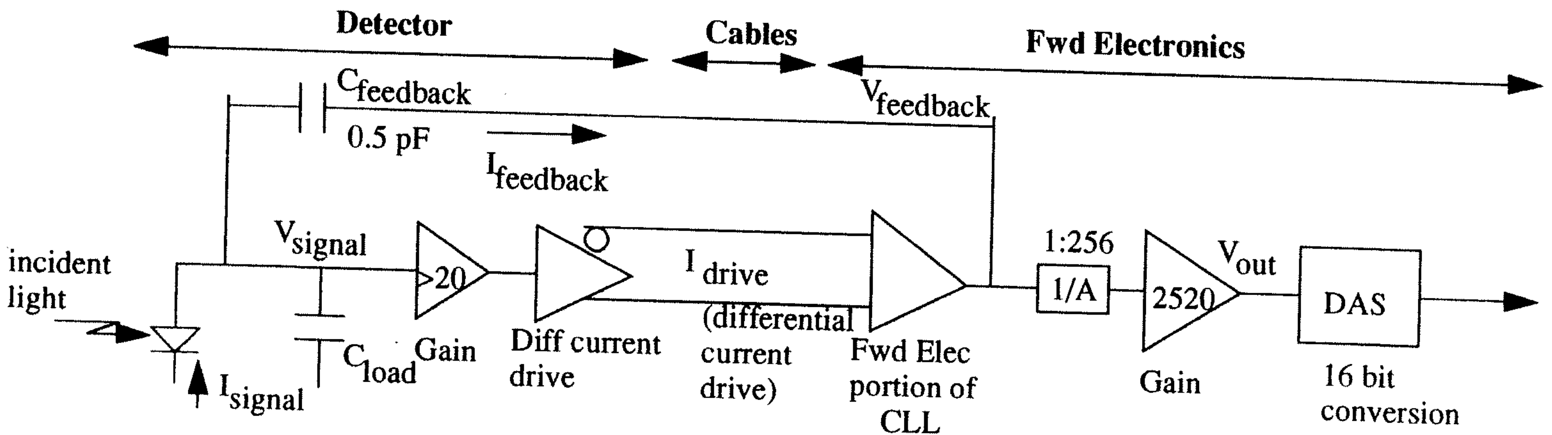
Fwd
TRE

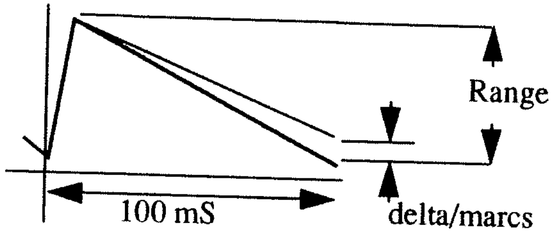
Shield

TRE Detector

Interface design controls contributors to bias error (e.g. leakage currents, filter attenuation, thermocouples, etc.) to acceptable levels.

TELESCOPE READ-OUT SIGNAL LEVELS





I_{signal}	Min	Max
total	75k e/s	325k e/s
per marcs	110 e/s	631 e/s

$V_{feedback}$	Min	Max
Range	2.4e-3 V	10.4e-3 V
delta/marcs	3.5e-6 V	20e-6 V

V_{signal}	Min*	Max*
Range	60e-6 V	867e-6 V
delta/marcs	90e-9 V	1.7e-6 V

I_{drive}	Min*	Max*
Range	150e-9 A	2.2e-6 A
delta/marcs	230e-12 A	4.4e-9 A

V_{out}	Min	Max
Range	6 V / 20 K bits	18 V / 60 K bits
delta/marcs	9e-3 V / 29 bits	35e-3 V / 113 bits

* Open-loop equivalents

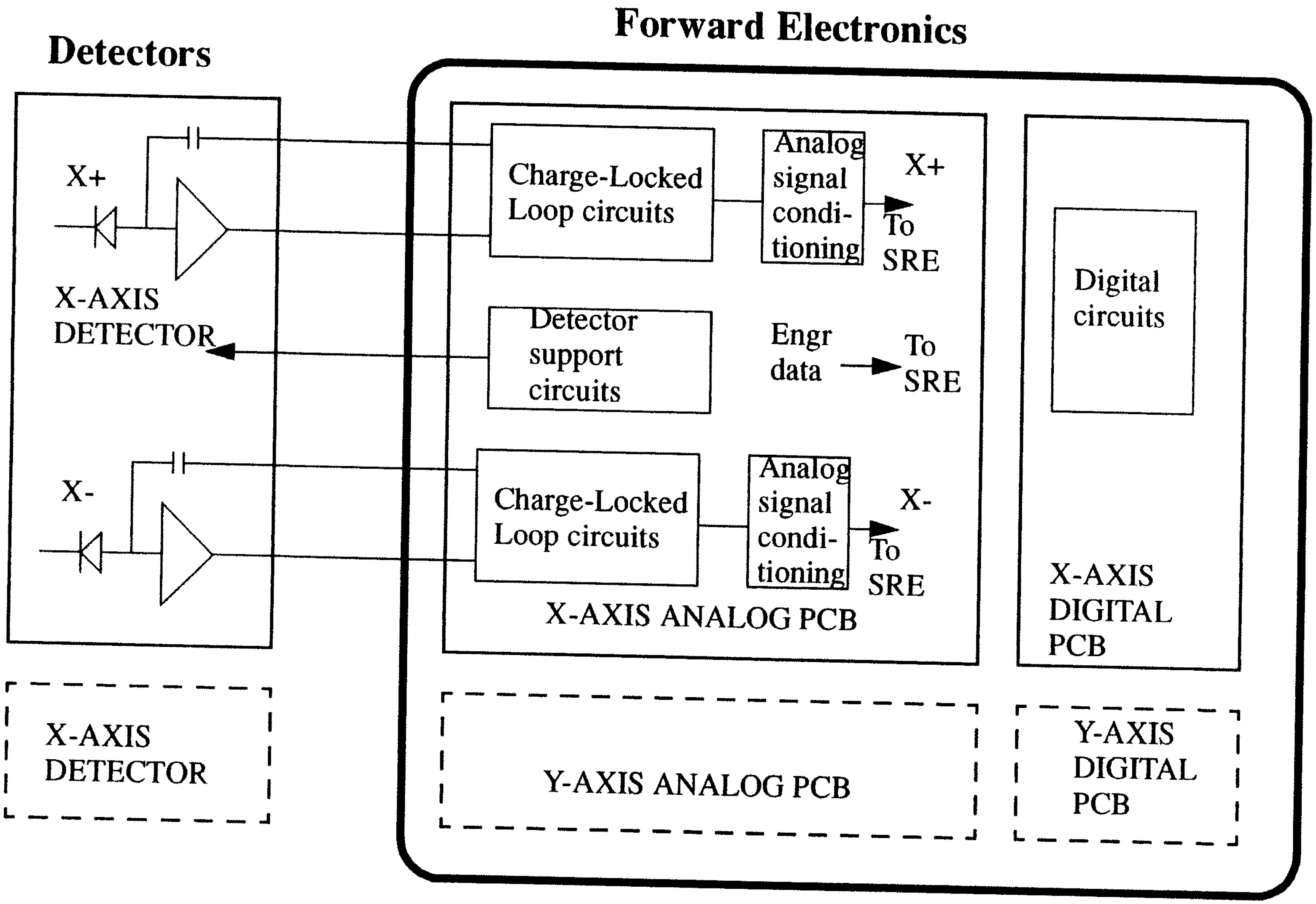
Each estimate is made by using ~200 samples. Min values based on 20% transmission, 50% strehl, and HR1099. Max signals based on 50% transmission, 65% strehl, and HR5110.

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

TRE FWD ELECTRONICS

Partition
Grounding and Shielding
Power Distribution

TRE PARTITIONING



Detectors

Forward Electronics

X+

X-AXIS DETECTOR

X-

Charge-Locked Loop circuits

Analog signal conditioning

X+ To SRE

Detector support circuits

Engr data

To SRE

Charge-Locked Loop circuits

Analog signal conditioning

X- To SRE

X-AXIS ANALOG PCB

Digital circuits

X-AXIS DIGITAL PCB

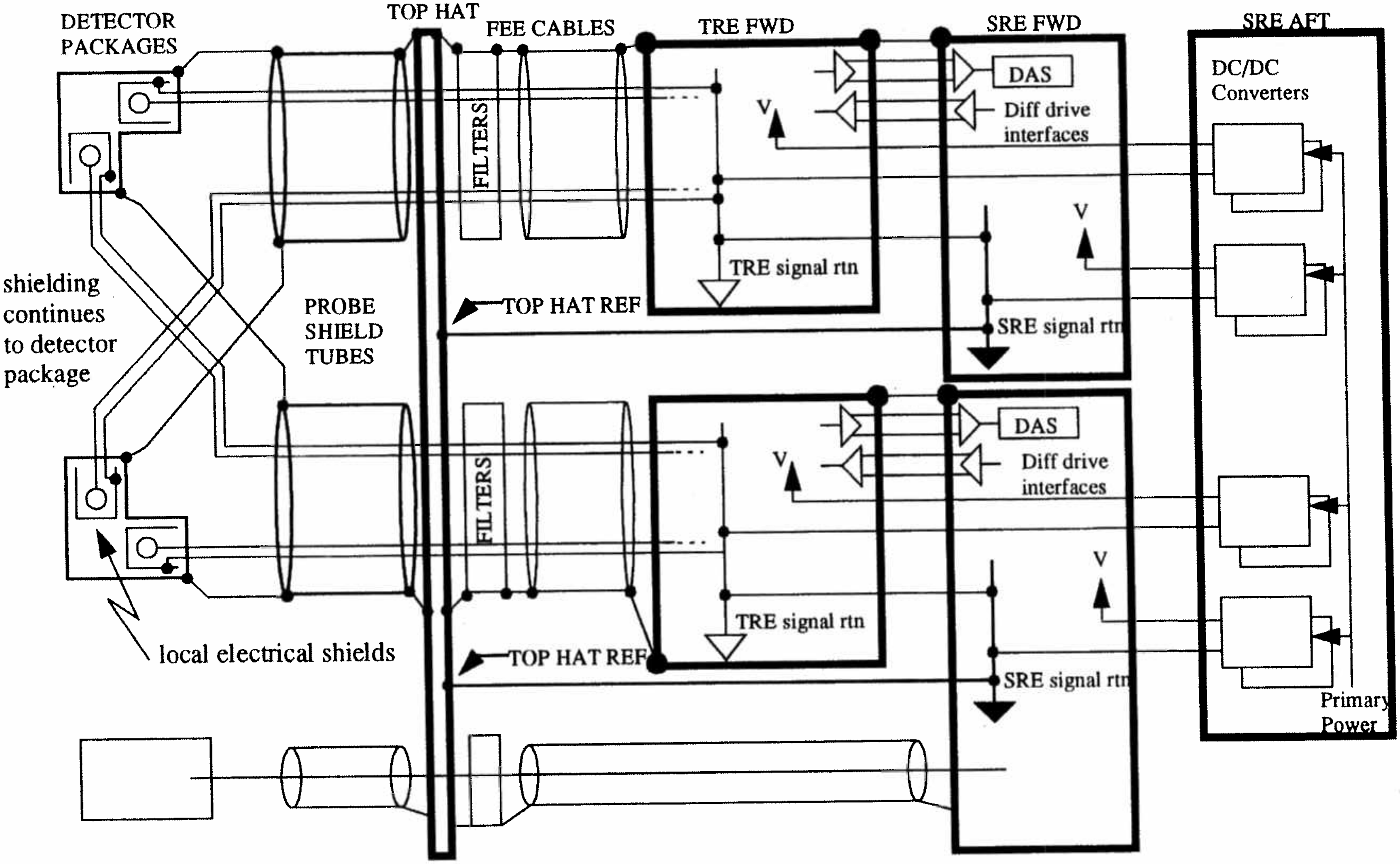
X-AXIS DETECTOR

Y-AXIS ANALOG PCB

Y-AXIS DIGITAL PCB

FORWARD TRE CONSISTS OF 4 CIRCUIT BOARD (TWO DESIGNS)

TRE GROUNDING AND SHIELDING



Grounding Scheme follows "good-practice" rules and allows use of shared Data Acquisition System in SRE

SRE/TRE POWER DISTRIBUTION BLOCK DIAGRAM

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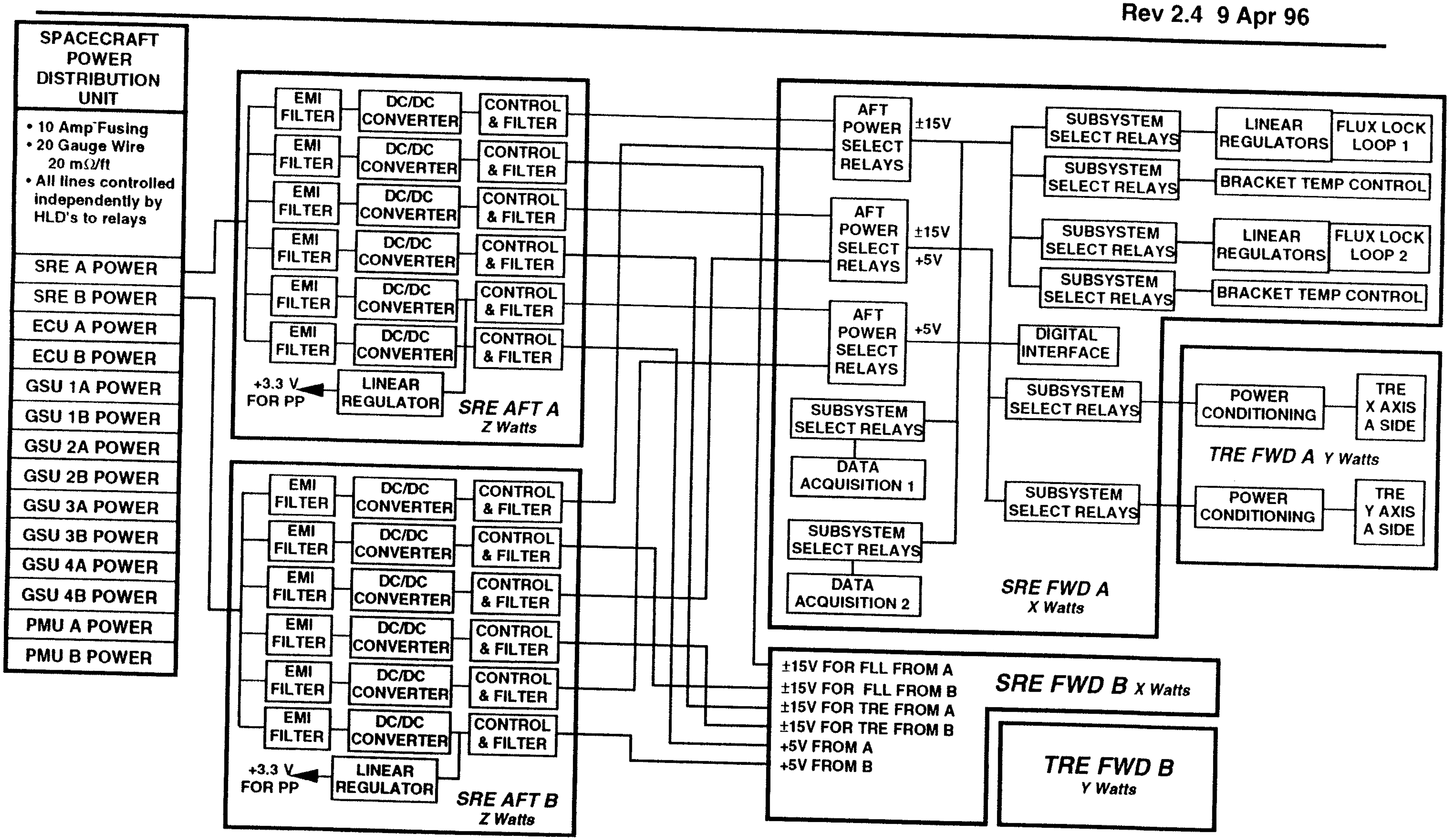
Rev 2.4 9 Apr 96



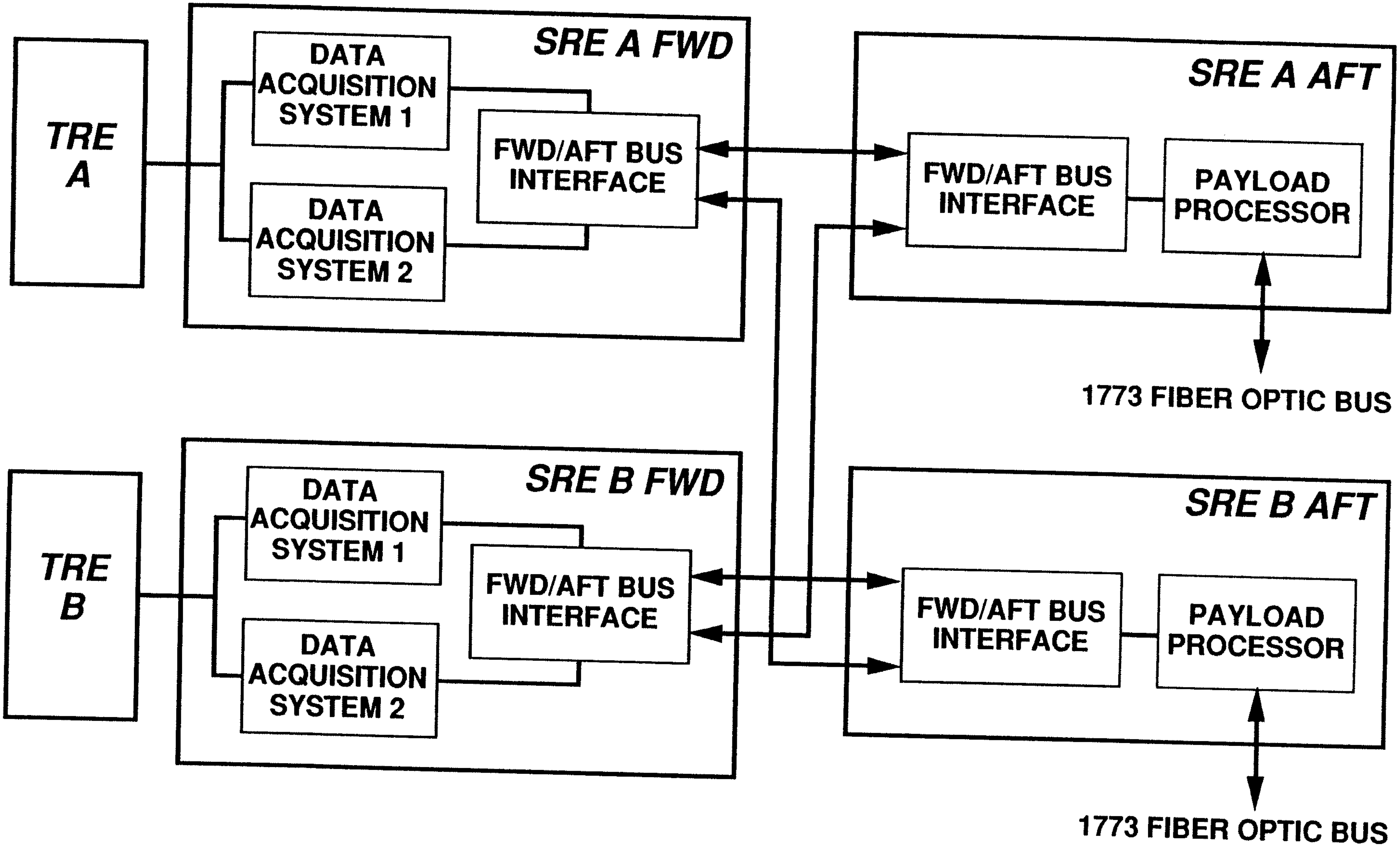
- **ALL DC/DC CONVERTERS ARE REDUNDANT.**

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

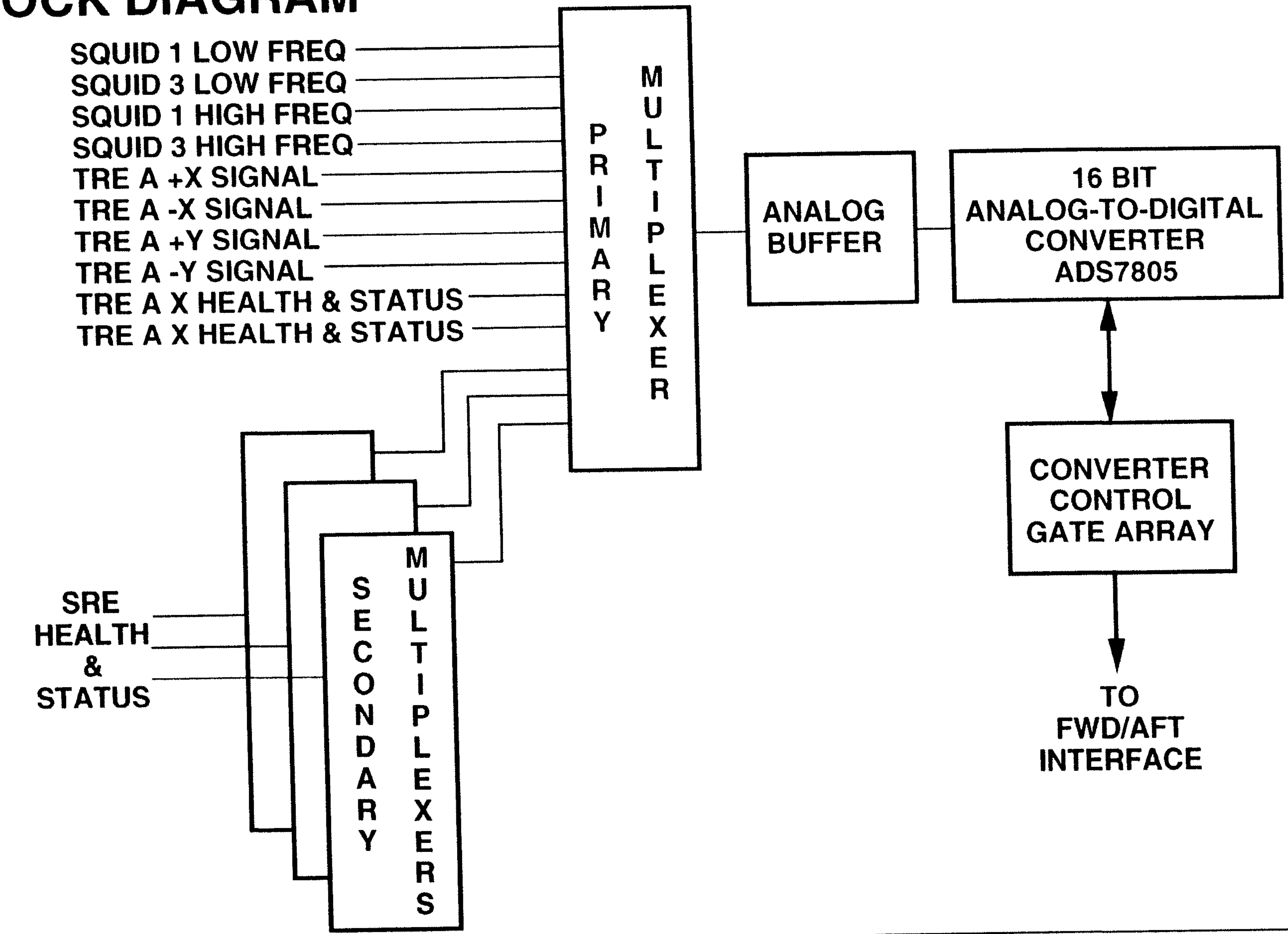
DATA ACQUISITION

Configuration
Block Diagram
Features

TRE DATA ACQUISITION CONFIGURATION



SRE/TRE DATA ACQUISITION SYSTEM BLOCK DIAGRAM



Design Features to meet the requirements

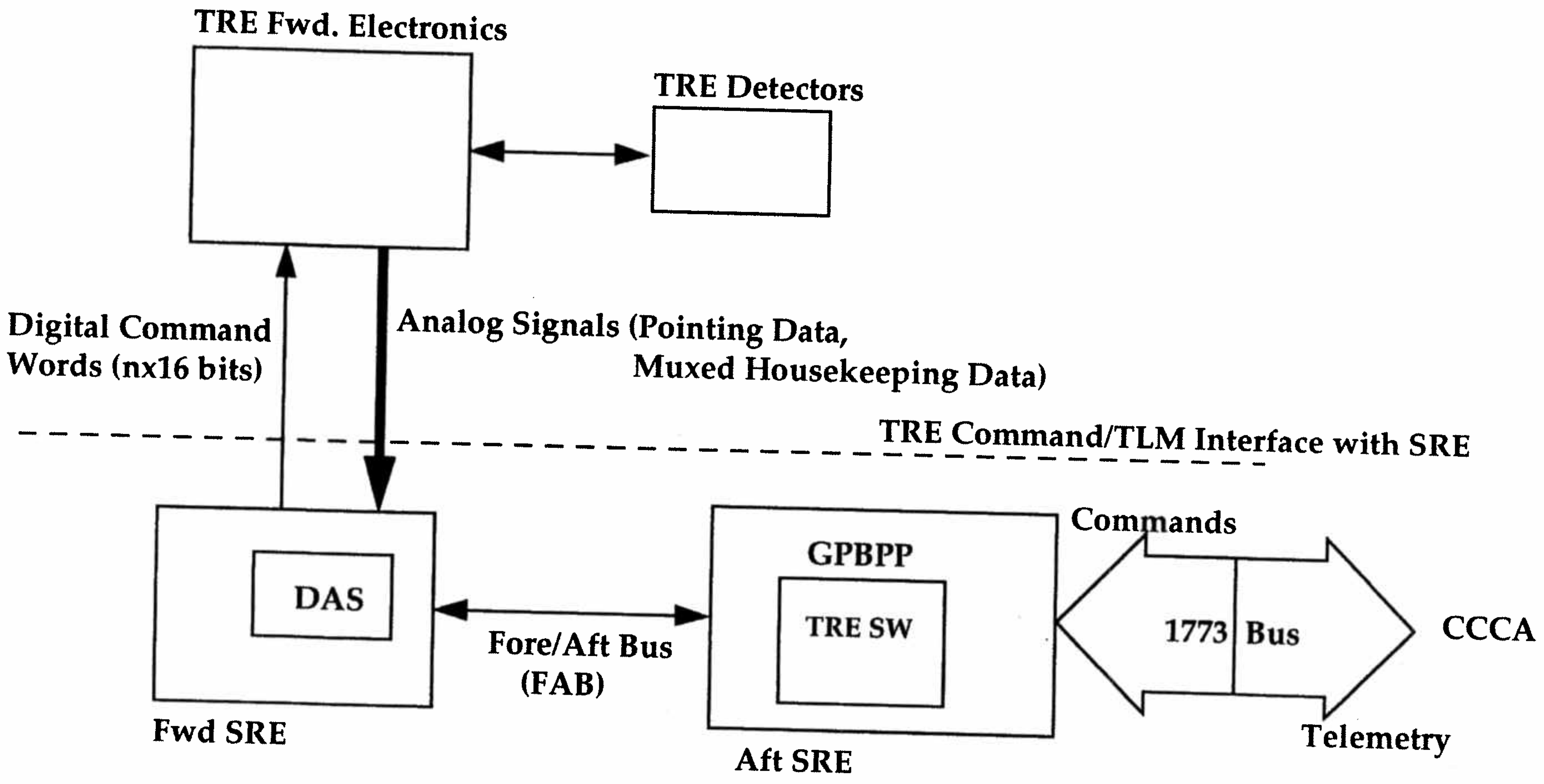
- DATA REDUCTION CIRCUITS IN THE FORWARD ENCLOSURE
  - TO PROVIDE A MORE CONSTANT THERMAL ENVIRONMENT
  - TO REDUCE THE DISTANCE TRAVELED BY DELICATE ANALOG SIGNALS
- IDENTICAL CIRCUITS FOR TRE AND SRE IN THE SAME ENCLOSURE
  - TO MAKE THE SQUID AND TELESCOPE READOUT SIGNAL PROCESSING AS SIMILAR AS POSSIBLE
  - TO PUT ALL THE COMPONENTS IN THE SAME THERMAL ENVIRONMENT
- ALL SIGNALS PROCESSED BY TWO ANALOG-TO-DIGITAL CONVERTERS
  - TO PROVIDE A REASONABLE TRADE BETWEEN REDUNDANCY AND COMPLEXITY
  - TO REDUCE THE CHANCE OF SYSTEMATIC ERRORS
- READOUT ERRORS CONTRIBUTED BY DATA ACQUISITION SYSTEM:
  - BIAS STABILITY ERROR < 0.002 mARCS.
  - RANDOM NOISE < 0.1 mARCS/RT HZ

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

COMMAND, TELEMETRY, AND SOFTWARE

Overview
Command Items
Telemetry Items
Software Elements

TRE Command/Telemetry and Software Overview



TRE Fwd. Electronics

TRE Detectors

Digital Command Words (nx16 bits)

Analog Signals (Pointing Data, Muxed Housekeeping Data)

TRE Command/TLM Interface with SRE

DAS

Fwd SRE

Fore/Aft Bus (FAB)

GPBPP

TRE SW

Aft SRE

Commands

1773 Bus

Telemetry

CCCA

TRE Commands

Command Name	Command Function
TRE_s_Digital_On TRE_s_Digital_Off	Turns Digital Power On/Off to the TRE axis
TRE_s_Analog_On TRE_s_Analog_Off	Turns Analog Power On/Off to the TRE Axis
STz_Monitor	Sets the TRE Control Register
STz_TIA_Disable STz_TIA_Enable	Enables/Disables Transimpedance Mode
STz_Temp_Disable STz_Temp_Enable	Enables/Disables Local Closed Loop Temperature Control
STz_Diagnostic_Mode_n	Invert Reset, Invert Gate, TIA Mode, Inhibit Reset Clock
STz_Detector_Power_On STz_Detector_Power_Off	Turns TRE Detector Power On/Off
STz_Local_Temp_SP	Sets TRE z Local Closed Loop Temperature Setpoint
STz_Detector_Heater	Sets TRE z Detector Heater
STz_Clamp+ STz_Clamp-	Sets TRE z +/- Clamp Voltage
STz_Gain+ STz_Gain- Stz_Primary_Bias	Sets TRE z +/- Gain and/or PhotoDiode Bias Voltage
STz_Secondary_Bias+ STz_Secondary_Bias-	Sets Second Stage Bias Control

TRE Telemetry

Telemetry Monitor	Telemetry Type
Slope Estimation (ATC)	**ATC TLM output on 1773 at 10 Hz**
Slope Estimation (Science)	**Science TLM output on 1773 at 10 Hz**
Transimpedance Signal Amplifier Voltage	Engineering TLM output on 1773 at 0.5 Hz
Transimpedance Reference Amplifier Voltage	Engineering TLM output on 1773 at 0.5 Hz
Offset DAC Output	Engineering TLM output on 1773 at 0.5 Hz
Direction Feedback Point	Engineering TLM output on 1773 at 0.5 Hz
Reset Drive Level	Engineering TLM output on 1773 at 0.5 Hz
Diode Bias	Engineering TLM output on 1773 at 0.5 Hz
Signal Common 0, 1, 2	Engineering TLM output on 1773 at 0.5 Hz
Detector Temperature	Engineering TLM output on 1773 at 0.5 Hz
Local Box Temperature	Engineering TLM output on 1773 at 0.5 Hz
Heater Voltage	Engineering TLM output on 1773 at 0.5 Hz
Temperature Command DAC	Engineering TLM output on 1773 at 0.5 Hz
Temperature Servo Error Voltage	Engineering TLM output on 1773 at 0.5 Hz
+12V, -12V, +5V	Engineering TLM output on 1773 at 0.5 Hz
Reference +0.5V, +5V, +4V, -10V	Engineering TLM output on 1773 at 0.5 Hz
Second Stage Bias	Engineering TLM output on 1773 at 0.5 Hz
Analog Clock 1, 2 Monitor	Engineering TLM output on 1773 at 0.5 Hz

TRE Software

Software Component	Algorithm	Status
Scheduler		Identical to scheduler in CCCA
Command Routing	• Commands received from CCCA at 10 Hz • Commands transmitted to Fore SRE at 10 Hz to mitigate SEUs	Comprehensive list documented in Section 9 of the Software Design Document SE-16
ATC Slope Estimator	• ATC Slope Fit	Requirements definition complete. Awaiting customer sign-off.
Science Slope Estimator	• Science Slope Fit	Requirements definition complete. Prototyping in progress
Engineering Data Filter	• Low Pass	Preliminary specification complete.
Digital Closed Loop Thermal Control	• PID	Preliminary specification complete
Telemetry Processing	• Pointing TLM available at 10 Hz • Engineering TLM available at 0.5 Hz • Snapshot TLM available on demand or on event	Comprehensive list documented in Section 9 of the Software Design Document SE-16.

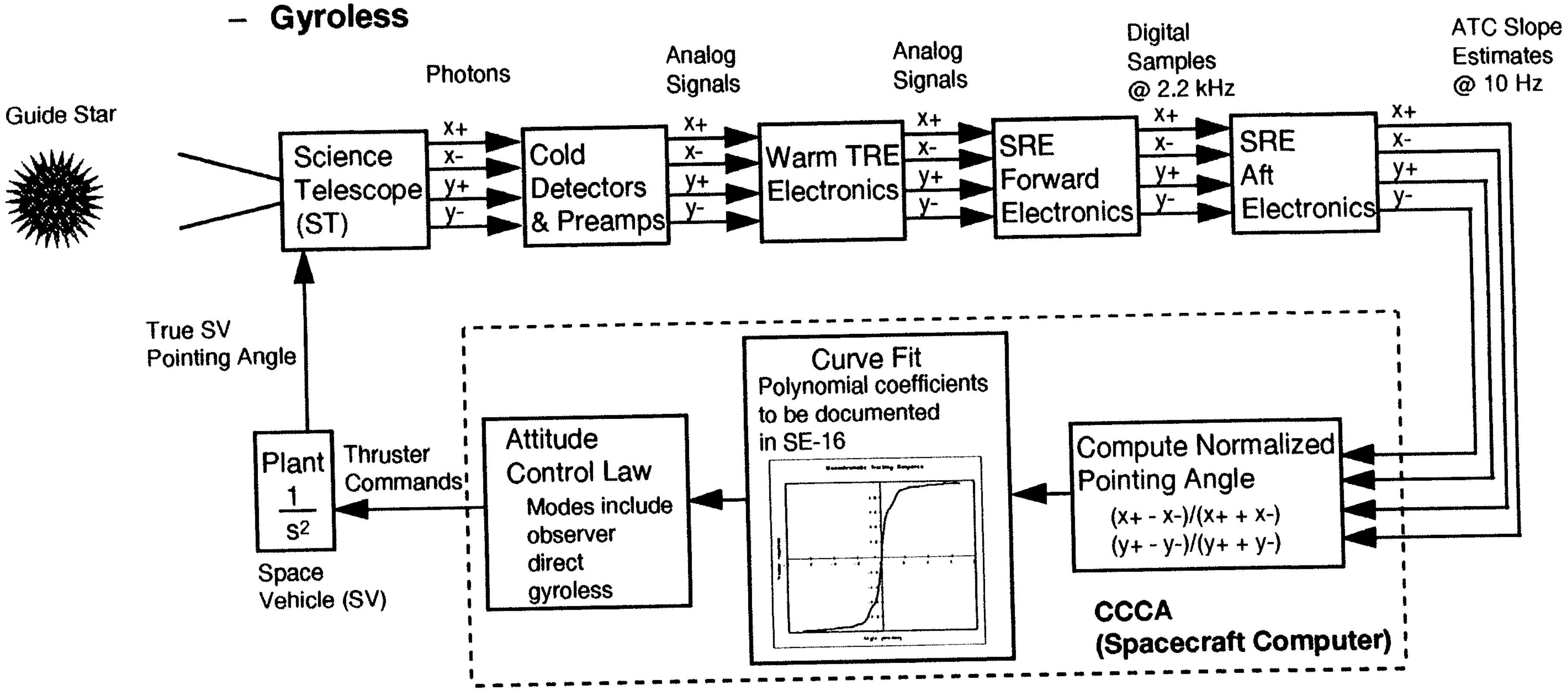
TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

ATC INTERFACE

Block diagram
Requirements
Telescope processing model

ATC Interfaces

- ATC data flow well defined
- Aft SRE performs error check on high frequency data
- Attitude control law supports multiple modes
  - Observer
  - Direct
  - Gyroless



Guide Star

Photons

Science Telescope (ST)

x+
x-
y+
y-

Cold Detectors & Preamps

Analog Signals

x+
x-
y+
y-

Warm TRE Electronics

Analog Signals

x+
x-
y+
y-

SRE Forward Electronics

Digital Samples @ 2.2 kHz

x+
x-
y+
y-

SRE Aft Electronics

ATC Slope Estimates @ 10 Hz

x+
x-
y+
y-

Compute Normalized Pointing Angle
(x+ - x-)/(x+ + x-)
(y+ - y-)/(y+ + y-)

Curve Fit
Polynomial coefficients to be documented in SE-16

Attitude Control Law
Modes include
observer
direct
gyroless

CCCA
(Spacecraft Computer)

Thruster Commands

Plant
$\frac{1}{s^2}$
Space Vehicle (SV)

True SV Pointing Angle

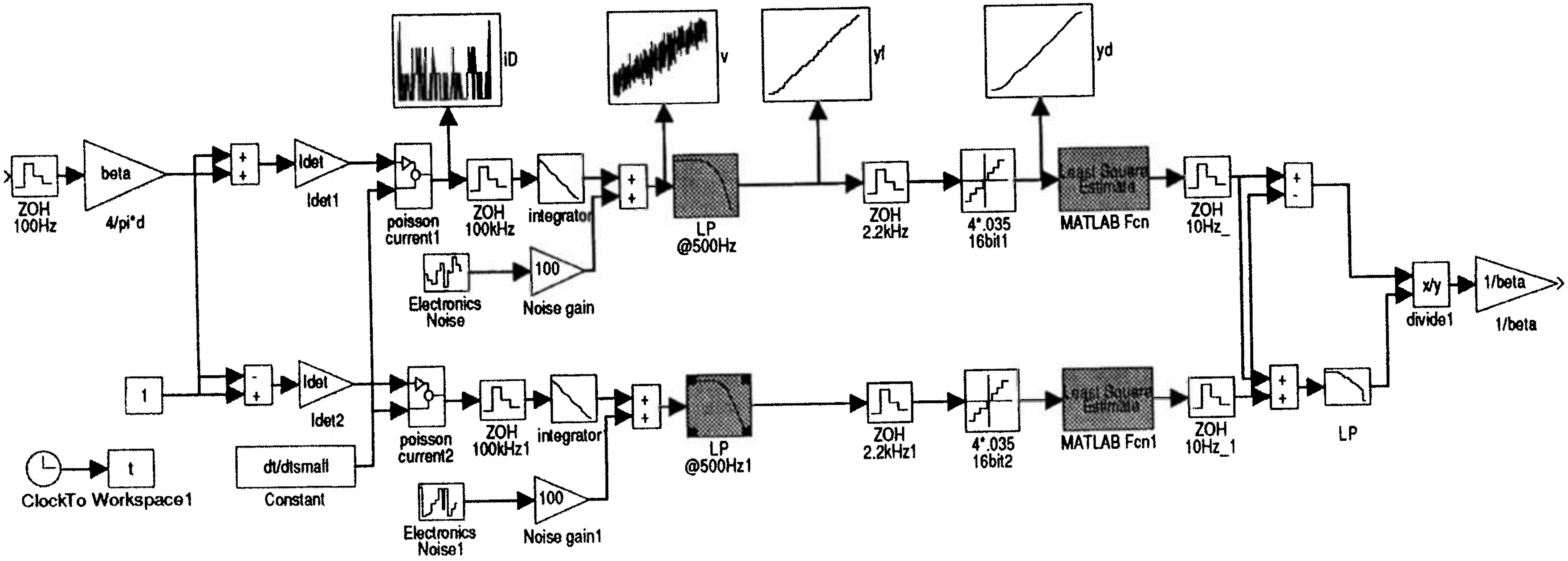
ATC ST requirements

	Verification
1) The science telescope shall provide the slope fit to the integrated pointing error from the plus and minus sides of the yaw and pitch detectors. Signal filtering shall be greater than 100 Hz.	Design
2) The science telescope noise, after a 10 Hz slope fit, shall be less than 10 marcs/√Hz (one-sided).	Test
3) The science telescope signals shall allow determination of the star magnitude to within ±0.2 Mv (20%).	Test
4) Resets shall occur on 10 Hz boundaries.	Test
5) The science telescope quantization shall be less than or equal to 0.25 marcs (12 bits over ±500 marcs).	Test
6) The science telescope shall provide more than 75% full reading when beyond ±500 marcs and within the total field-of-view of ±60 arcsec.	Test
7) The science telescope shall be linearizable over the range of ±500 marcs (see 8 for error).	Test
8) The residual linearization error of the science telescope shall be less than 6% over any 5 marcs range within ±60 marcs and less than 15% from 60 marcs to 500 marcs.	Test
9) The ATC data shall be available after receipt of the 10 Hz ATC strobe.	Test

*Telescope data word format is controlled in Flight Software Specification, SE-16, Section 9

*PCB to add these requirements to TRE Spec is in data package file: bdeti.m

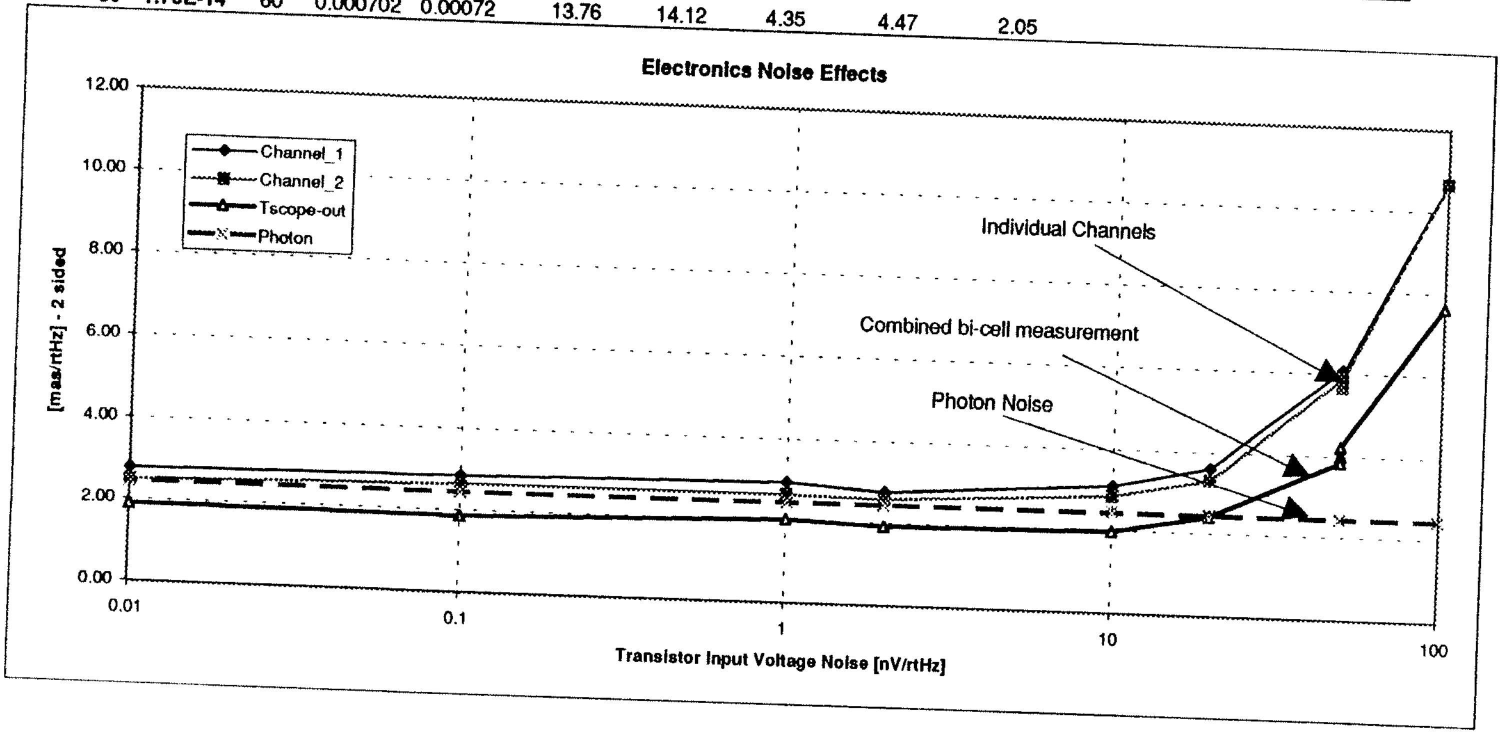
TELESCOPE PROCESSING MODEL



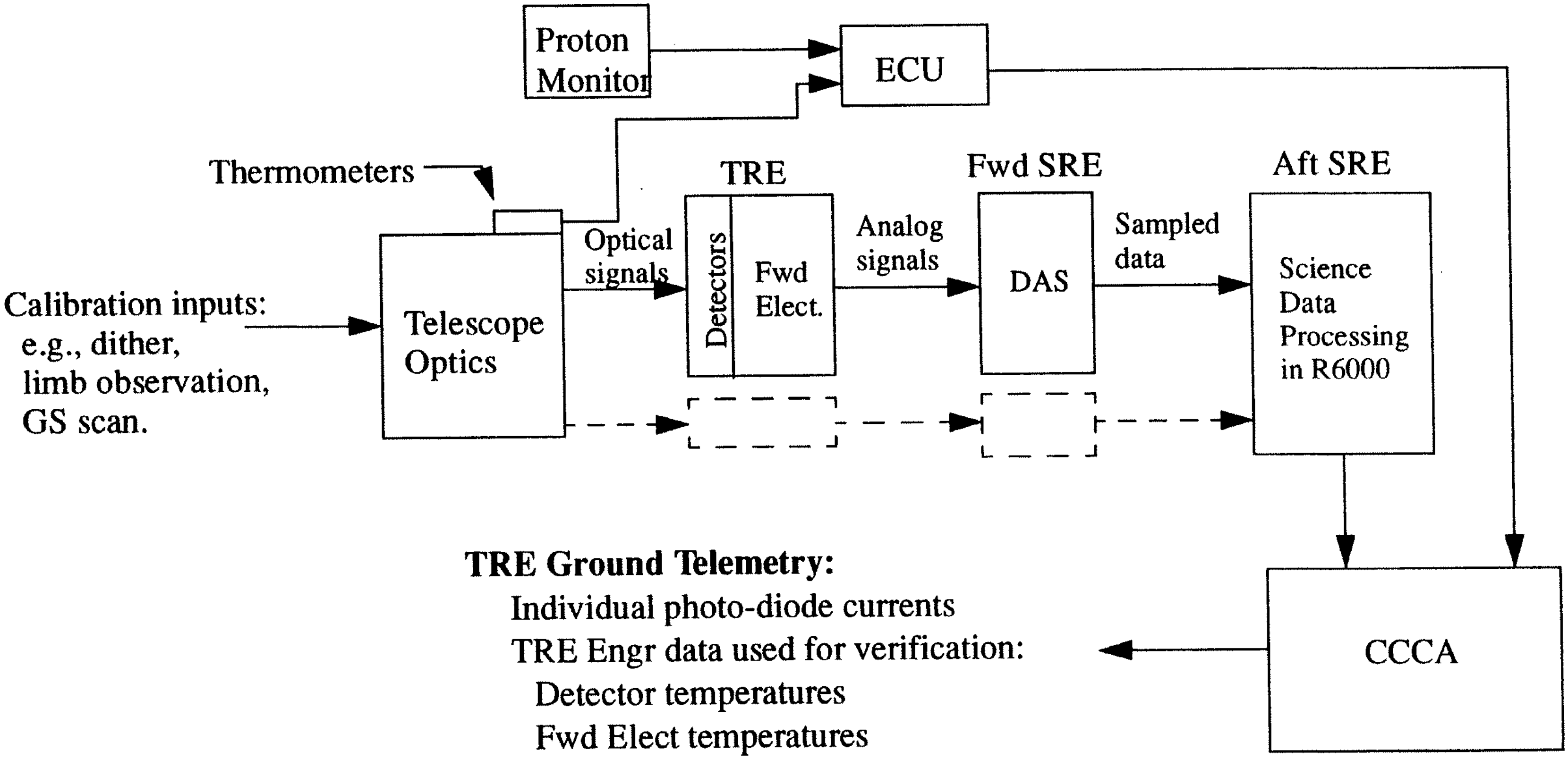
TELESCOPE PROCESSING MODEL RESULTS

dt	0.1	sec
Cf	5.00E-13	F
beta	0.0015	1/mas
el	1.60E-19	C
run time	100	sec
transient	12	samples

			Individual Channels							Combined bi-cell meas.		
			V/sec		[mas]		[mas/RtHz]		[mas/RtHz]	[mas] t>50		[mas/RtHz]
elNps	Idet	teta	**sig_vp**	**sig_vn**	sig_ch1	sig_ch2	Channel_1	Channel_2	Photon	Amean	**Asigma**	Tscope-out
100	1.19E-14	60	**0.0012**	**0.0012**	33.76	33.76	10.67	10.67	2.45	59.9819	24.2	7.65
50	1.19E-14	60	**0.000672**	**0.000655**	18.89	18.41	5.97	5.82	2.45		13.31	4.21
50	1.19E-14	60	**0.000677**	**0.000636**	19.04	17.88	6.02	5.66	2.45		**12.64**	4.00
50	1.19E-14	60	**0.000684**	**0.00066**	19.25	18.57	6.09	5.87	2.45	59.61	**12.13**	3.84
20	1.19E-14	60	**0.000405**	**0.000371**	11.40	10.45	3.61	3.30	2.45	60.27	**7.63**	2.41
10	1.19E-14	60	**0.00035**	**0.000321**	9.83	9.04	3.11	2.86	2.45	60.19	**6.24**	1.97
2	1.19E-14	60	**0.000311**	**0.000291**	8.74	8.19	2.76	2.59	2.45	60.34	**6.07**	1.92
1	1.19E-14	60	**0.000329**	**0.000296**	9.25	8.31	2.93	2.63	2.45	60.16	**6.39**	2.02
0.1	1.19E-14	60	**0.000319**	**0.000297**	8.98	8.34	2.84	2.64	2.45	59.79	**5.86**	1.85
0.01	1.19E-14	60	**0.000311**	**0.000279**	8.76	7.86	2.77	2.48	2.45	59.72	**5.98**	1.89
20	**0.00E+00**	60	0.000233	0.000233								
50	**1.70E-14**	60	0.000702	0.00072	13.76	14.12	4.35	4.47	2.05			



ST SCIENCE DATA INTERFACE



TRE Ground Telemetry:

Individual photo-diode currents

TRE Engr data used for verification:

- Detector temperatures
- Fwd Elect temperatures
- Measured set-point values

Primary and redundant signals are in telemetry stream.

TRE SUPPORTS ALL SCIENCE DATA PROCESSING AND VERIFICATION REQUIREMENTS

TRE Compliance to Critical Specifications

Spec # / Parameter	Reqmnt.	Design for Compliance	Verification Methods	Achieved to Date
T003 7.5 Random Noise	< 10 marcs $/\sqrt{Hz}$ (1-sided)	Cold low-noise JFET 1st stage amplifiers Capacitive feedback in CLL avoids Johnson noise in feedback	Measured in detector acceptance test, integrated P/L test, S/V thermal vac On-orbit check of dark noise with shutter closed during GI	**8.2 marcs $/\sqrt{Hz}$ (lab test)**
3.2.15.2 Bias Variation	<0.05 marcs at critical frequencies	Bi-cell photodiode detectors and preamps co-located on temp. stable sapphire platform CLL minimizes dynamic range of voltage on photodiodes and JFETs	Dev. & aceptance test with unfocussed light System test with Artificial Star & Telescope in GTU-2 and integrated P/L On-orbit check between redundant sides of TRE	Designed to meet spec.
3.2.15.3 Scale Factor Variation	< 1%	Both halves of bi-cell read out; signal normalized $(x^+ - x^-) / (x^+ + x^-)$	Dev. & aceptance test with unfocussed light System test with Artificial Star & Telescope in GTU-2 and integrated P/L On-orbit check using S/V dither On-orbit check between redundant sides of TRE	Designed to meet spec.
3.2.15.6 Transfer Function Stability	< 0.01 rad.	High rate (>2kHz) sampling with critical filtering performed digitally makes pre-sample analog filters non-critical	Direct measurement in lab vs. temperature variation of electronics On-orbit verification using S/V dither	Designed to meet spec.
3.2.1 EMI	Operate within spec with TLM xmtr ON	Shielding of cables in Probe. Internal shield around detector platforms referenced to TRE signal ground.	EMI tests in on TRE boxes and detector packages; in GTU-2, during P/L integration and during S/V integration	Designed to meet spec.
3.2.2, 3.3.3 Ionizing Radiation	Operate within spec in spec'd environment (PCB for exception in SAA)	Loss of data in SAA acceptable to system High rate (>2kHz) sampling allows detection of high-energy events Resets (10Hz) limit persistence of events	Electronic development tests in lab Total dose (γ) and transient (protons from cyclotron) test program Correlate with Proton Monitor data on orbit	Designed to meet spec.
3.2.5 Detector Mount	$f_0 > 100$ Hz Allignment wrt light spots	Very stiff Adjustable within package for allignment	Development / acceptance test in lab	Designed to meet spec.

TRE Compliance to Critical Specifications

3.2.6 Detector Power	1 mW / platform	Nominal dissipation 1 mW/detector (4 mW total) 75% for circuit operation, 25% for heater Heater power commandable in flight	Development / acceptance test in lab Temperature measurements on orbit	Designed to meet spec.
3.2.7 Operation Range	10 fA 10 pA 1 µA	TIA mode allows operation at warm temperature and high current for test modes	Development / acceptancetest in lab	Designed to meet spec.

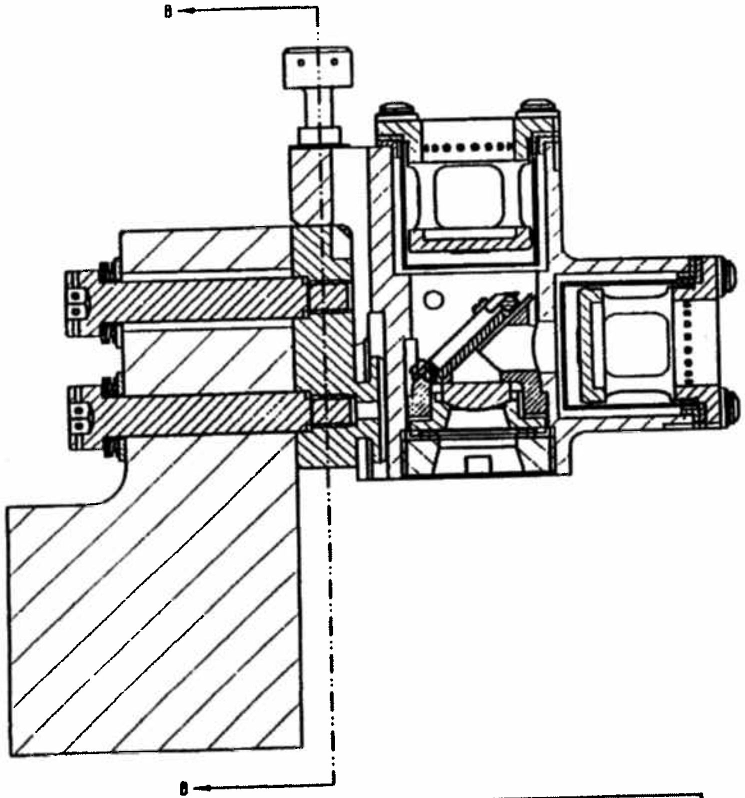
TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

ELECTRICAL DESIGN OF TRE DETECTOR

J. GOEBEL

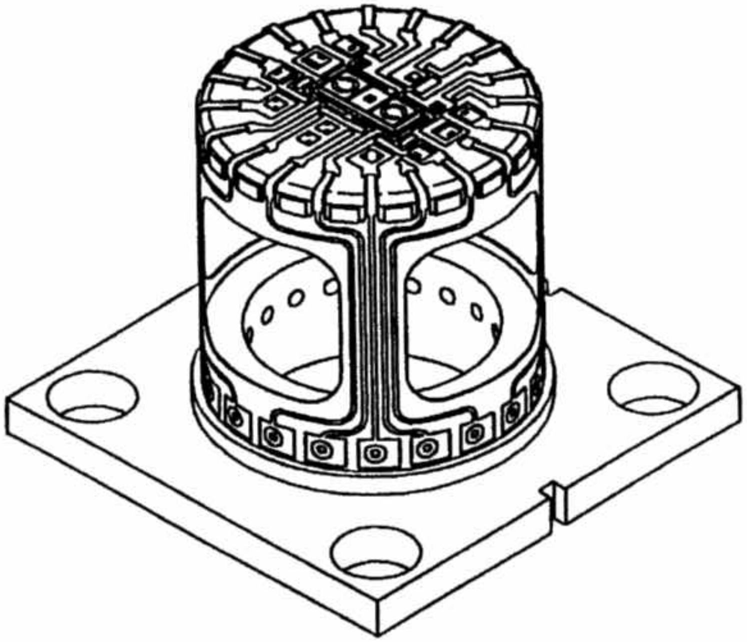
Schematics
Layout
Specifications
SAA Effects on TRE
Test Program

Critical Design Review Telescope Readout Electronics

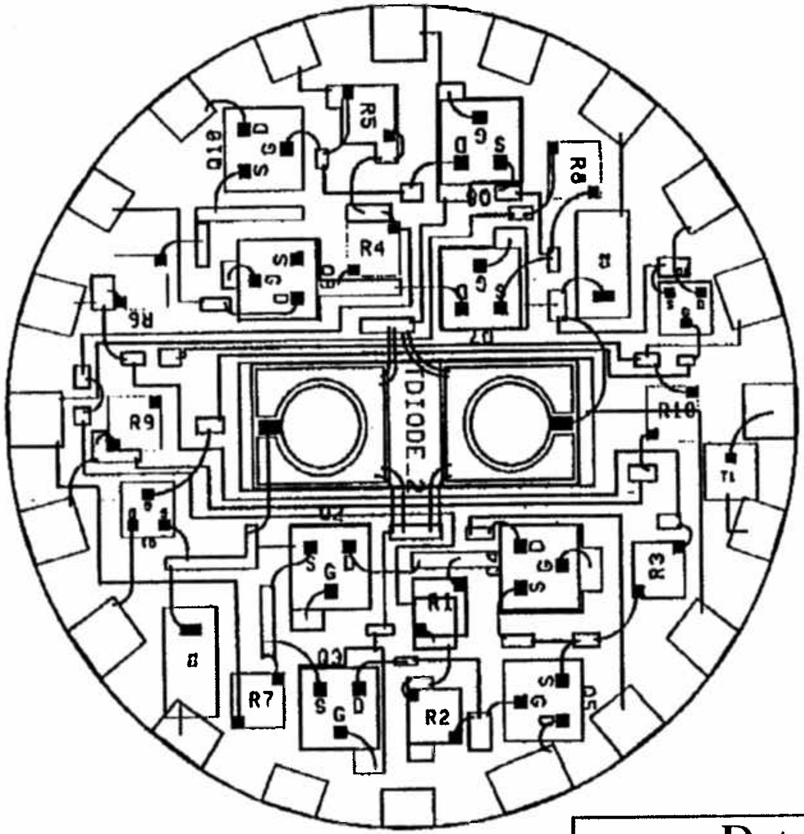


Detector Mount Assembly

Critical Design Review Telescope Readout Electronics

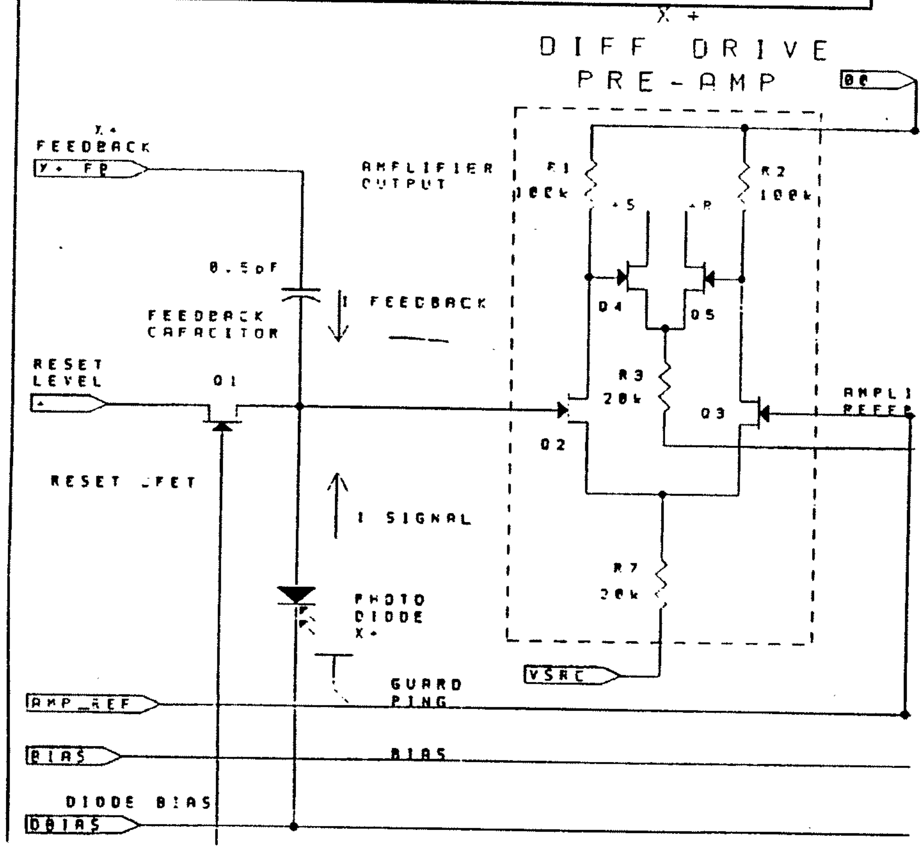


Detector Mount



Detector
(Layout)

One-Half of Differential Amplifier



Telescope Readout Electronics Critical Design Review

TRE Detector Component Parametric Performance

Parameter	Value	Simulation	Test Program	Schedule
Dark Current	$I_{dark} \leq 0.01$ fA	In progress	In Preparation Area of Concern	June 1
Si Photodiode External Quantum Efficiency @ 550-900 nm	$\eta_{ext} \geq 80\ \%$	In progress	In Preparation Area of Concern	> GTU-2
Diameter of Photoactive Area	TBD $0.5 \leq D_{Det} \leq 0.8$ mm	Centronic Blueprint	Suwen	Available
Sense Node Capacitance	$C_T \leq 20$ pF	In progress	In Preparation	June 1
Operating Temperature	TBD $40 < T_{op} < 120$ K	In progress	In Preparation Area of Concern	June 1
Sense Node Referred Noise	$N_{EQ} \leq 50\ e^{-}/T_{\mathrm{int}}$	In progress	In Preparation Area of Concern	Aug1
Component Si-JFET Transconductance	$g_m \geq 0.3$ mS	In progress	In Preparation	June 1

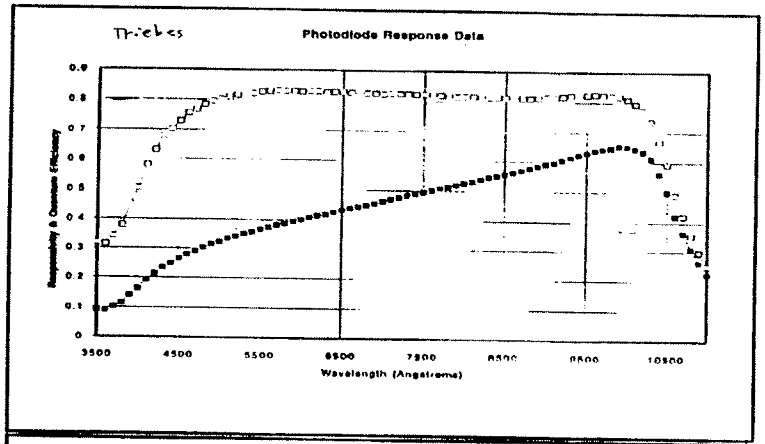
Telescope Readout Electronics Critical Design Review

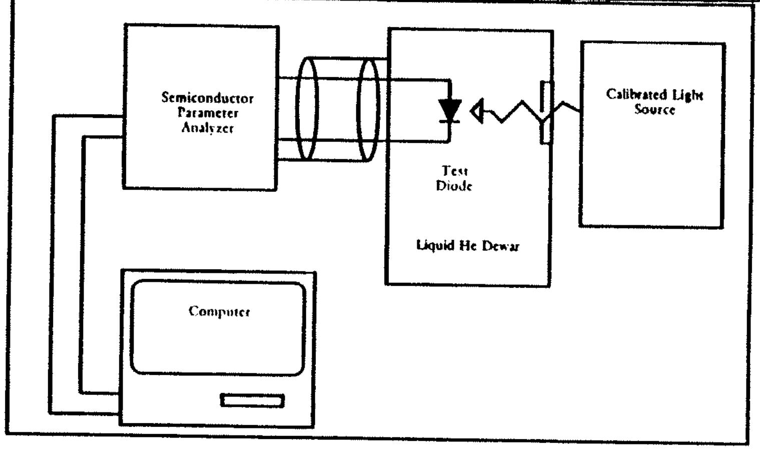
TRE Detector Parametric Performance

Parameter	Value	Simulation	Test Program	Schedule
Temperature Stability @ roll	$\Delta T \leq 2$ mK	In progress	In Preparation Needs Confirmation	> GTU-2
Power Dissipation per Platform	$P_{Plat} \leq 1$ mW	In progress	In Preparation Needs Confirmation	June 1
CTIA Sense Node Capacitance	$C_T \leq 20$ pF	Howard Demroff Bob Farley	In Preparation	June 1
Operating Temperature	$40 < T_{op} < 120$ K	In progress	In Preparation Needs Confirmation	June 1
CTIA Sense Node Referred Noise	$\sqrt{S_{CTIA}} \leq 100$ nV/$\sqrt{\text{Hz}}$	In progress	In Preparation	> GTU-2
FET Threshold Voltage Matching	$\lvert \Delta V_{TH}/V_{TH} \rvert \leq 1\%$	In progress	In Preparation	> GTU-2
FET Threshold Voltage Temperature Coefficient Matching	$\lvert \Delta(\partial V_{TH}/\partial T)/(\partial V_{TH}/\partial T) \rvert \leq 1\%$	In progress	In Preparation	> GTU-2
Channel Gain Matching Temperature Coefficient Matching	$\lvert \Delta(\partial G/\partial T)/(\partial G/\partial T) \rvert \leq 5\%$	In progress	In Preparation	> GTU-2
EMI	TBS	In progress	In Preparation Area of Concern	> GTU-2

Critical Design Review Telescope Readout Electronics

- Test Plan for Si-PD External Quantum Efficiency
  - Determine $\eta(T)$
  - $\eta(300K) = 82\%$
  - $\eta(77K) = ?$
  - Bias Dependence
  - Trade with Noise





Detector Mount Assembly at *Top*

Requirements	Model	Test
> 80%	TBD	TBD

Critical Design Review Telescope Readout Electronics

- Test Plan for Si-PD Dark Current
  - Determine $I_D(T)$
  - $I_D(300\text{K}) =$
  - $I_D(77\text{K}) = ?$
  - Bias Dependence
  - Trade with $\eta(T)$

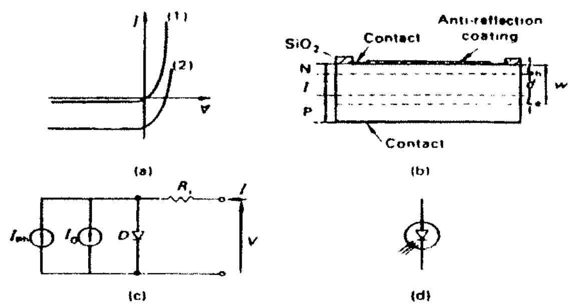
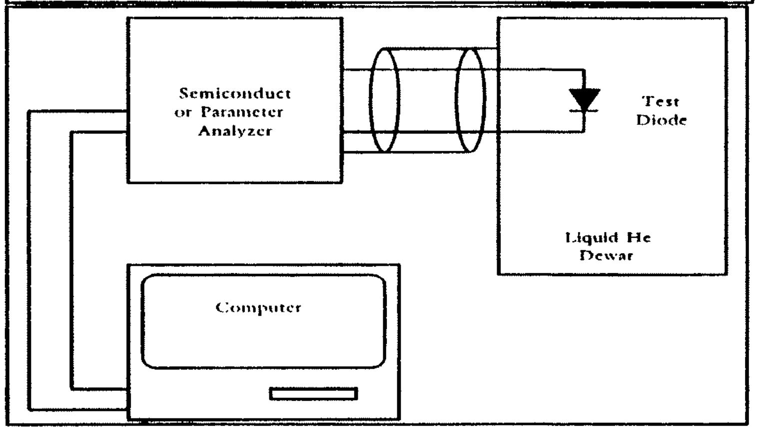


Figure 10.3. The PIN photodetector: (a) the I-V characteristic (1—in the dark, 2—with light); (b) PIN diode structure; (c) the equivalent circuit; (d) standard circuit symbol.

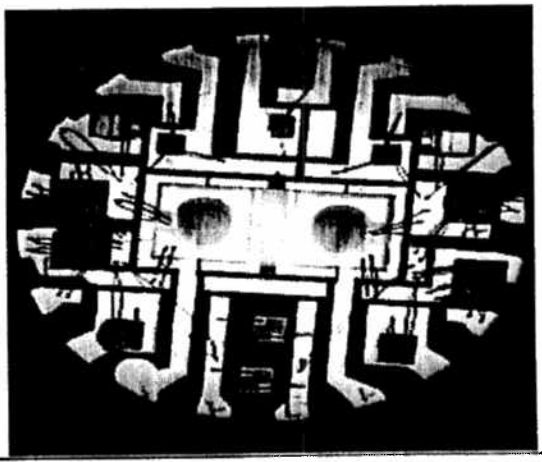
Detector Mount Assembly at *Top*

Requirements	Model	Test
< 0.01 fA	TBD	TBD



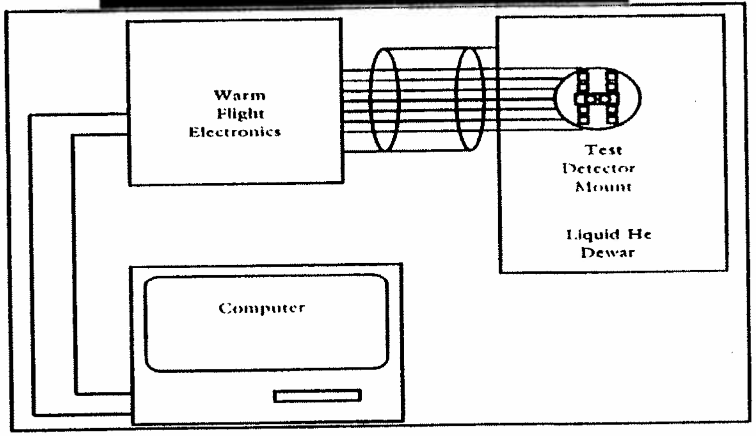
Critical Design Review Telescope Readout Electronics

- Test Plan for Platform Leakage Current
  - Determine $I_L(T)$
  - $I_L(300K) =$
  - $I_L(77K) = ?$
  - Bias Dependence



Detector Mount Assembly at *Top*

Requirements	Model	Test
< 0.01 fA	TBD	TBD



Critical Design Review Telescope Readout Electronics

- Test Plan for Si-JFET Gain
  - Determine g_m
  - $g_m(300\mathrm{K}) =$
  - $g_m(77\mathrm{K}) = ?$
  - Bias Dependence
  - Trade with Noise and Power Dissipation

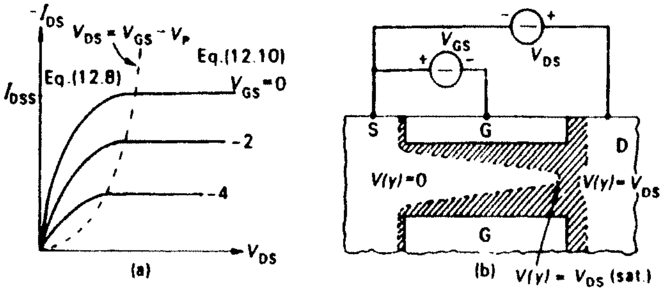
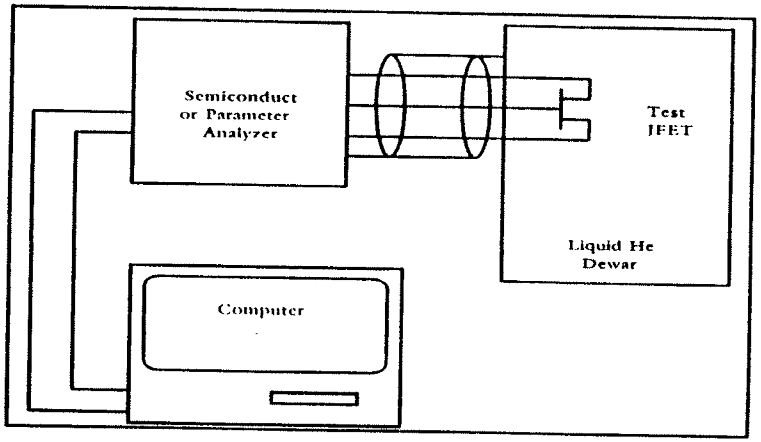


Figure 12.3. (a) The JFET drain characteristics determined by (12.8) up to the pinch-off point; (b) the depletion layer for $V_{DS} > V_{DS}(\mathrm{sat})$.

Detector Mount Assembly at *Top*

Requirements	Model	Test
300 uS	TBD	TBD



Critical Design Review Telescope Readout Electronics

- Test Plan for Si-JFET Threshold Voltage
  - Determine V_{TH}
  - $V_{TH}(300K) = 1.1V$
  - $V_{TH}(77K) = 1.1V$
  - Current Dependence

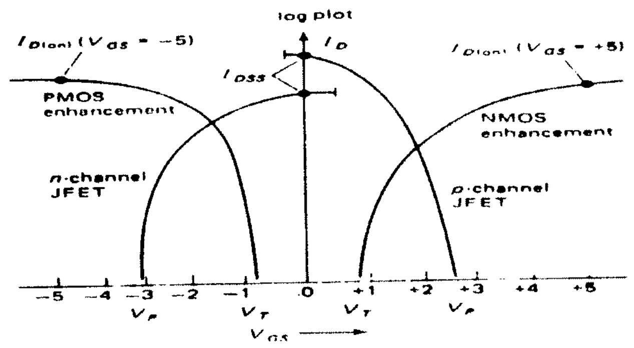
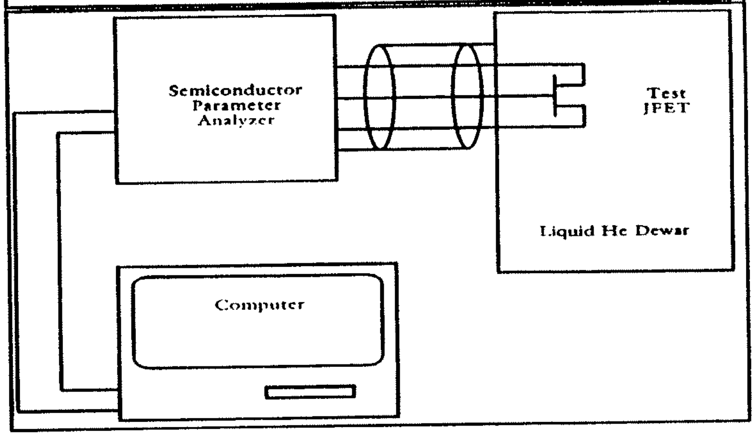


Figure 3.11

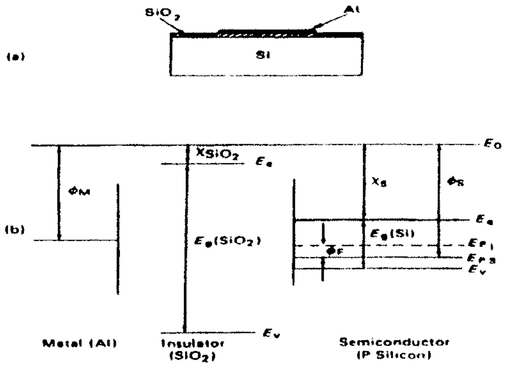
Detector Mount Assembly at *Top*

Requirements	Model	Test
1.1 V	TBD	1.1V



Critical Design Review Telescope Readout Electronics

- Test Plan for Si-PD Component Capacitance
  - Determine $C(T)$
  - $C(300\text{K}) = 0.5$ pF
  - $C(77\text{K}) = ?$
  - FETs, PD, C_F
  - Trade with Noise and CTIA Gain
  - Bias Dependence



Detector Mount Assembly at *Top*

Requirements	Model	Test
< 5 pF	TBD	TBD

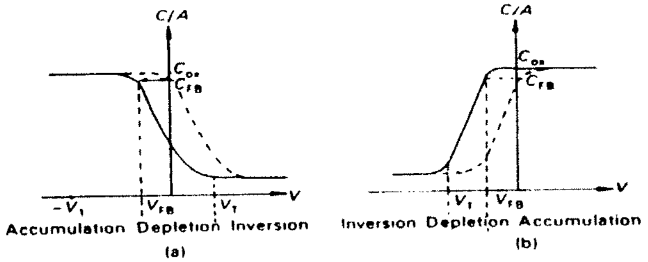
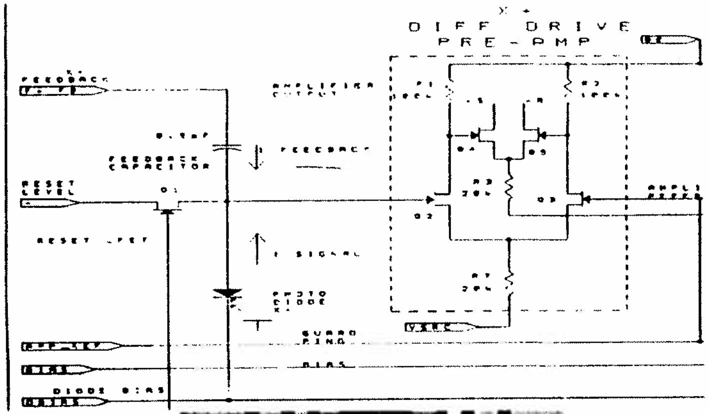


Figure 12.9. The $C(V)$ curves of MOS capacitors measured at 1 MHz (—— real capacitor; ------ ideal capacitor with $\phi_{MS}=0$, $Q_{ox}=0$); (a) capacitor built on a P-type substrate; (b) capacitor built on an N-type substrate.

Critical Design Review Telescope Readout Electronics

- Test Plan for Sence Node Capacitance
  - Determine $C_T(T)$
  - $C_T(300K) = ?$
  - $C_T(77K) = ?$
  - Trade with Noise and CTIA Gain
  - Bias Dependence

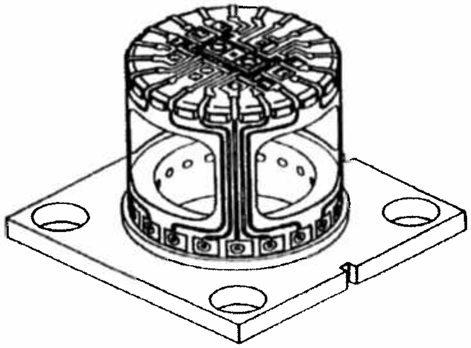


Detector Mount Assembly at *Top*

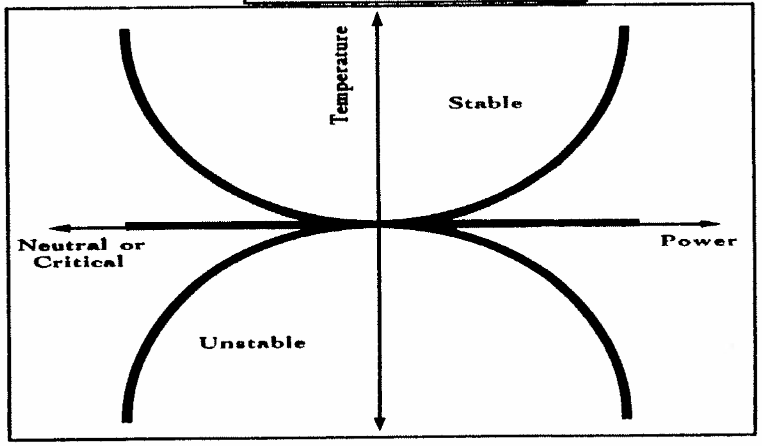
Requirements	Model	Test
< 20 pF	TBD	TBD

- Model of Thermal Dynamics
  - Thermal Time Constant
  - Radiation Sensitivity

- Model ID: ThermalDyn1.0
  - Status: Under Development
  - Question: Is the platform stable against perturbation?
  - Answer: Complex

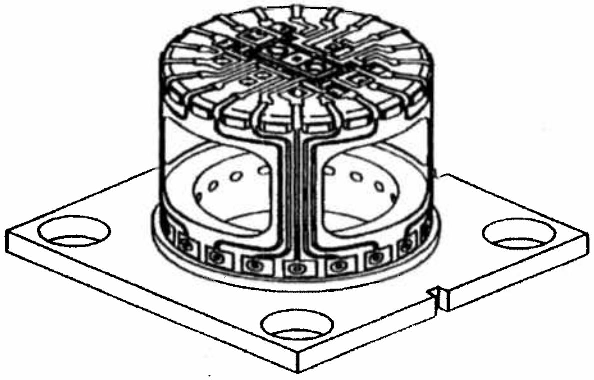


Detector Mount



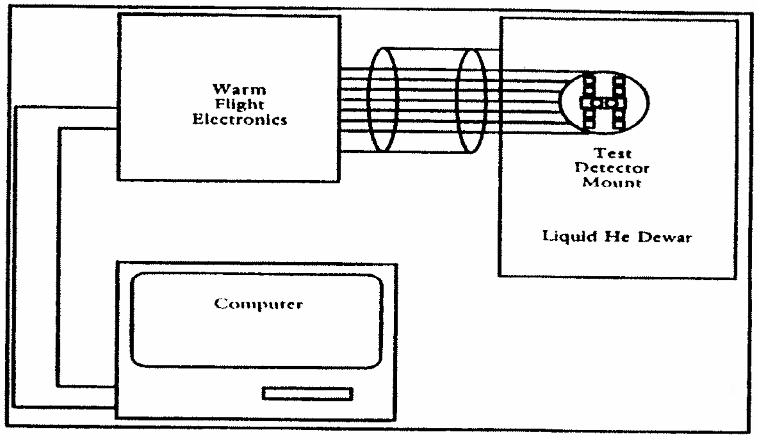
Critical Design Review Telescope Readout Electronics

- Test Plan for Thermal Stability and Control
  - Determine Z(T)
  - Z(300K) = N/A
  - Z(77K) = ?
  - Bias Dependence
  - Trade with Power Dissipation



Detector Mount Assembly at *Top*

Requirements	Model	Test
< 2 mK	TBD	TBD



- Test Plan for Component Noise
  - Determine $S(T)$
  - $S(300\text{K}) =$
  - $S(77\text{K}) = ?$
  - Bias Dependence
  - Trade with Power Dissipation

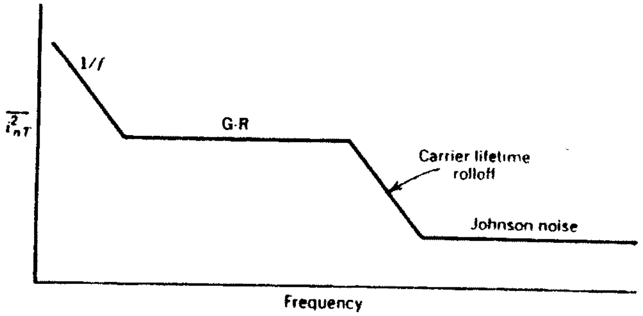
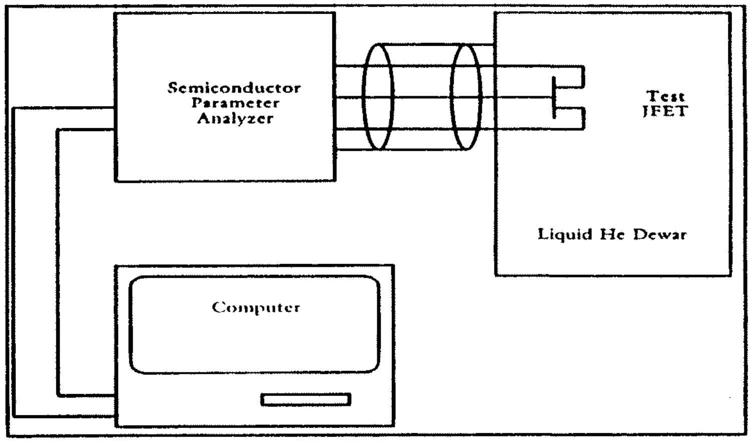


Figure 4-8 Typical photoconductor mean square noise spectrum.

Detector Mount Assembly at *Top*

Requirements	Model	Test
< 100 nV/√Hz	TBD	TBD

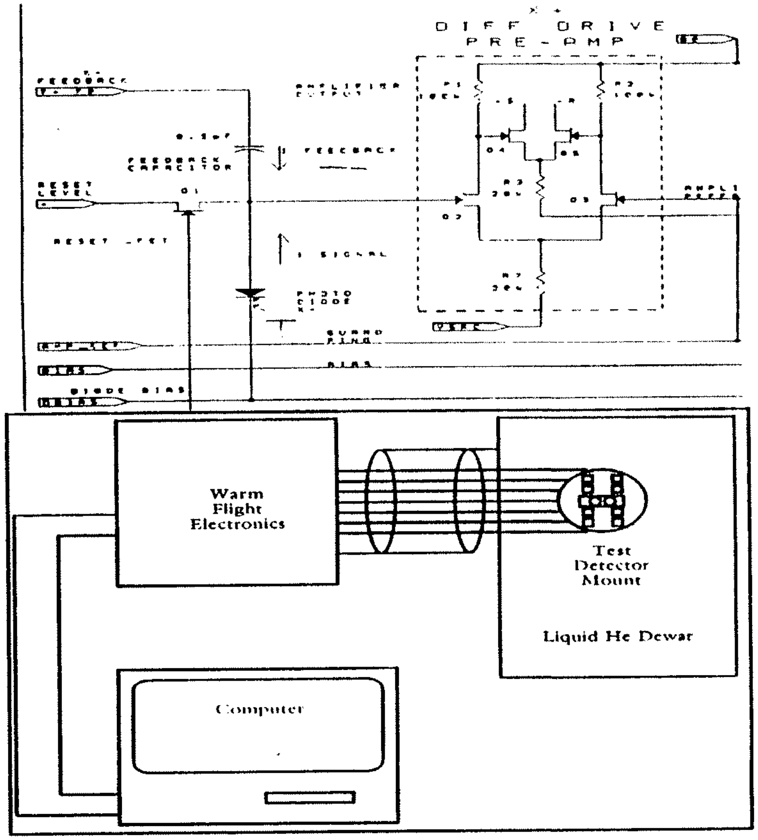


Critical Design Review Telescope Readout Electronics

- Test Plan for Si-PD Preamp Noise
  - Determine $S(T)$
  - $S(300\text{K})$ =
  - $S(77\text{K})$ = ?
  - Bias Dependence
  - Trade with Power Dissipation

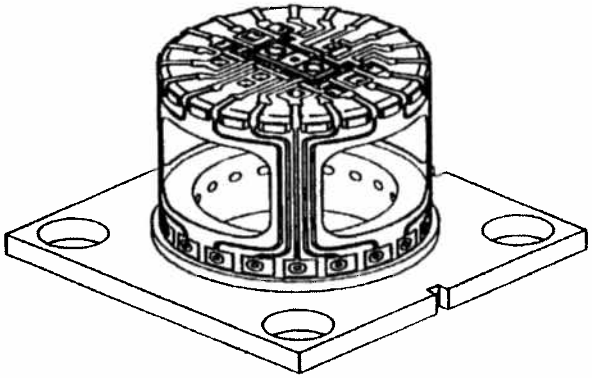
Detector Mount Assembly at *Top*

Requirements	Model	Test
< 300 nV/√Hz	TBD	TBD



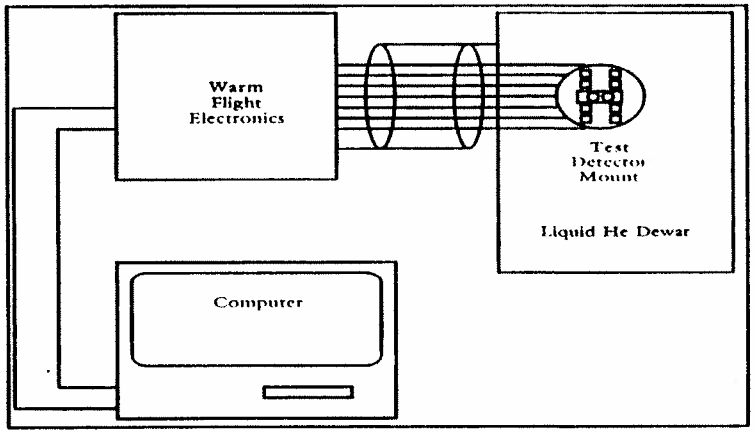
Critical Design Review Telescope Readout Electronics

- Test Plan for Optimum Operating Temperature
  - Determine T_{op}
  - Noise Trade
  - Signal Trade
  - Stability Trade



Detector Mount Assembly at *Top*

Requirements	Model	Test
< 120 K	TBD	TBD



Critical Design Review Telescope Readout Electronics

- Test Plan for EMI
  - Determine Detector & Preamp Bandwidth with Shielding
  - Diode can be made resistive
  - Bias line can be filtered at detector

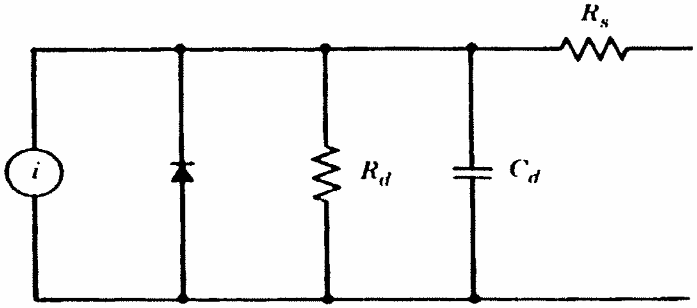
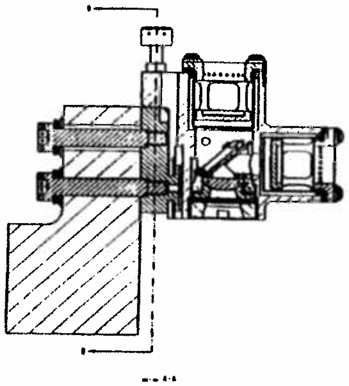


Figure 3-11 Detector equivalent circuit.

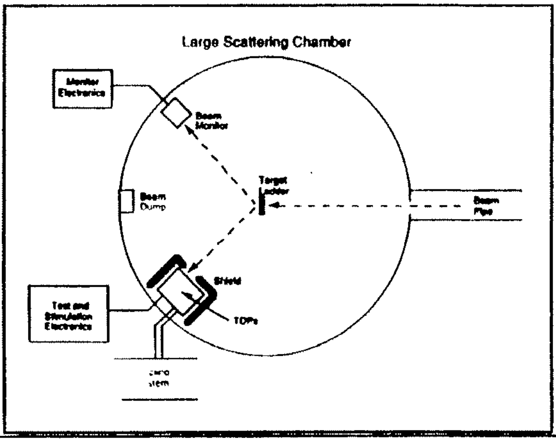
Detector Mount Assembly at *Top*

Requirements	Model	Test
?	TBD	TBD



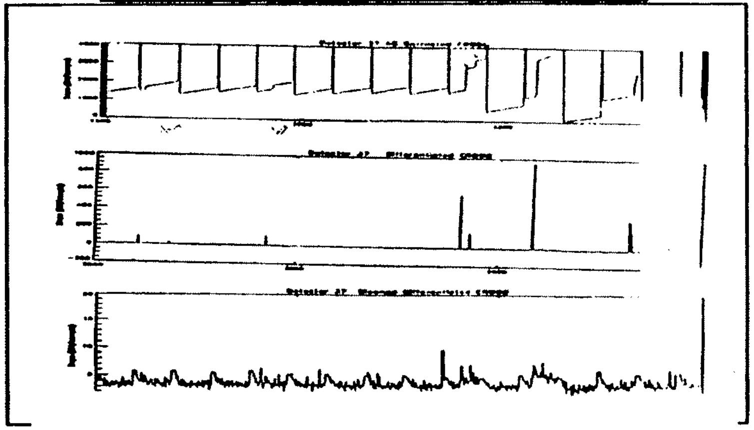
Critical Design Review Telescope Readout Electronics

- Test Plan for Ionizing Radiation
  - Need ~100 Mev protons
  - Can do preliminaries with γ-rays
  - PD, FETs, and Capcitors most sensitive
  - Bias Dependence



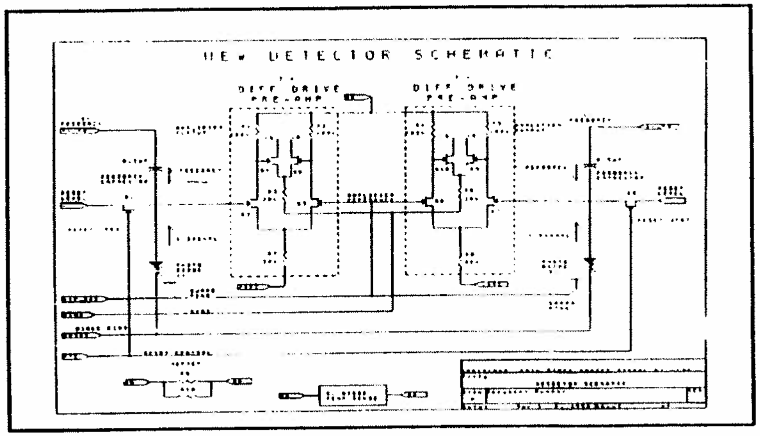
Detector Mount Assembly at *Top*

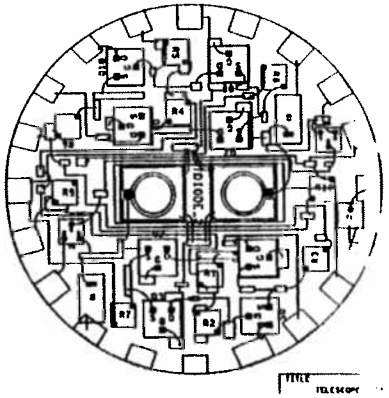
Requirements	Model	Test
?	TBD	TBD



Critical Design Review Telescope Readout Electronics

- Test Plan for CTIA Performance
  - Integration of above tests
  - Coupled to warm electronics
  - Long leads used in GTU-2





Detector Mount Assembly at *Top*

Requirements	Model	Test
$< \sqrt{7,500}$ e-/read	TBD	TBD

Critical Design Review Telescope Readout Electronics

- Manufacturing Plan DMA
    - Assemble Sapphire Hybrid
    - Construct Kapton Thermal Isolator
    - Construct Base Assembly
    - Construct Rigidizer
    - Construct Cable-Connector Assembly
    - Integrate Cable-Base Assembly
    - Integrate Cable-Base-Isolator Assembly
    - Integrate Hybrid, Isolator and Cable-Base

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

DESIGN OF TRE DETECTOR PACKAGE AND MOUNT

M. SULLIVAN

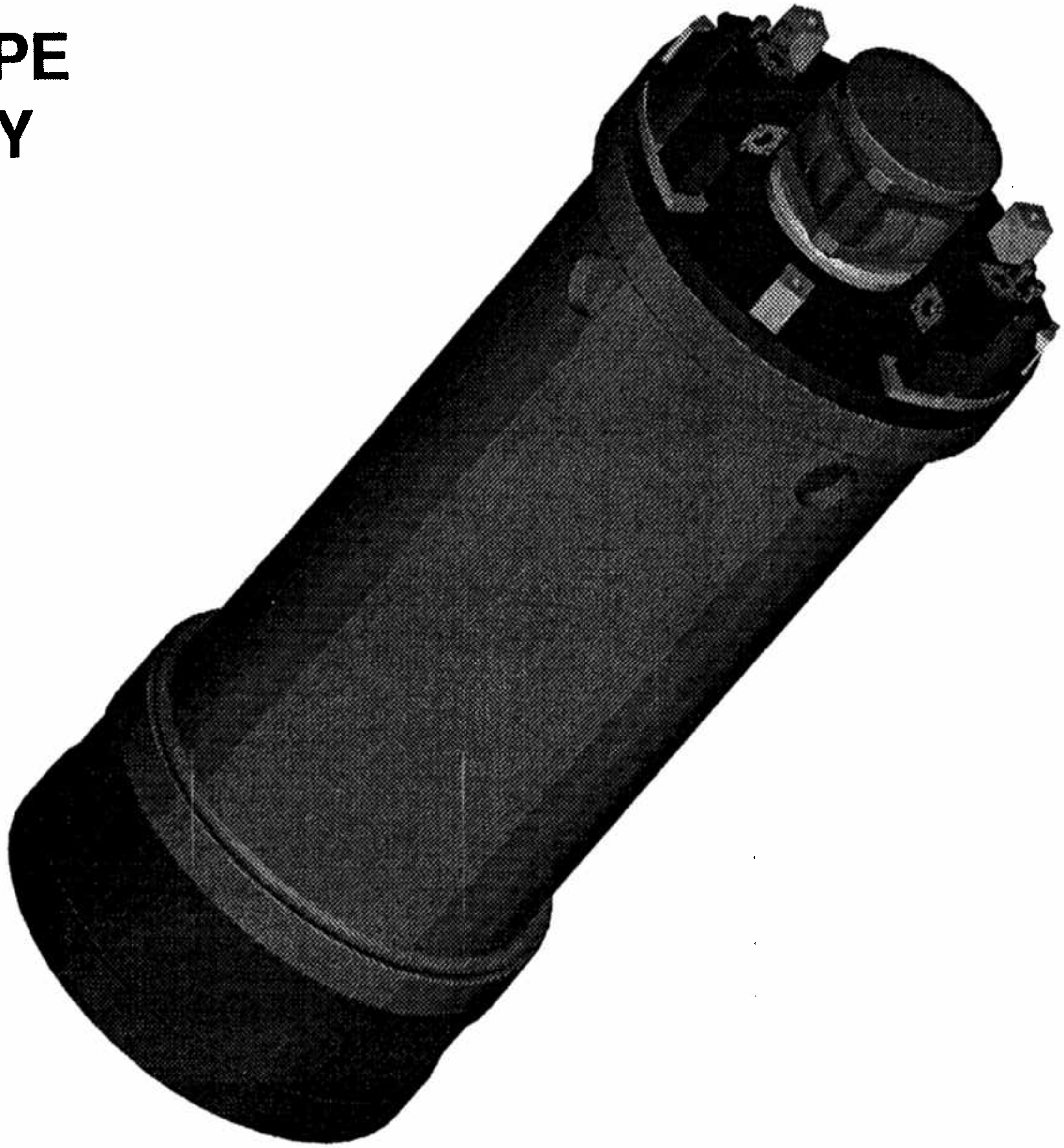
Specification/Requirements
Baseline Design
Hardware Status
Additional Development

TELESCOPE DETECTOR PACKAGE ASSEMBLY

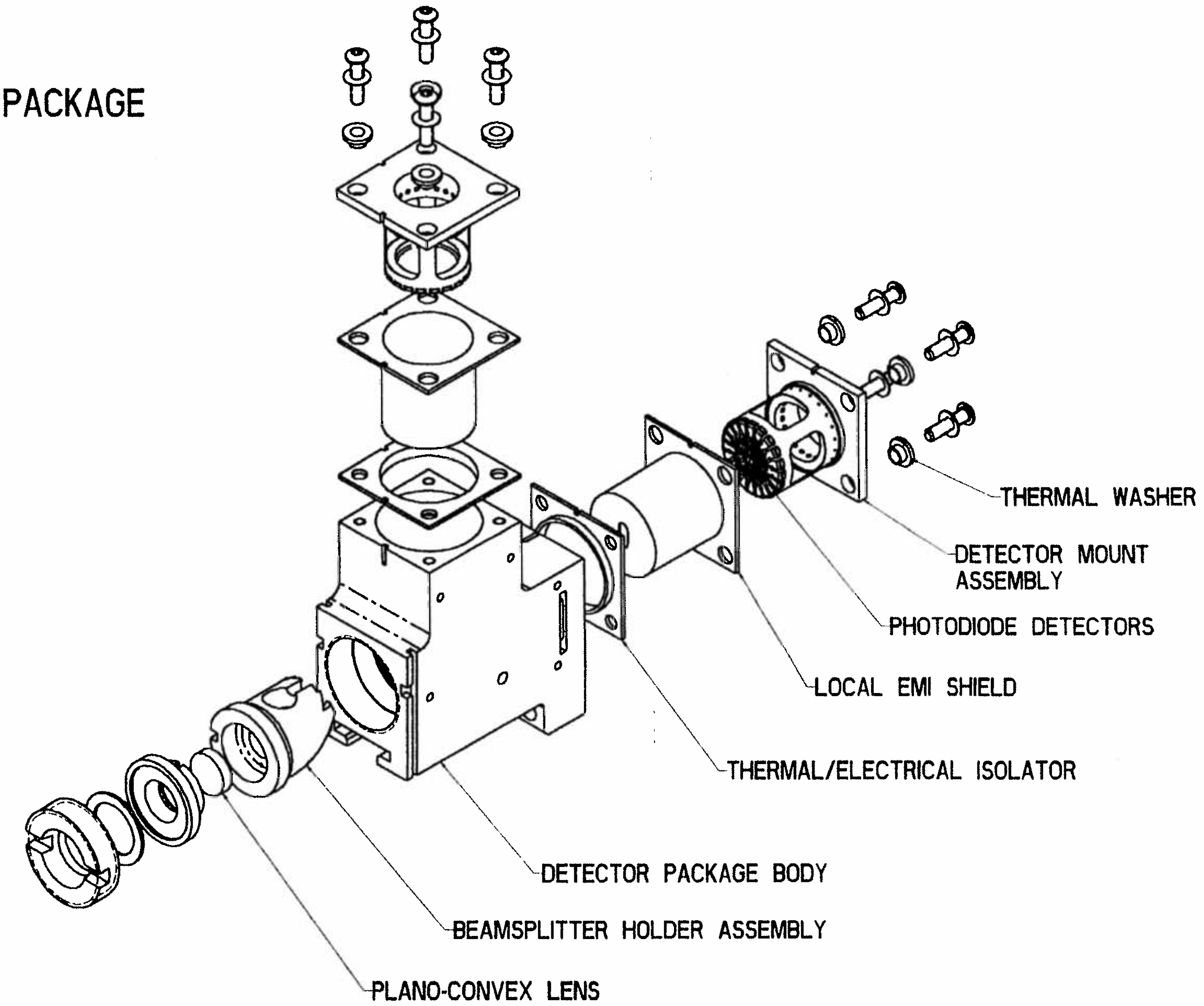
REQUIREMENTS

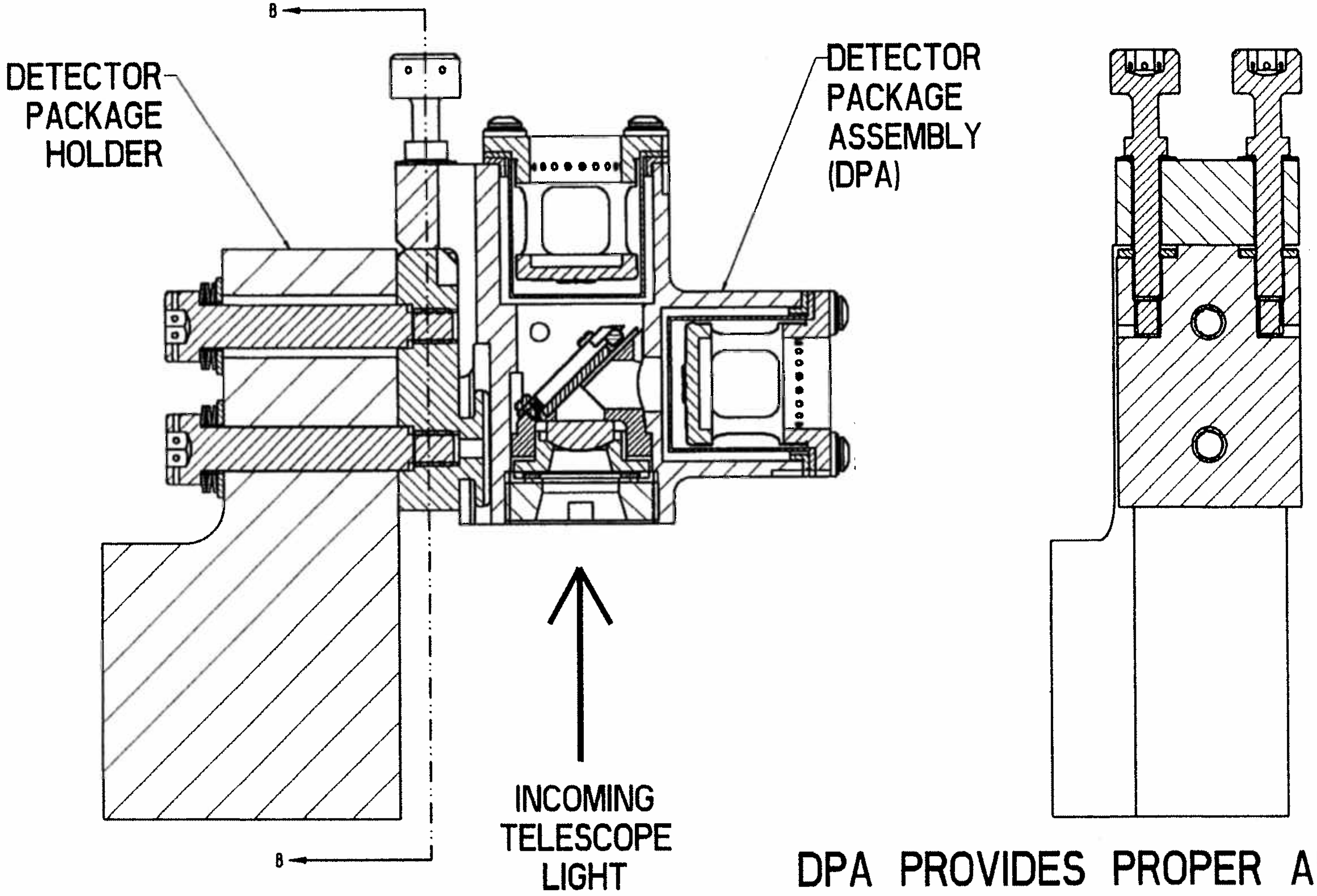
- Provide stable structural mounting for Telescope Detectors
- Thermally isolate 75 K JFETs from 3 K Telescope optics
- Provide isothermal platform to minimize temperature-induced JFET scale factor mismatch
- Provide electrical connection from cryogenic Telescope Read-Out electronics to Probe Top Hat
- Provide EMI shielding

TELESCOPE ASSEMBLY



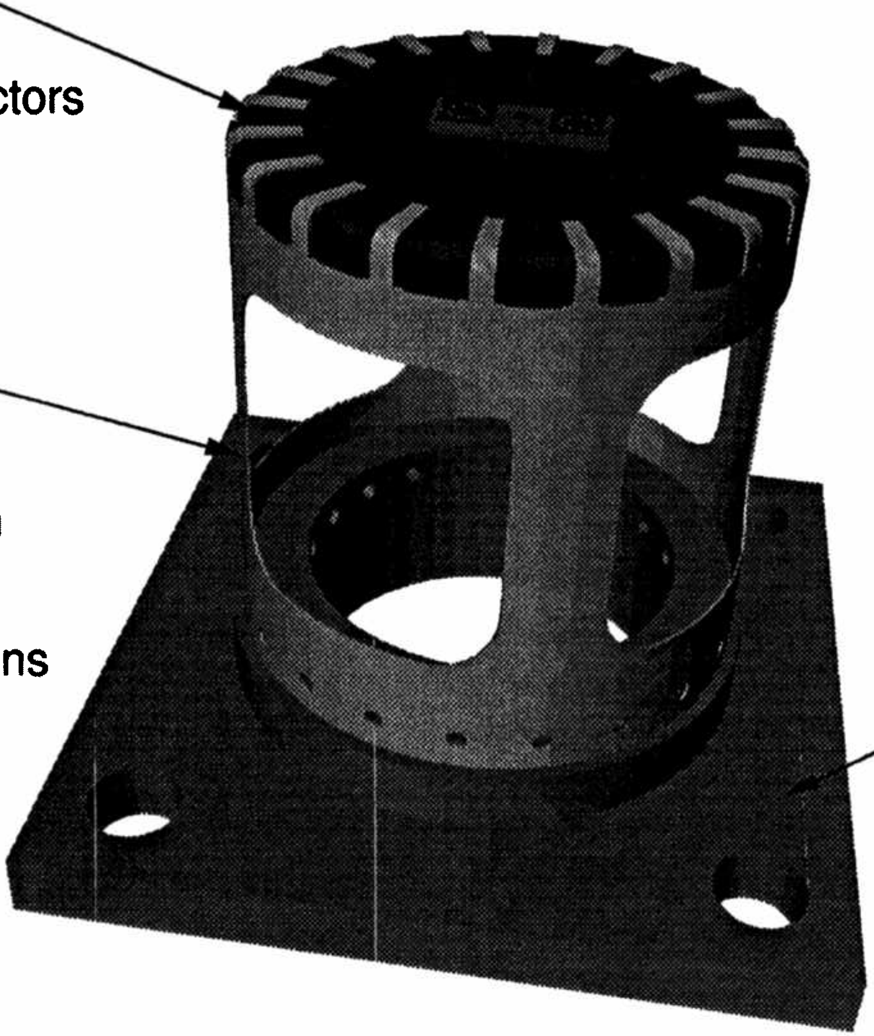
TELESCOPE DETECTOR PACKAGE ASSEMBLY





DPA PROVIDES PROPER ALIGNMENT OF PHOTODIODE DETECTORS TO TELESCOPE

DETECTOR MOUNT ASSEMBLY



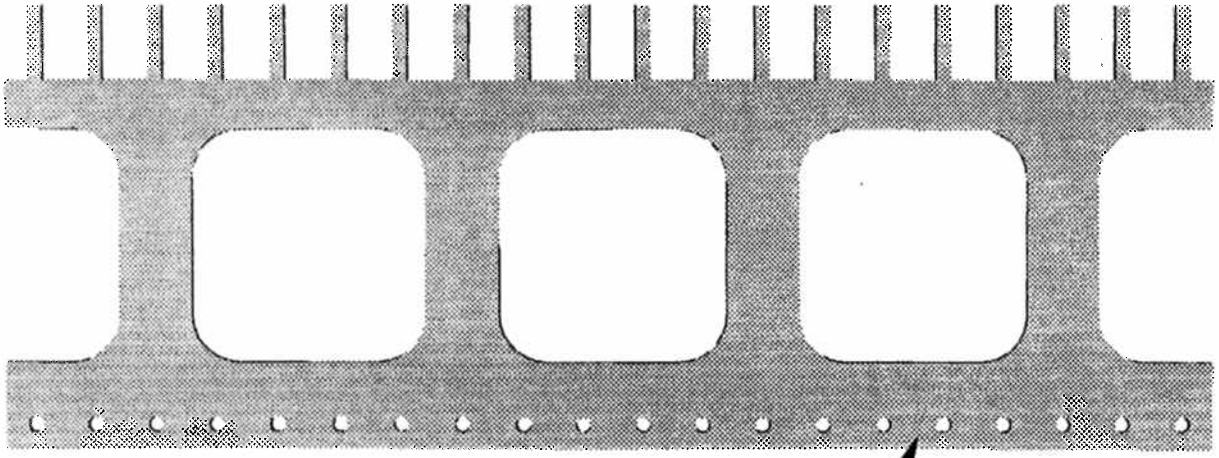
Thermal Platform
- Synthetic Sapphire
- 2 Photodiode Detectors
- Isothermal platform

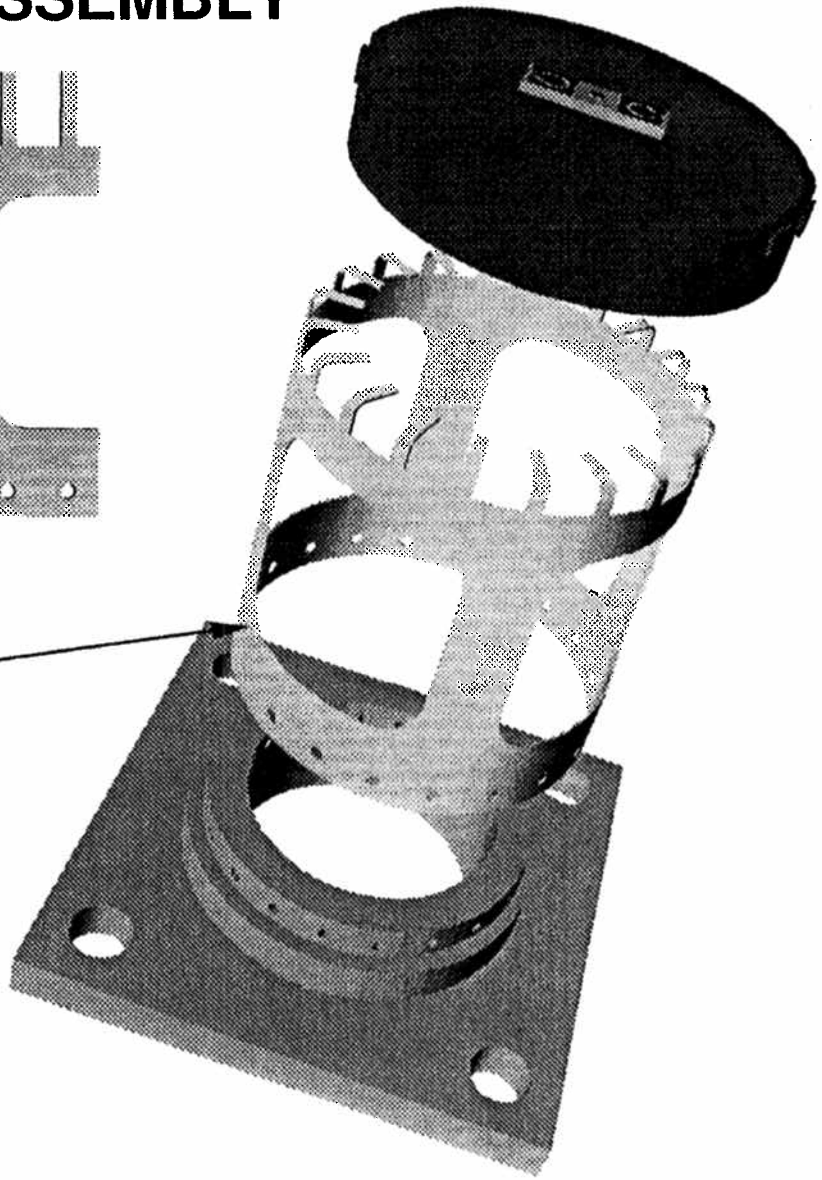
Thermal Isolator
- .002" thick Kapton
- .400" OD
- Copper Traces with Gold Overcoat
- Thermal isolation
- Electrical connections

Base
- Titanium
- Interface to Detector Package

Predicted Performance
- $f_o = 500$ Hz
- $q = 1$ mW for $\Delta T = 72$ K

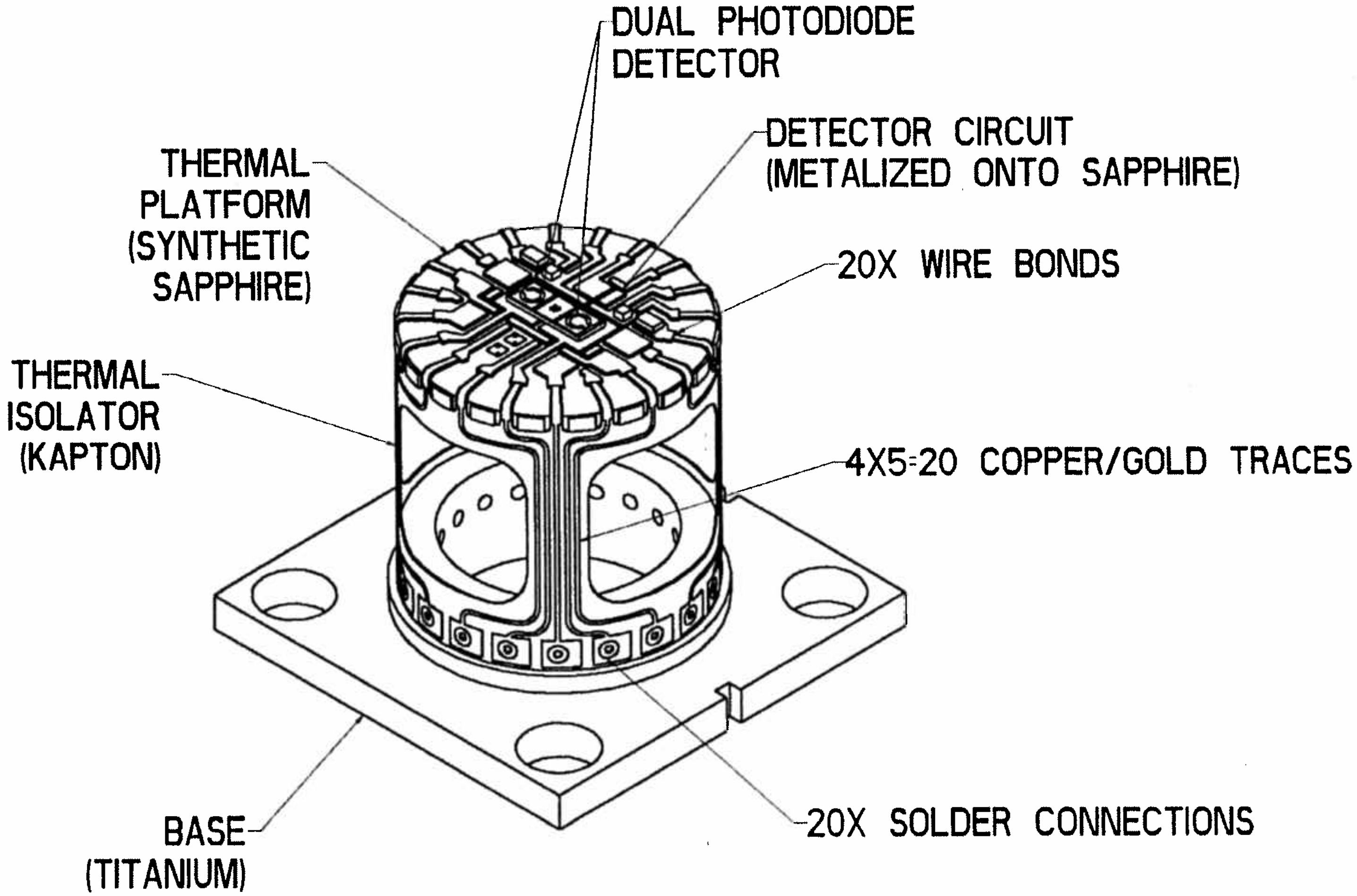
DETECTOR MOUNT ASSEMBLY





Detector Mount (Thermal Isolator)
- .002" Kapton sheet
- Pattern cut by reactive ion etch in flat form
- Electrical Leads photolithographically placed
    - ➤ 2500 angstroms Cu
    - ➤ 500 angstroms Au
- Rolled & glued
- Traces wire bonded to electrical contacts on top
- Wire bundle soldered to traces on bottom

DETECTOR MOUNT ASSEMBLY (DMA)



DETECTOR PACKAGE REQUIREMENTS

PLSE-13, Pt 3 Specification Number	Parameter Name		Required Value	Verification	Test Description
3.2.4, 3.2.5.1	Vibration		$f_0 \geq 100$ Hz	A & T	Shake table (ARC) & GTU-2
3.2.5.2.1, 3.2.5.2.2, 3.2.5.2.3	Alignment	Tip/Tilt	≤ 5 degrees	I & T	Room temperature mechanical & optical inspection; cryo qualification testing & GTU-2
		Defocus	≤ 200 μm		
		Decenter	≤ 100 μm		
3.2.6.1	Allowable Heat Transfer		≤ 1 mW	A & T	Cryo qual testing & GTU-2
3.2.5.3	Platform Temperature Variation		≤ 2 mK	A & T	GTU-2
3.2.5.4	Number of Electrical Leads		20	I	
3.2.5.5	Electrical Lead Resistance		≤ 100 Ω	A & T	Cryo qual testing & GTU-2
3.2.5.6.1, 3.2.5.6.2, 3.2.5.6.3	Temperature	Operational	2–80 K	T	RT & cryo qual testing & GTU-2
		Test	2–372 K		
3.2.5.7	EMI		TBS	T	EMI test booth & GTU-2

DETECTOR PACKAGE HARDWARE STATUS

DESIGN

- **Detector Mount Assembly (DMA) design completed**
  - Base, Thermal Isolator, & Thermal Platform drawings released
  - Assembly drawings in review
- **Detector Package Assembly (DPA) design completed**
  - Metallic & optical part drawings released
  - Assembly drawings in review
- **Detector Cable Assembly (DCA) design in process**
  - Thermal & electrical grounding paths determined
  - Interfaces coordinated with Lockheed-Martin
  - Detailed design underway

DETECTOR PACKAGE HARDWARE STATUS (cont'd)

FABRICATION

- **All Detector Mount Assembly parts expected by May 10**
  - Additional Thermal Isolators being made as backup
- **All Detector Package Assembly parts expected by May 15**
  - 982 piece parts (many spares) currently being delivered by Watts Machining and FM Industries (flight-approved vendors)
  - Mechanical & magnetic inspection to be done in parallel with Integration & Testing
- **Detector Cable Assembly parts being developed**
  - GTU-2 Cable interfaces are different than for Science Mission
    - ➤ GTU-2 uses Probe B
    - ➤ SM uses Probe C
  - GTU-2 Detector Cable Assembly will be made to support a single Detector Package channel (no redundancy)
  - SM DCA will support 4 DPA channels

DETECTOR PACKAGE HARDWARE STATUS (cont'd)

HARDWARE SUMMARY

Part #	Part Name	Design Comp'd	Dwg Released	Material Ordered	Material Rec'd	Material Appr'd	Material Issued	Parts Ordered	Parts Rec'd	Parts Insp'd	Parts Mag Accept'd
25071-101	Body, Detector Package	■	■	■	■	■	■	■			
25072-101	Mount, BS, Detector	■	■	■	■	■	■	■			
25073-101	Lens, Plano-Convex	■	■	■	■	■	■	■	■		
25074-101	Lens, BS, Detector	■	■	■	■	■	■	■	■		
25075-101	Fastener, Bezel	■	■	■	■	■	■	■	■		
25337-101	Clamp, Beamsplitter	■	■	■	■	■	■	■	■		
25342-101	Bezel, Lens	■	■	■	■	■	■	■	■		
25381-101	Washer, Wave Spring	■	■	■	■	■	■	■			
25408-101	Isolator, Thermal	■	■	■	■	■	■	■			
25409-101	Platform, Thermal	■	■	■	■	■	■	■	■		
25410-101	Base, Detector Mount	■	■	■	■	■	■	■	■		
25411-101	Shield, Ground	■	■	■	■	■	■	■	■		
25413-101	Washer, Insulating	■	■	■	■	■	■	■	■		
25417-101	Washer, Shoulder	■	■	■	■	■	■	■	■		
25453-101	Washer, Flat, Det Pack	■	■	■	■	■	■	■			
25454-101	T-Bolt, Detector Package	■	■	■	■	■	■	■			
25457-107	Screw, SBHC, #0-80 x .25	■	■	■	■	■	■	■	■		
25458-101	Washer, Belleville, #0	■	■	■	■	■	■	■	■		
25458-104	Washer, Belleville, #2	■	■	■	■	■	■	■	■		
25458-108	Washer, Belleville, #6	■	■	■	■	■	■	■	■		
25463-101	Screw, Shoulder, Det Pack	■	■	■	■	■	■	■	■		
25464-101	Screw, Pn Head, .80 UNM	■	■	■	■	■	■	■	■		
25487-101	Screw, Captive, DPA	■	■	■	■	■	■	■	■		
25488-101	Washer, Captive, DPA	■	■	■	■	■	■	■	■		
25489-101	Key, Beamsplitter Mount	■	■	■	■	■	■	■	■		

DETECTOR PACKAGE HARDWARE STATUS (cont'd)

INTEGRATION & TESTING

- **Assembly of Detector Package in process**
  - ➊ Mechanical assembly of Detector Mount Assembly
    - ➤ Glue Base, Isolator, & Platform (Stycast 1266 epoxy)
    - ➤ Solder cable wires to traces (Indalloy #1 solder)
    - ➤ Wire bond traces to circuit (Gold wire)
  - ➋ Electrical testing of DMA
  - ➌ Assemble Package parts
  - ➍ Opto-mechanical alignment—Phase 1
    - ➤ Plano-convex lens centered in Package Body
    - ➤ Beamsplitter Assembly installed
  - ➎ Detector Mount Assemblies integrated with Detector Package Assembly
  - ➏ Opto-mechanical alignment—Phase 2
    - ➤ Detectors aligned with plano-convex lens and beamsplitter
  - ➐ Final electrical test
  - ➑ Detector Package Assembly ready for integration with Telescope

- **Fully integrated Detector Package expected June 21**

DETECTOR PACKAGE ASSEMBLY DEVELOPMENT

FUTURE EFFORTS

- **Thermal Isolator fabrication**
  - Refine epoxy bonding application
    - ➤ Investigating precision dispensers
  - Improve gold passivation of copper traces
    - ➤ Oromerse
    - ➤ Titanium barrier layer
  - Develop assembly and alignment jigs
  - Evaluate alternate wire bond materials
    - ➤ Lead/Tin/Gold
    - ➤ Aluminum

- **Cryogenic thermal cycling**

- **Thermal modelling of DMA and DPA/SIA system**

- **Vibration testing of Detector Package Assembly**

- **EMI testing of Detector Cable Assembly prototype**

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

QUALITY ASSURANCE AND RELIABILITY FOR TRE DETECTOR

F. BERKOWITZ

Quality Provisions
Fabrication
Procurement
Status

- **Quality Provisions per SU's "Science Mission Quality Plan" P0108**
- **Configuration Control per “Science Mission Configuration Management Plan” P0098**
  - Drawings Release through Drawing Release Review and Change Control (ECB)
  - Drawing tree updated as required; controlled trough drawing release process
  - Changes of requirements through Program Change Board (PCB)
  - Changes of Drawings through Engineering Change Board (ECB)
- **Fabrication Control:**
  - Identification, Traveler, As-Built Configuration
  - Workmanship
  - Special Processes: Per written procedures
  - ESD Control per MIL-STD-1686A
  - Authorized fabricators complete specialized training (e.g. soldering course)

- **Inspection and Tests:**
  - Incoming inspection for workmanship and functional
  - Dimensional Inspection: 100% per the approved drawings
  - Tests: Per written and approved procedures
  - Periodic calibrated equipment for RE defined final/specs tests
- **Configuration and Test Database**
  - Database includes:

    Requirements, Specs and other documents, Reviews and Action Items, PCBs
  - Inclusion in process :

    ECOs, DR's, Drawing Tree, Components, As-Built Configuration, Tests Plans and Tests Results etc.
- **Nonconformance Control:**
  - Discrepancy Reports including Analysis and Corrective Action.
  - Disposition by Material Review Board (MRB).

- **Procurement Control**
  - Vendors selection from SU Approved Vendors List
  - Vendors Quality System meets the requirements of MIL I 45208A
  - Procurement document reviewed by the Quality Engineer
- **Reliability:**
  - FMECA to be completed.
- **Reports:**
  - All Discrepancy Reports (DRs) and Engineering Changes ECOs are reported to NASA in the Monthly Reviews

Parts Status for Telescope Read Out Detector. As of 5/2/96

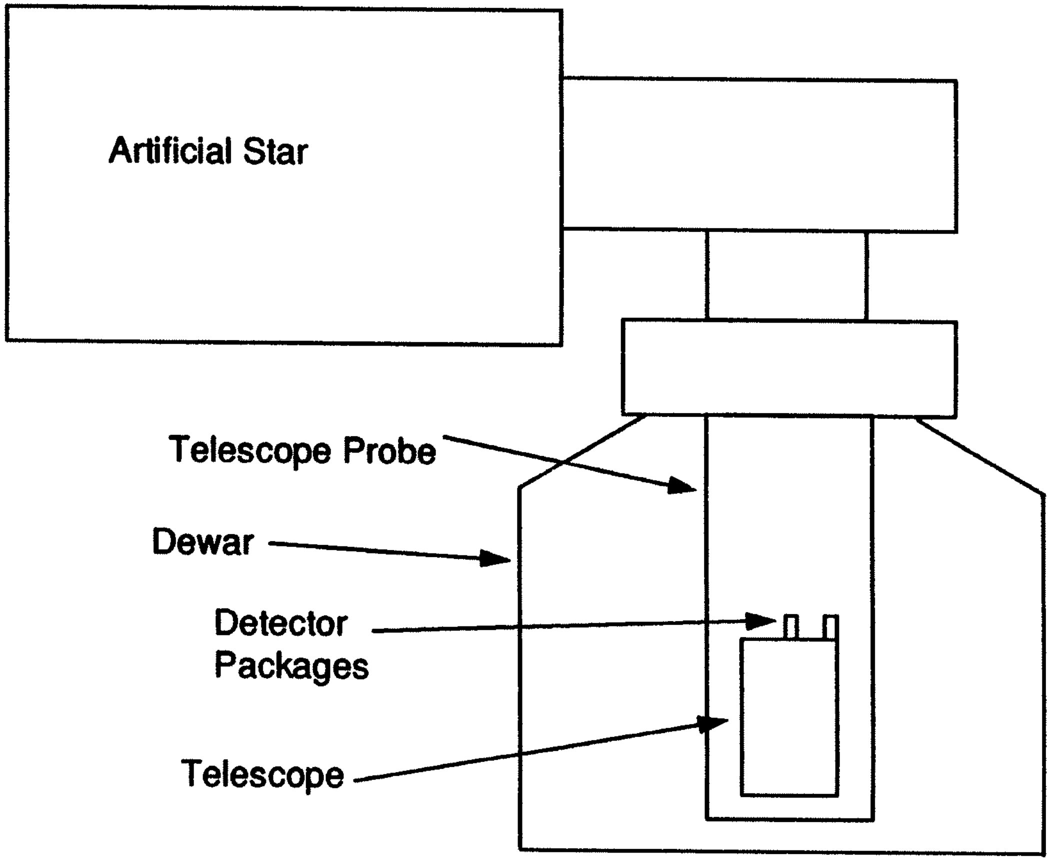
#	Part Title	Qty per Assy	Vendor	Qty ordered	RFQ date	Date ordered	Promised date	Recvd date	PO #	Total Cost	notes
1	Photodiode die	2	Centronics	100+100		3/14/95	6/19/95	7/3/95	E035220	$40,600.00	Extra 50 units, for assembly practice have been received (free of charge) on 7-24-95
1.1	Photodiode die - 100 of each (.8 and .5)	2	Centronics	100+100		12/4/95	6 WEEKS	~1/1/1996	E405660	$17,700.00	
2	Differential FET die	4	NASA Goddard	160 a		2/2/95	4/1/95	8/24/95*		$60,000.00	
3	Current source resistor,die		Mini System Inc.	440 d		same 6	7/21/95	partially	E13523	$7,635.00	Kim Barlow will call on 8-29-95 for new delivery date
4	Reset FET die	2	InterFet	180		5/22/95	Original: 7/21/95 Current:	2/2/96	E13516	$1,257.00	Shipment problems, can't pack as req., will agree and proceed
5	Capacitor die	2	Electro Films Inc.	10000 b		4/25/95	5/16/95 c Revised: 9/30/95	no	E09523	$1,020.00	8-28-95: RFQ was faxed to second source- California Micro Devices
5.1	Capacitor die UNCA-129-5000DL	2	Electro Films Inc.	10000 b	2/5/96	2/8/96	12 weeks		E508200	$485.00	@ dice, Expected : end May
6	Heat Resistor	1	Mini System Inc.	same as item 6		5/22/95	7/21/95		See item 3	$7,635.00	
6.1	Resistor#MSTF 2SN-80000B-X, 10000, 12001	1	Mini System Inc.	110*3	1/10/96	1/29/96	8w + 4w		E485150	$4,423.00	Expected: 5-10-96
7	Si Temperature sensor	1	Univ. of Southampton, Inst. of Cryogenics,	100		7/12/95	7/21/95		U3XD E21192	$1,600.00	Initial order not including tests.
7.1	Si Temperature sensor	1	Univ. of Southampton, Inst. of Cryogenics,	200	12/22/95	2/1/96	??			$9,628.00	ordered
8	Thermal platform disc	1	Meller Optics	250		4/21/95	6/19/95	7/13/95	E09139	$2,287.00	Mark - received 20, sent 5 to Goddard
9	Support tube	16	IR Laboratories	17		6/8/95	7/14/95		U3XD E155880	$1,882.00	Non flight parts.
	Total cost for parts:									$156,152	
	Notes										
	a. Fourth wafer, the first to meet room temp. requirements.										
	b. Whole wafer										
	c. Without life test										
	d. 110 of 4 different resistance values flight chips + 100 x 4 non-flight.										
	e. Passed promised date										

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

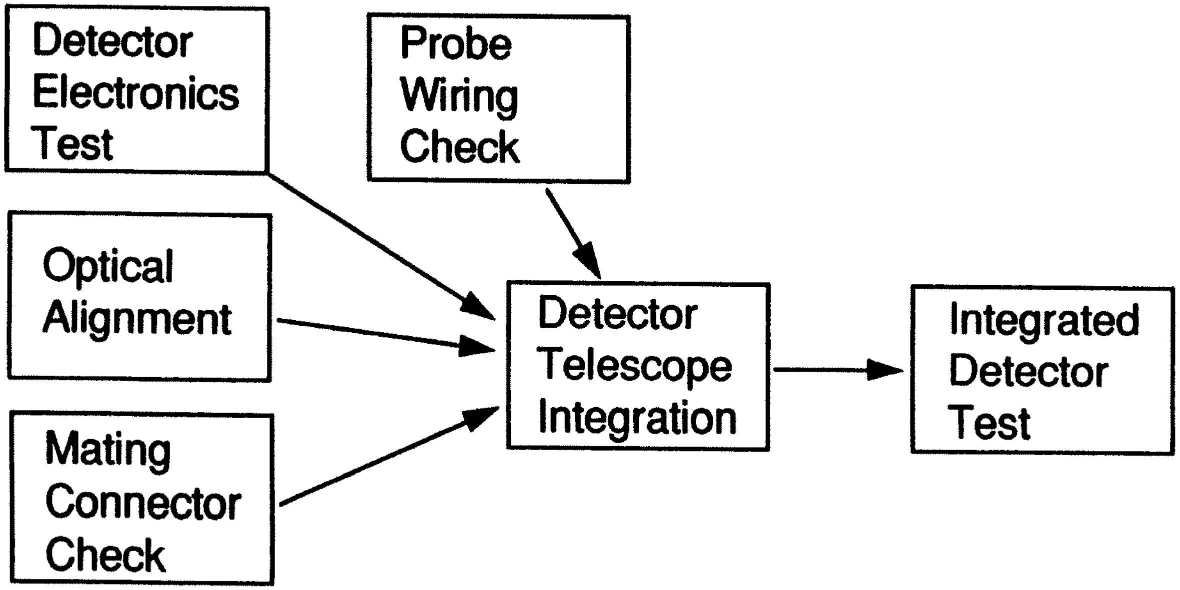
TRE DETECTOR TO TELESCOPE INTEGRATION

S. WANG

TRE Detector to Telescope Integration and Testing



TRE Detector Integration Test Flow



Detector Electronics Test

Probe Wiring Check

Optical Alignment

Mating Connector Check

Detector Telescope Integration

Integrated Detector Test

TRE Detector to Telescope Integration and Testing

Telescope Electronics CDR **May 8, 1996**

I. Pre-integration:

♦ Qualification Testing Before Integration:

- Radiation
- Magnetics
- Calibration of Thermometers on the Thermal Platforms
- Temperature on Thermal Platform Measured as a Function of Heating Power
- Functional Performance of TIA Mode
- Cross Talk Between the Channels
- Calibration of Output as a Function of Photo Current
- Test Results of Noise, Linearity, Sensitivity and Photodiode Surface Uniformity
- Thermal Cycle Reproducibility

- Qualification Testing Before Integration (Cont'd)
    - Long Term Stability of Better Than 0.05% for At Least Hours*
    - Output Sensitivity on Temperature of the Thermal Platform
    - Room Temperature Dependence of the Output
    - Operational at 10 fA, 10 pA and 10 nA Photo Current Levels at 4.2 K and 2 K Ambient Temperature
    - Operational at 10 pA Photo Current at Temperatures Ranging from 300 K to 4.2 K Ambient
- Confirm The Optical Alignment of Detectors Packages
    - Raster Scan Results to Show the Centering of Light Spots on the Photodiodes
- Check Mating Connector on the Telescope Probe -- Magnetics, Continuity

- Check Wiring on the Telescope Probe -- Continuity

II. Integration Process

- Integration Procedure
  - Performed In Class 10 Clean Room
  - Non Magnetic Tools for Flight Parts
  - Proper Thermal and Mechanical Anchoring of Wires
  - Limit Light Input Through Telescope Aperture to Non-Collimated Room Levels for the Protection of Detectors

III. Integrated Tests

- Verification of Noise Performance
- Verification of Cross Talk

TRE Detector to Telescope Integration and Testing

- Measurement of Temperature Stability of the Thermal Platform
- Temperature Control of Room Temperature Electronics *

*

- ♦ NEED A FEW HOURS TO PERFORM A LINEARITY SCAN ON TELESCOPE
- ♦ THE ELECTRONICS OUTPUT NEEDS TO BE STABLE TO 0.05% DURING THE SCAN
- ♦ AIR CONDITIONER CAN CONTROL TEMPERATURE TO 1 DEGREE WITH A PERIOD OF 20 MIN.
- ♦ DRIFT OF ELECTRONICS IS MOSTLY FROM TEMPERATURE FLUCTUATIONS

⇒ NEED TEMPERATURE CONTROL OF ROOM TEMPERATURE ELECTRONICS TO ACHIEVE READOUT STABILITY

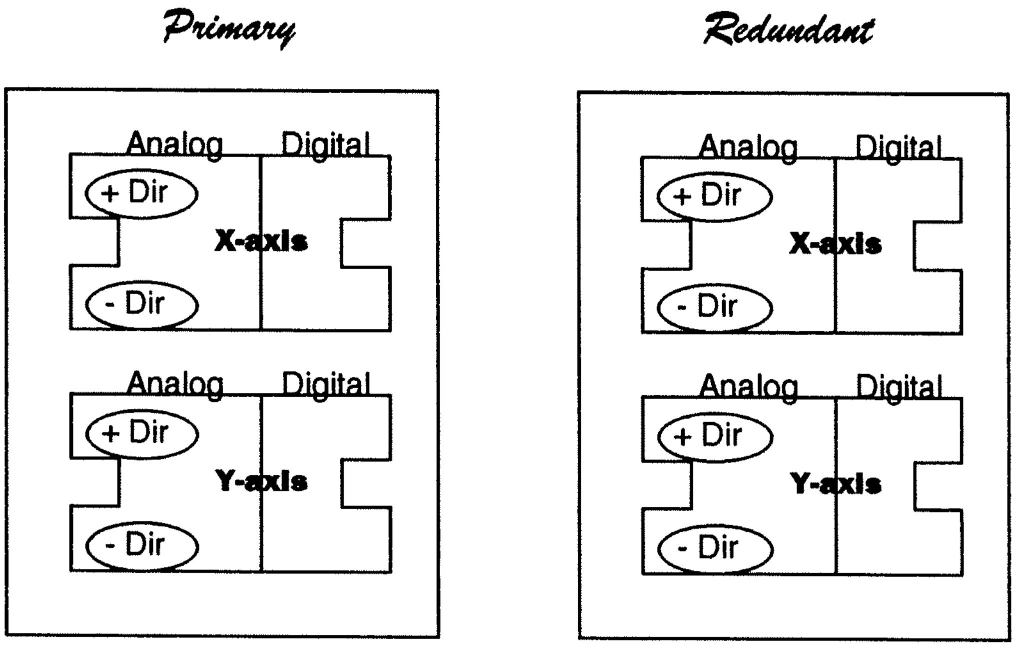
TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

TRE FWD ELECTRONICS DESIGN

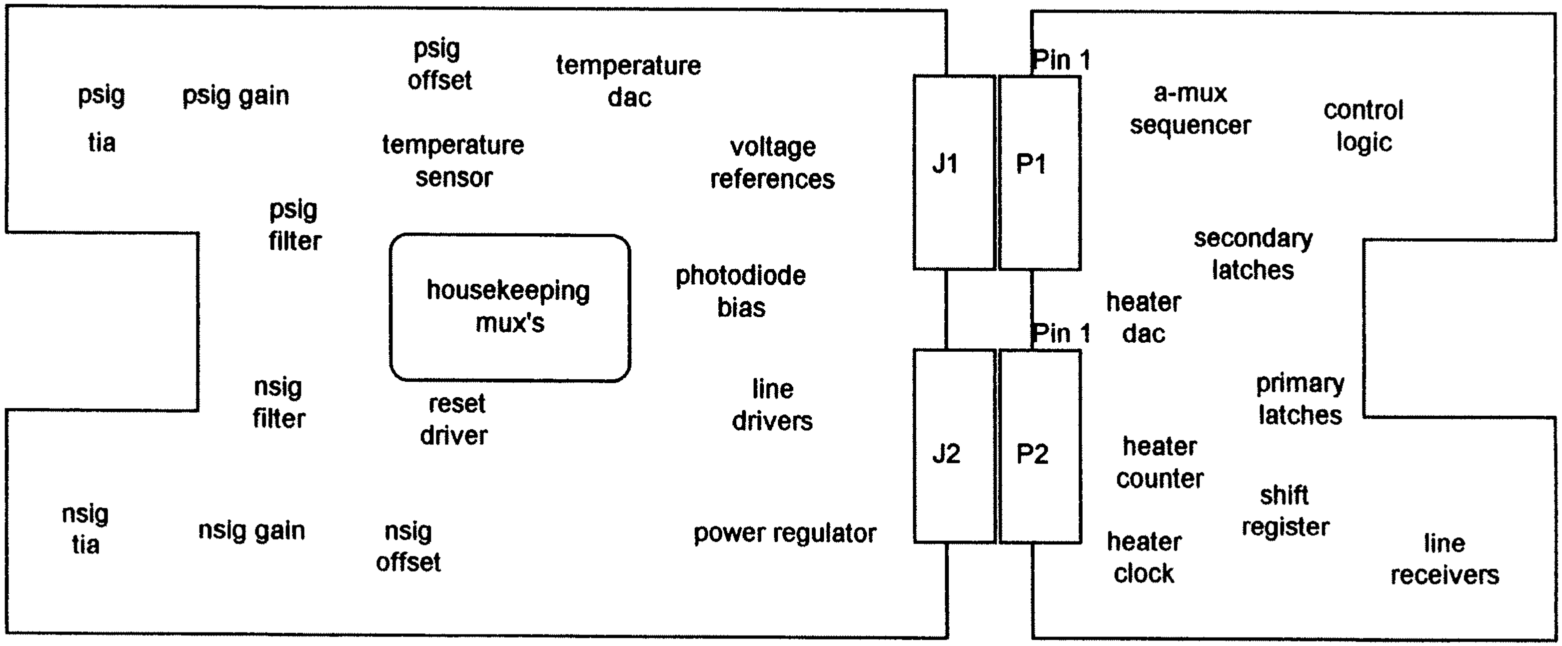
R. FARLEY

Partition
Charge-locked loop
Signal paths
Operation Modes
Detector Support Functions
FEE Cables

TRE FWD

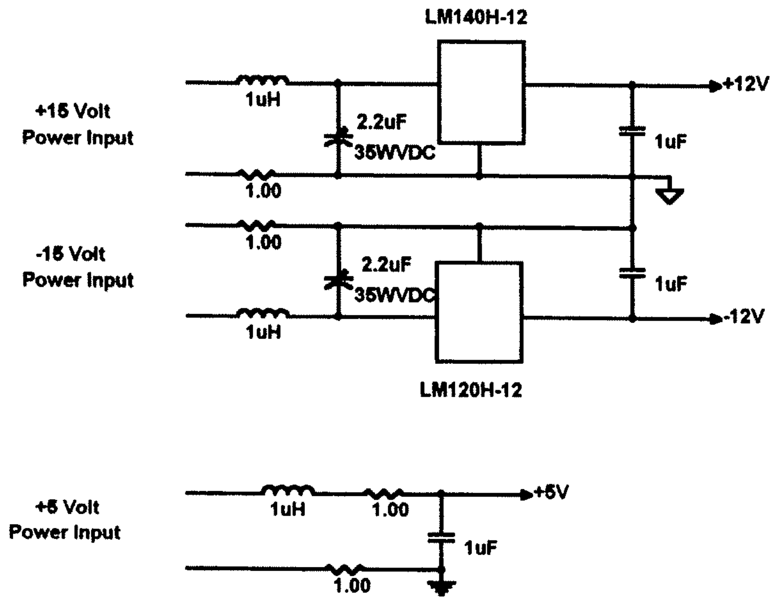

Primary
Redundant
Analog
Digital
+ Dir
X-axis
- Dir
Analog
Digital
+ Dir
Y-axis
- Dir
Analog
Digital
+ Dir
X-axis
- Dir
Analog
Digital
+ Dir
Y-axis
- Dir

TRE Circuits



A layout aid used for assigning connector pins.

TRE Local Power Inputs



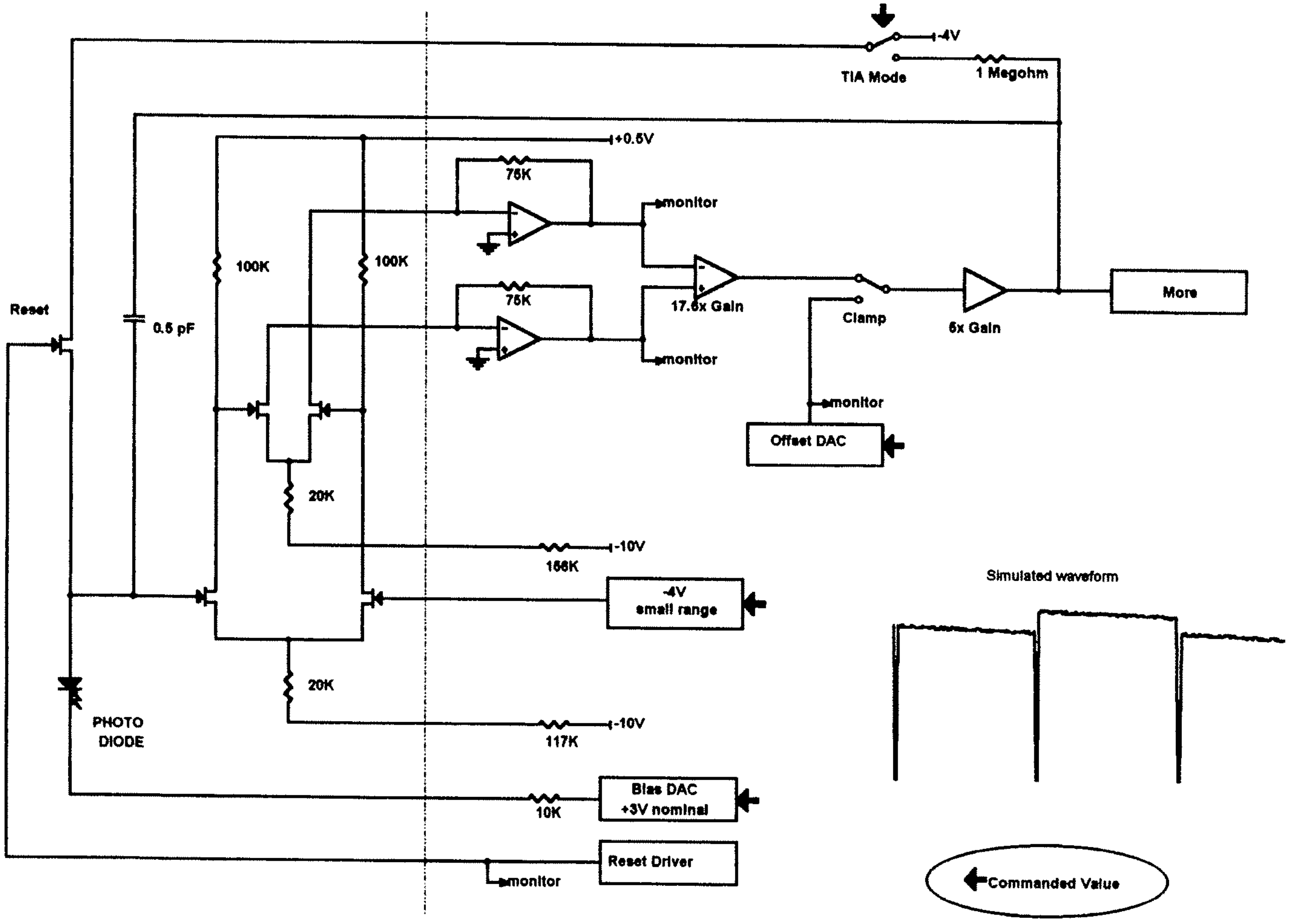
LM140H-12/883
TO-39 Metal Can
12V, 1A

LM120H-12/883
TO-39 Metal Can (Input)
-12V, 0.2/0.5A

- **Linear regulators are located on the Analog Board.**
- **Regulators will require heat sinks.**
- **Five volts used mostly on the Digital Board.**

The Charge Locked Loop

Simplified Schematic



Analog Signal Path

Open loop beyond the CLL

CLL

16 TAP LADDER ATTENUATOR 3dB / STEP

ANALOG MULTIPLEXER

31.9 x GAIN TRACK/HOLD AMPLIFIER

500 HERTZ LOW PASS FILTER 4 x GAIN

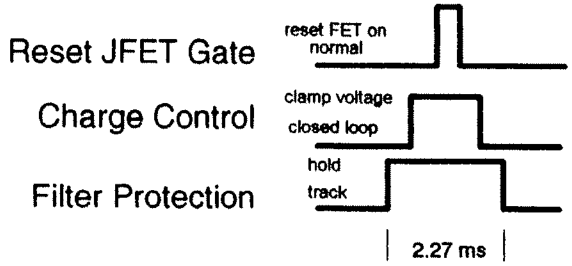
DIFFERENTIAL LINE DRIVER 20 x GAIN

+/-10 volts line to line

- **The +direction signal and the -direction signal paths must have very high gain stability to minimize errors.**

- **With no attenuation, the Detector Signal Transfer gain is estimated to be ≈5.1 v/(sec-fA)**

The Charge Locked Loop Reset Cycle



- **The rising edge of the 2.2 kHz Data Acquisition clock after the rise of the ATC strobe initiates a data hold period at the input of the 500 Hz low pass filter.**

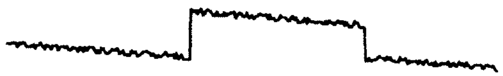
- **The detector feedback loop is opened, and the CLL output level is driven to a programmed offset voltage sufficient to cause the closed loop output level to be near zero volts.**

- **The reset JFET is activated, discharging the photodetector, and preloading the feedback capacitor.**

- **The reset JFET is turned off, dumping a small amount of charge onto the photodetector anode.**

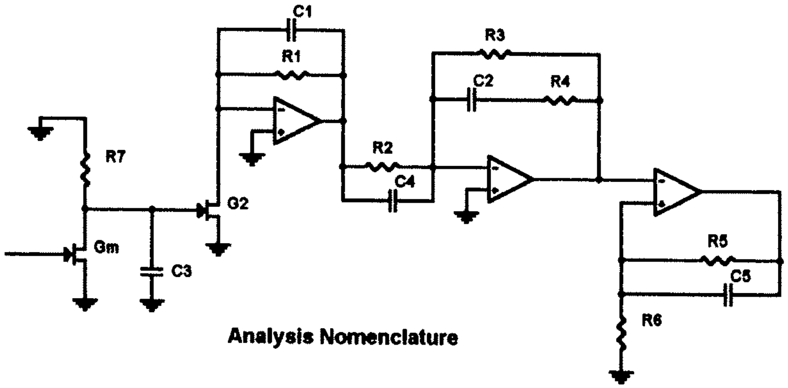
- **The feedback loop is closed, and a transient decays.**

- **The track/hold returns to its input following state, minimizing the transient applied to the low pass filter input.**



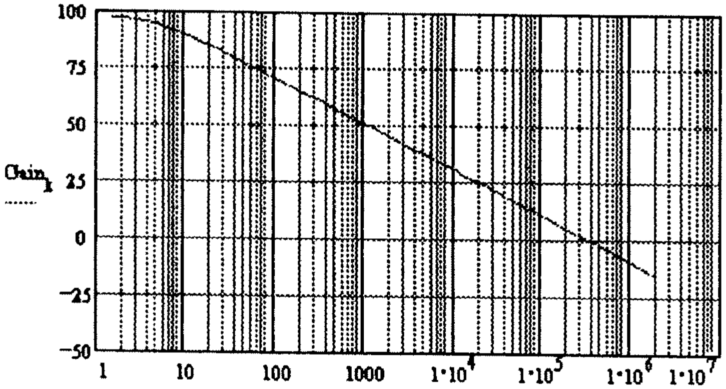
Simulated waveform after the Track / Hold circuit

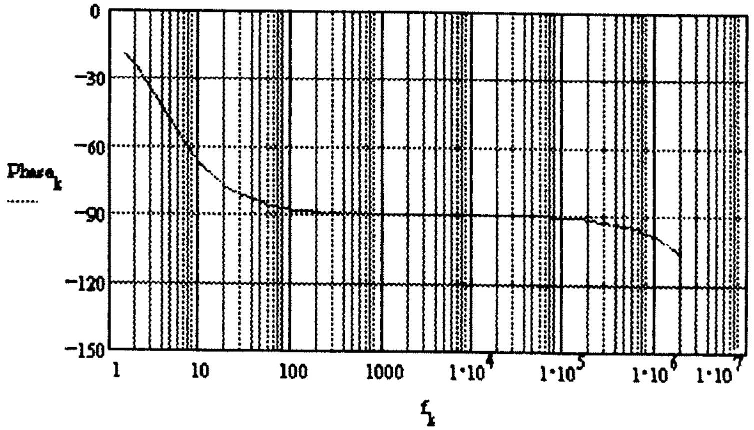
Open Loop Transfer Function of the CLL



Analysis Nomenclature

$$F(s) := g_m \cdot g_2 \cdot \frac{R_1}{\left(1 + C_1 \cdot s \cdot R_1\right)} \cdot \frac{R_3 \cdot \left(R_4 \cdot C_2 \cdot s + 1\right) \cdot \left(1 + C_4 \cdot s \cdot R_2\right)}{\left[\left(R_3 \cdot C_2 \cdot s + R_4 \cdot C_2 \cdot s + 1\right) \cdot R_2\right]} \cdot \frac{\left(R_5 + R_6 + R_6 \cdot s \cdot C_5 \cdot R_5\right)}{\left[\left(1 + s \cdot C_5 \cdot R_5\right) \cdot R_6\right]} \cdot \frac{R_7}{1 + R_7 \cdot C_3 \cdot s}$$

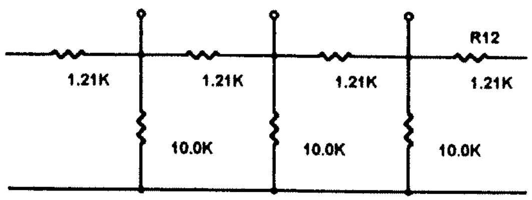




Gain Control Implementation

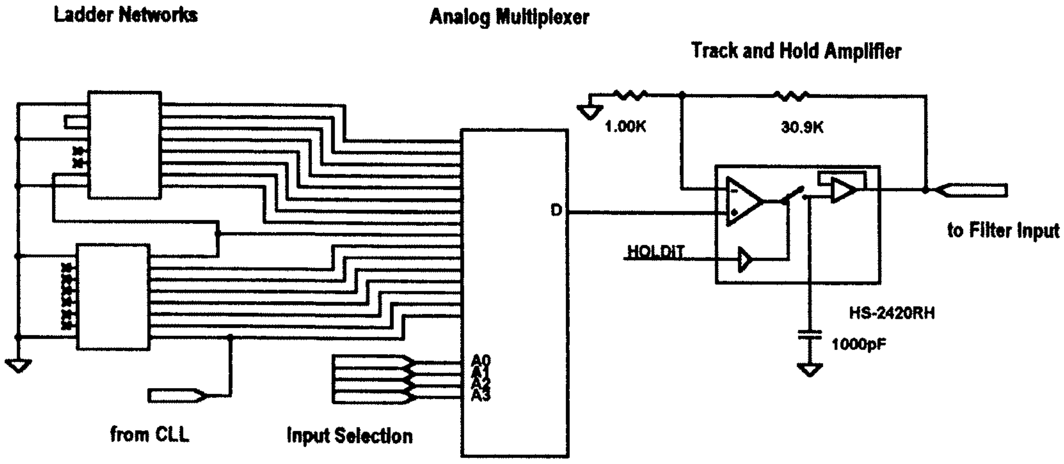
- Each detector channel gain is selectable over a range of 256 to 1 in 3dB steps.
- Gain control allows optimal matching of input signal to A/D converter for alternative sources; not intended for plus / minus direction channel matching.
- Resistor ladder network provides 1/√2 gain per tap. Node resistance is 1.71KΩ. A rad hard 16 Channel Analog Multiplexer selects output tap. Constant impedance at each tap implies uniform frequency response for region of interest.
- This approach uses fewer control bits and less power than a multiplying DAC.

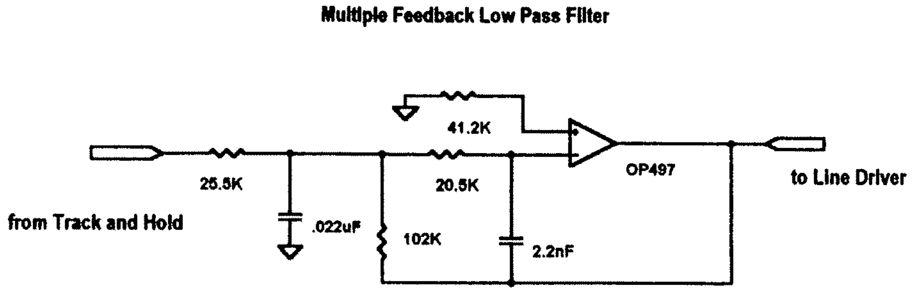
Partial Resistor Network

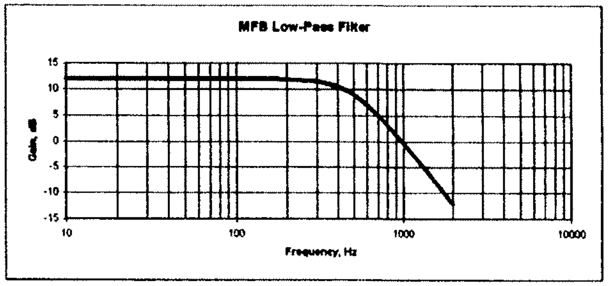


- Design approach is practical, and can achieve good matching between channels by using stable, accurate components.
  - Custom resistor packs from Vishay with ±0.02% absolute tolerance, ±0.6 ppm/°C absolute TCR.
  - 16-pin dual in-line package is symmetrical with optional terminating resistors at each end to allow cascading, and layout flexibility.

Analog Signal Conditioning





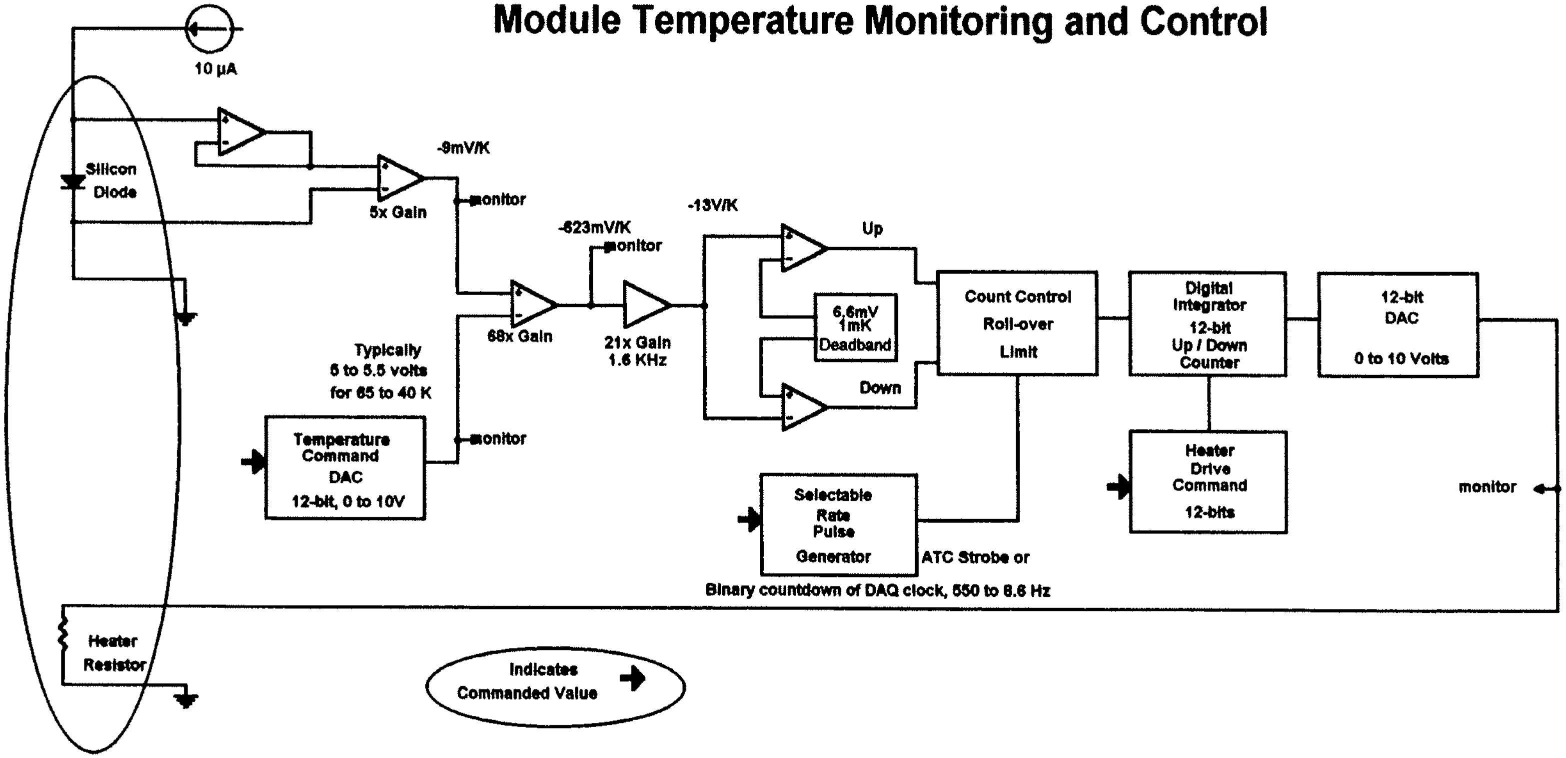


Control Modes Allow Diagnostics

- The Charge Locked Loop options:
  - Normally the detectors are reset at a periodic rate (ATC Strobe). The feedback is through the 0.5 pF capacitor.
  - <u>Detector Power Enable</u>--connects the -10 volt reference to the source resistors.
  - <u>TIA Mode</u>--The periodic reset cycle is halted. Feedback to the detector node is via the turned-on reset JFET through a 1 MΩ resistor.
  - <u>Inhibit Cycle</u>--a diagnostic mode that inhibits the reset clocks, but the 1 MΩ resistor is not connected.
  - Two control bits invert the sense of the reset clock and the output clamp switch.
    - When <u>INVGAT</u>=0, the TIA amplifier output is driven from the focal plane module; when <u>INVGAT</u>=1, the TIA output is driven from the offset (clamp voltage) DAC.
    - When <u>INVRST</u>=0 the gate drive to the reset JFETs turns the device on; when <u>INVRST</u>=1 the reset JFET is turned off.

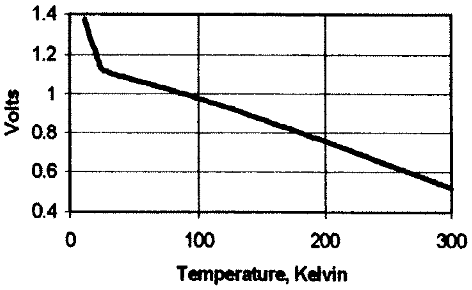
- The Engineering Data channel options:
  - The analog multiplexer is normally sequenced through up to 27 signals during the 1/10th second interval.
  - Setting a control bit causes the multiplexer to monitor a specific channel for the whole period. The channel is selected by five address bits.

Module Temperature Monitoring and Control

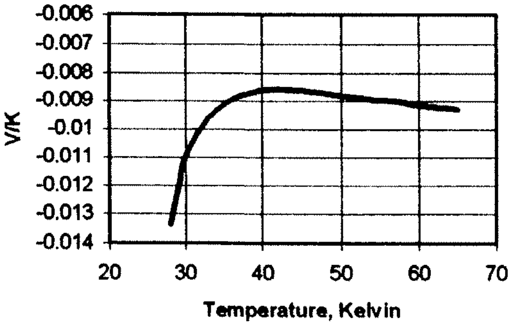


- **Open Loop Control drives heater dac with 12 bit value received from SRE.**
- **Local Closed Loop Control drives heater dac from an up/down counter, updated on temperature error.**

Standard Curve #10



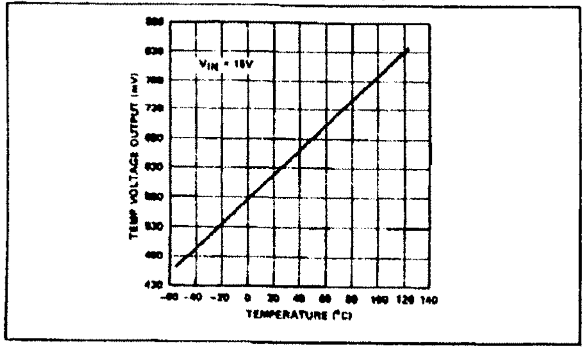
Scale Factor after 5x Gain



TRE Box Temperature Measurement

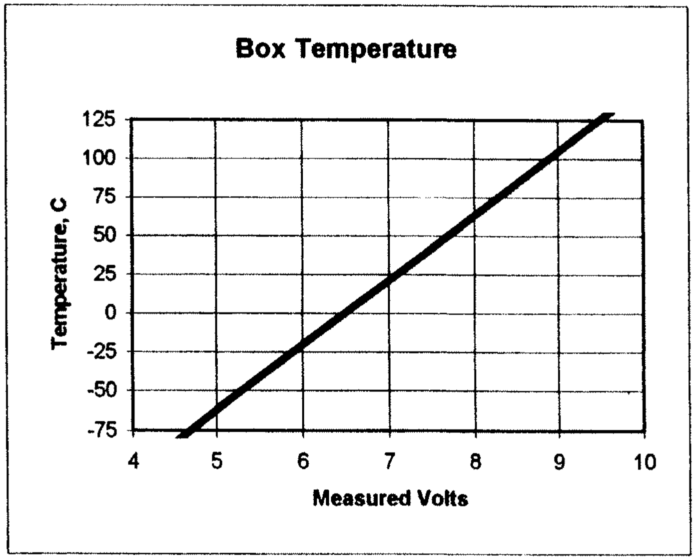
- Uses the Temperature output of the REF02 that generates the +5 volt reference voltage.
- Output is amplified with low offset voltage non inverting amplifier.

TYPICAL TEMPERATURE VOLTAGE OUTPUT vs TEMPERATURE (REF-02A)



Plot from the data sheet.

Voltage as indicated by Engineering Data A/D Converter



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The Engineering Data Channel

Multiplexed analog voltages

- **23 of the 27 available periods have monitored signals, the remaining channels are grounded.**

signal name	gain*		
TRE-A/B +X/Y Transimpedance Signal Voltage	**0.6667**	**TRE-A/B X/Y Temperature Command DAC**	**0.6667**
TRE-A/B +X/Y Transimpedance Reference Voltage	**0.6667**	**TRE-A/B X/Y Temperature servo error**	**0.6667**
TRE-A/B +X/Y Offset DAC Output	**2.0000**	**TRE-A/B X/Y +12V**	**0.6667**
TRE-A/B +X/Y Direction Feedback Point	**0.6667**	**TRE-A/B X/Y -12V**	**0.6667**
TRE-A/B -X/Y Transimpedance Signal Voltage	**0.6667**	**TRE-A/B X/Y +5V**	**1.0000**
TRE-A/B -X/Y Transimpedance Reference Voltage	**0.6667**	**TRE-A/B X/Y Diode Bias**	**0.6667**
TRE-A/B -X/Y Offset DAC Output	**2.0000**	**TRE-A/B X/Y Reference +5V**	**1.0000**
TRE-A/B -X/Y Direction Feedback Point	**0.6667**	**TRE-A/B X/Y Reference -4V**	**2.0000**
TRE-A/B X/Y Detector Temperature (Silicon Diode Voltage)	**6.0026**	**TRE-A/B X/Y Reference -10V**	**0.6667**
TRE-A/B X/Y Local Box Temperature (REF02 temperature output)	**11.280**	**TRE-A/B X/Y Reset Drive Level**	**1.0000**
TRE-A/B X/Y Heater Voltage	**0.6667**	**TRE-A/B X/Y Reference +0.5V**	**2.0000**

Bias Reference Voltages generated are:	**+5, +0.5, -4, -10**
Box Temperature readout resolution	**≈77 counts/K**
Photo Diode Bias DAC range:	**+3 to -12 v**
Detector Temperature readout resolution	**≈35.6 counts/K**
Temperature servo error readout resolution:	**≈2420 counts/K**

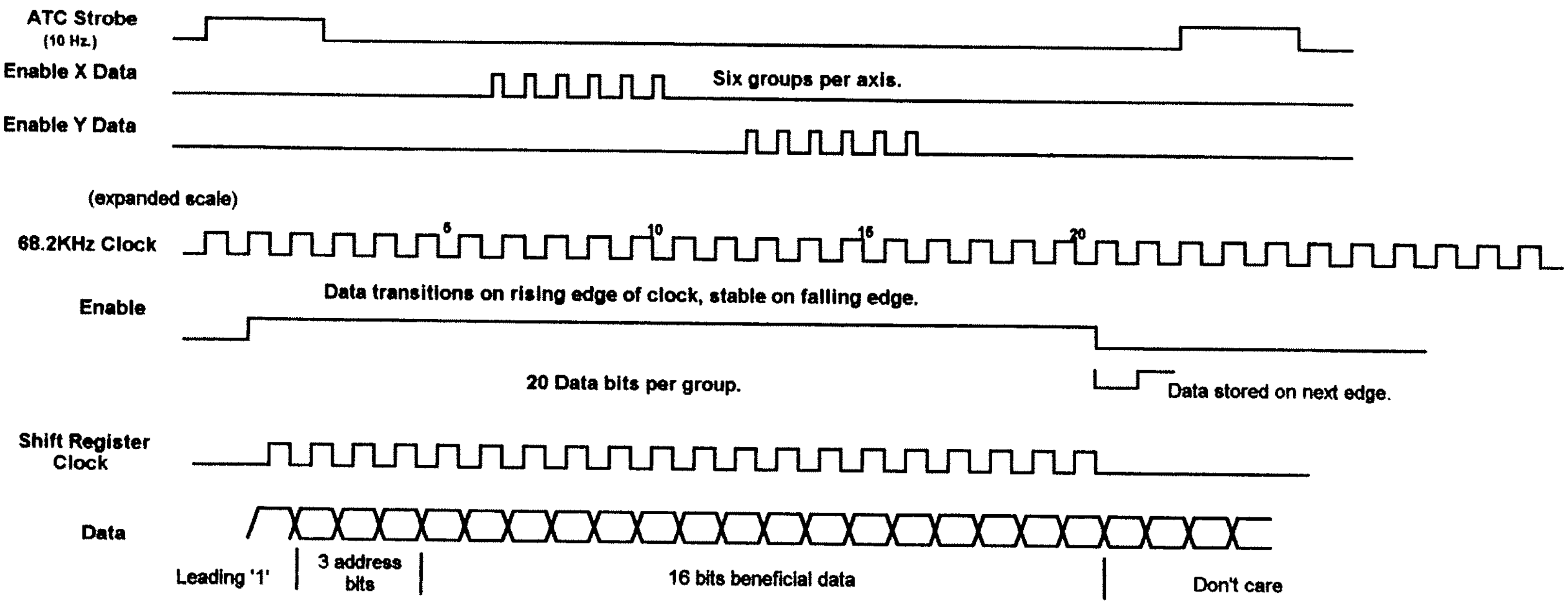
---

*Voltage gain between the monitored point and the differential output.

Digital Logic Functions

- Differential Line Receivers
  Five channels received
- Shift and Storage Registers
  Six groups of 20 bits
- DAC Data Handling
  Six DACs on Analog Board
- Analog Gain Control
  Two 16-input Analog Multiplexers on Analog Board
- Reset Interval Timing
  Three nested intervals required
- Analog Multiplexer Control
  Sequence through 27 channels, or Random Access Selection
- Temperature Servo Integrator
  Closed loop control uses an up/down counter as a digital integrator,
  Open Loop allows direct control of DAC
- Temperature Servo Timing Selector
  Integration timing selectable as ATC Strobe or Seven higher rates
- Mode Control
  Five bits provide test or control options

Timing and Data Definitions



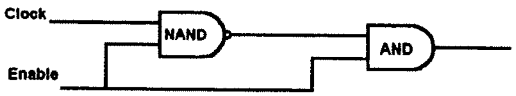
Six groups per axis.

Data transitions on rising edge of clock, stable on falling edge.

20 Data bits per group.

Data stored on next edge.

Simple Gating assures no glitches.



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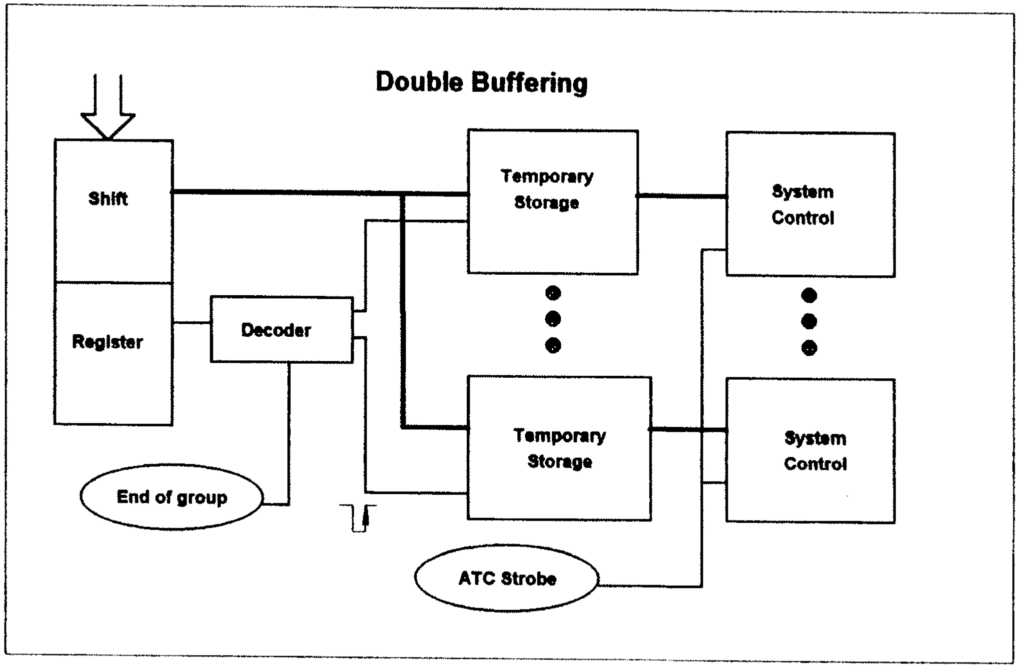
Startup Conditions

Before a complete command set is received

- A power-on reset clears all shift register cells to zero.
- Power to the mode decoder is delayed so the temporary storage registers will also be loaded with zeros. The end of the power on reset triggers a load pulse to initialize all of the output registers.
- Heater integrator is zeroed by the power-on reset.
- The temperature Servo mode is open loop.
- All DAC output voltages are scaled to be safe for any input code.
- The first rise of the ATC strobe after all six serial command groups are received begins commanded operation.



Analog / Digital Partitioning

Separating the functions to minimize interference.

Analog Board	Digital Board
• Filter, Line Drivers	--
• Voltage Regulators and Fixed Analog Biases	--
• Analog Switch	• Logic Driver
• Attenuator Multiplexer & Track/Hold	• Channel logic selection & Logic driver
• JFET reset driver	• Logic for switch control
• TIA Mode analog switch	• Logic driver
• Offset DACs	• Latched command word
• Photodiode bias DAC	• Latched command word
• Temperature Command DAC	• Latched command word
• Temperature sensor bias generator, voltage sensing, comparison, gain, error sense.	• Count command, clock, up/down counter, Heater DAC.
• Housekeeping multiplexer and line driver	• Sequencer control

Parts Selection

Parts must be reliable, accurate, stable, and radiation tolerant.

- **Stable Capacitors for Filters, Loop compensation**
  Hermetically-Sealed, Metalized Polycarbonate, ±1% tolerance, S failure rate
- **Stable Capacitors for Loop compensation, amplifier compensation**
  Ultra-stable Ceramic (CCROx-)
- **Bypass Capacitors for Power decoupling**
  CK0xBX Ceramic
- **Filter Capacitors for Voltage regulator filtering.**
  Solid electrolyte Tantalex®, Hermetically Sealed, Metal Cased, Tubular, B failure rate.

- **Stable Precision Resistors for Critical gain sensitive locations**
  Vishay S102C Bulk Metal® Foil, ±0.6ppm/°C TCR, ±0.1% tolerance, very stable.

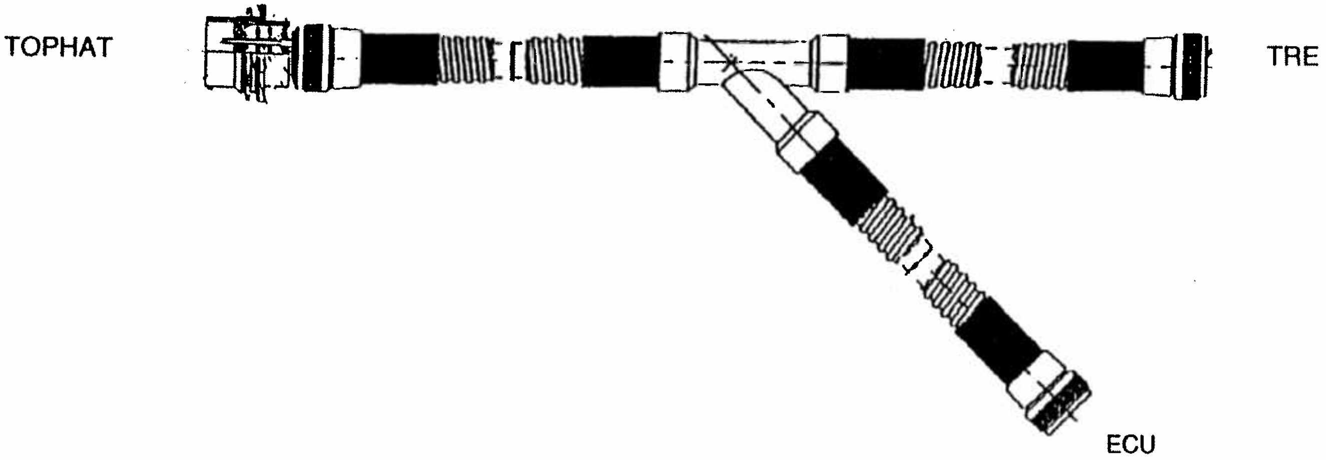
- **Precision Resistors used for General applications, isolation**
  RN55C Metal Film, ±1% tolerance, ±50ppm/°C

- **Power isolation Resistor**
  RWR81S Molded Wirewound

- **Semiconductors**
  Packages: Ceramic DIP or Metal Can
    Harris Rad Hard SOS HCSxx or HS-xxxx
    Analog Devices DI or LC^{2}MOS or Bi-polar
    Burr-Brown *Difet*®
    National Semiconductor LM140H & LM120H voltage regulators

CABLE DESIGN

EMI FILTER/CONNECTOR - DESIGNED & MANUFACTURED BY JERRIK
CABLE AND ATTENUATION COVER - DESIGNED & MANUFACTURED BY GLENAIR



Cable Manufacturing Specifications

- **LAC SPEC 3200 Fabrication and Assembly of Harness and Cable**
  - Proper installation of Foil Sheath
- **LAC SPEC 0411 Termination of Shielded Cables**
  - Requirements for termination of shields on shielded cables
- **MPS627-076 (Material Process Specification)**
  - Round Braid Shield Termination
- **MPS627-091**
  - Shield and Overwrap Termination
- **MPS627-092**
  - Terminate Harness Shield and Overwrap (rectangular connectors)

Open Issues

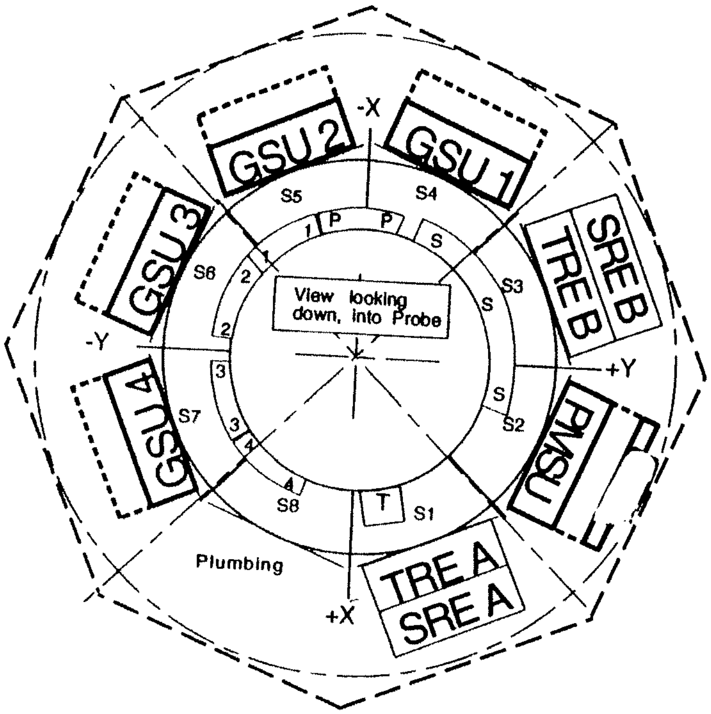
- Need values of JFET capacitances (influences the CLL compensation).
  - —Resolution: will measure when equipment arrives.
- Selecting method for balancing the differential gain stage.
  - —Resolution: review and select among the following options.
    - A commandable DAC to allow slightly offsetting the -4 volts to the reference gate.
    - Laser trimming the cold resistors.
    - Both of the above.
- Verification of frequencies used for updating the temperature controller (local closed loop control).

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

TRE FORWARD ELECTRONICS ENCLOSURE

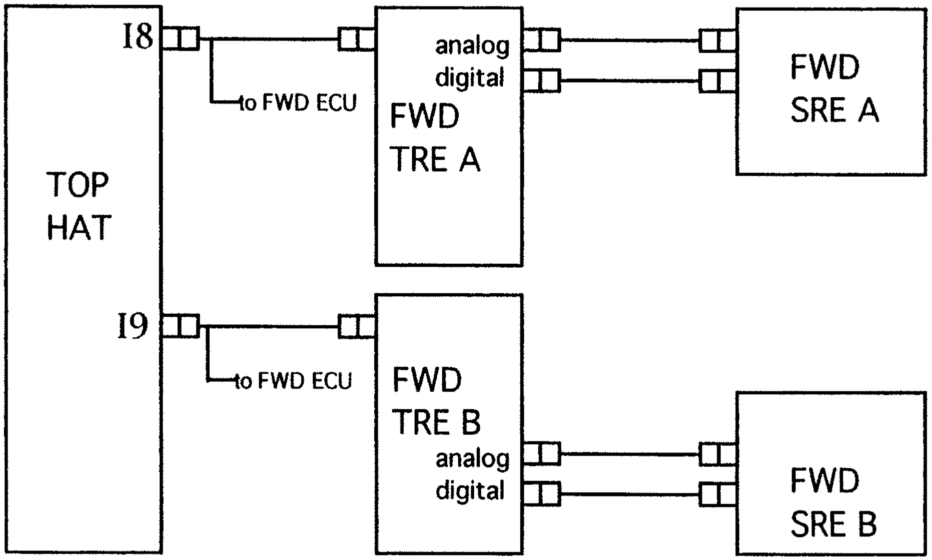
R. AJITOMI

FWD TRE ELECTRONICS LOCATION



- Telescope Readout Electronics (TRE) A located 22.5 deg from +X axis
  - TRE B located 90 deg from TRE A
- Location determined by:
  - Shortest cable length
  - 90 deg separation
  - Increase in FWD GSU/PMSU height
    - From 4” to 7.75”
  - FWD SRE located for max. thermal radiation

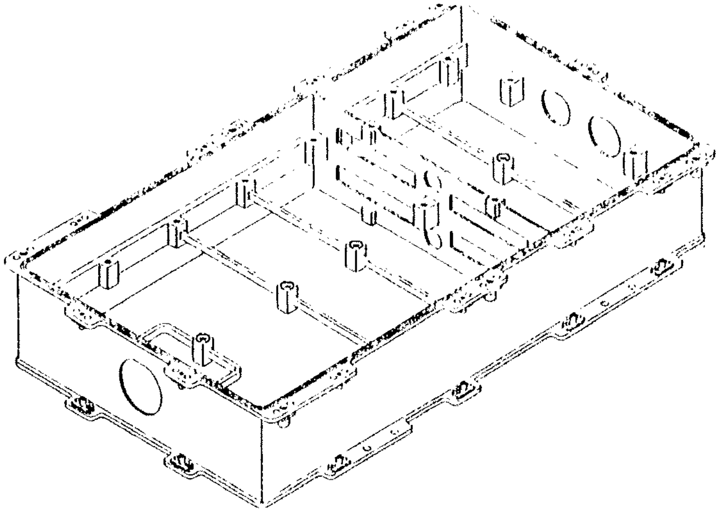
INTERCONNECT DRAWING



- Top Hat to FWD TRE
  - – 79 pin cylindrical connector, P/N# D38999/24FG35SN
- FWD TRE to FWD SRE
  - – 22 pin cylindrical connector, digital cable, P/N# D38999/24FC35PN
  - – 37 pin cylindrical connector, analog cable, P/N# D38999/24FD35PN

MECHANICAL DESIGN/ REQUIREMENTS

Spec Section Number	Parameter Name	Required Value	Verif.	Design Estimate
3.3.8.8	POWER	10W	T	10W
3.2.8.2	WEIGHT	6.25kg	I	6.25kg
3.2.8.1	LENGTH	17 in.	I	17 in.
3.2.8.1	WIDTH	9.7 in.	I	9.7 in.
3.2.8.1	HEIGHT	3.0 in	I	3.0 in
3.2.8.3	Relative Clocking Angle	90°	I	90°



- Material - Aluminum 6061-T651
- Manufacturing Process - Machining (hog out)
- Flat Black Silicone on box exterior per LAC SPEC 37-4777-0300
  - Emissivity of .89

Thermal Requirements/Design

Thermal Requirements

Spec Number	Parameter Name	Required Value	Acheived to Date	Verif.	Test Description
3.2.8.4	Roll; Box pk to pk Max temp variation	0.1 K		T	
3.2.8.5	Roll; Board Max gradient pk to pk temp variation	0.025 K		T	
3.2.8.6	Orbital; Box pk to pk Max temp variation	2 K		T	
3.2.8.7	Annual; Box pk to pk Max temp variation	20 K		T	

- Thermal Design
  - Operating Temperature Range: 286-294K
    - » Analysis done with FWD GSU at 2 watts
  - Hog out Maximizes Thermal Uniformity of Enclosure
  - Requires Forward Equipment Enclosure (FEE)
    - » Passive thermal control design
    - » 0.05 deg Box pk to pk variation at roll with FEE (preliminary thermal study 20 July 1994)

OPEN ISSUES

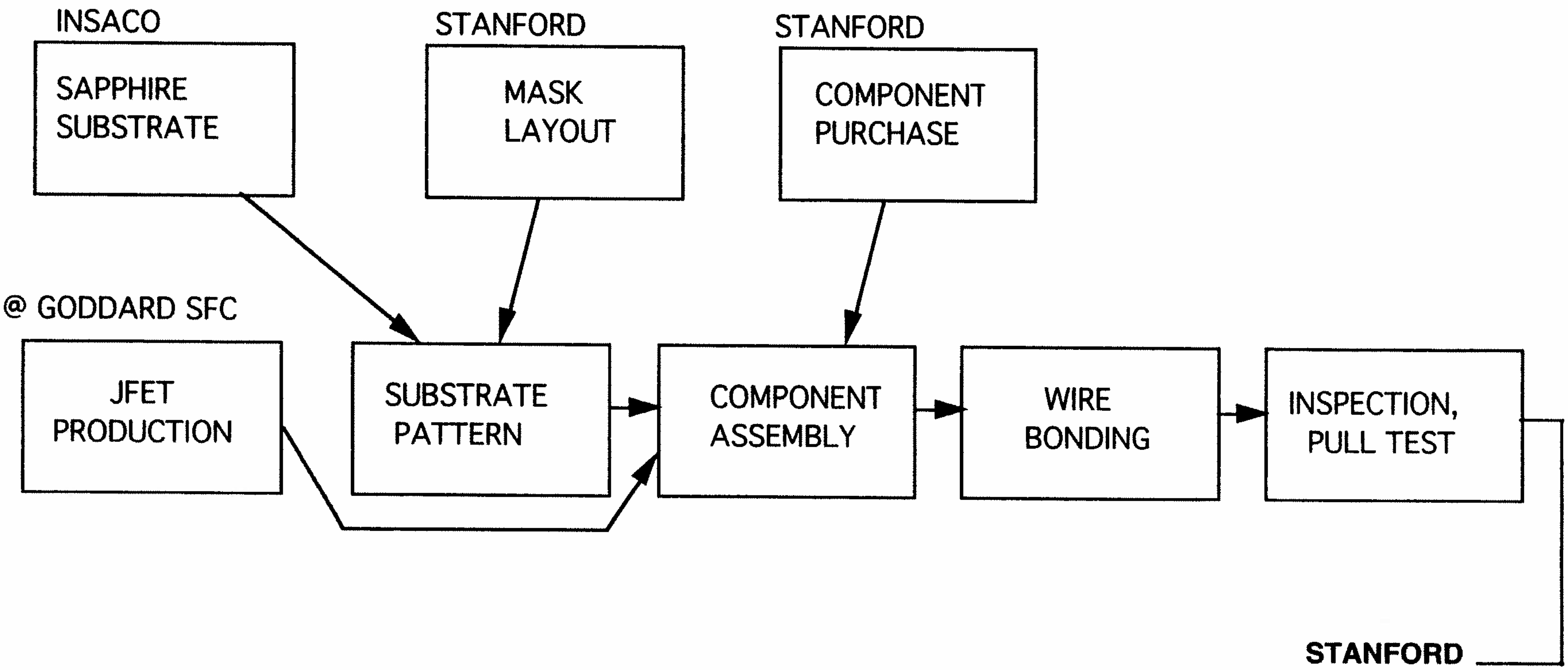
- Thermal Study
  - Detailed Thermal Analysis to be Performed After PC Board Layout is Completed
- Ionizing Radiation
  - Natural Oribital Environmental Spec. P0149
    - » Stanford System Engineering will Analyze Enclosure Design for Survivability

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

TRE MANUFACTURE AND TEST FLOW

G. SWART

TRE DETECTOR PACKAGE MANUFACTURING FLOW



INSACO

SAPPHIRE SUBSTRATE

STANFORD

MASK LAYOUT

STANFORD

COMPONENT PURCHASE

@ GODDARD SFC

JFET PRODUCTION

SUBSTRATE PATTERN

COMPONENT ASSEMBLY

WIRE BONDING

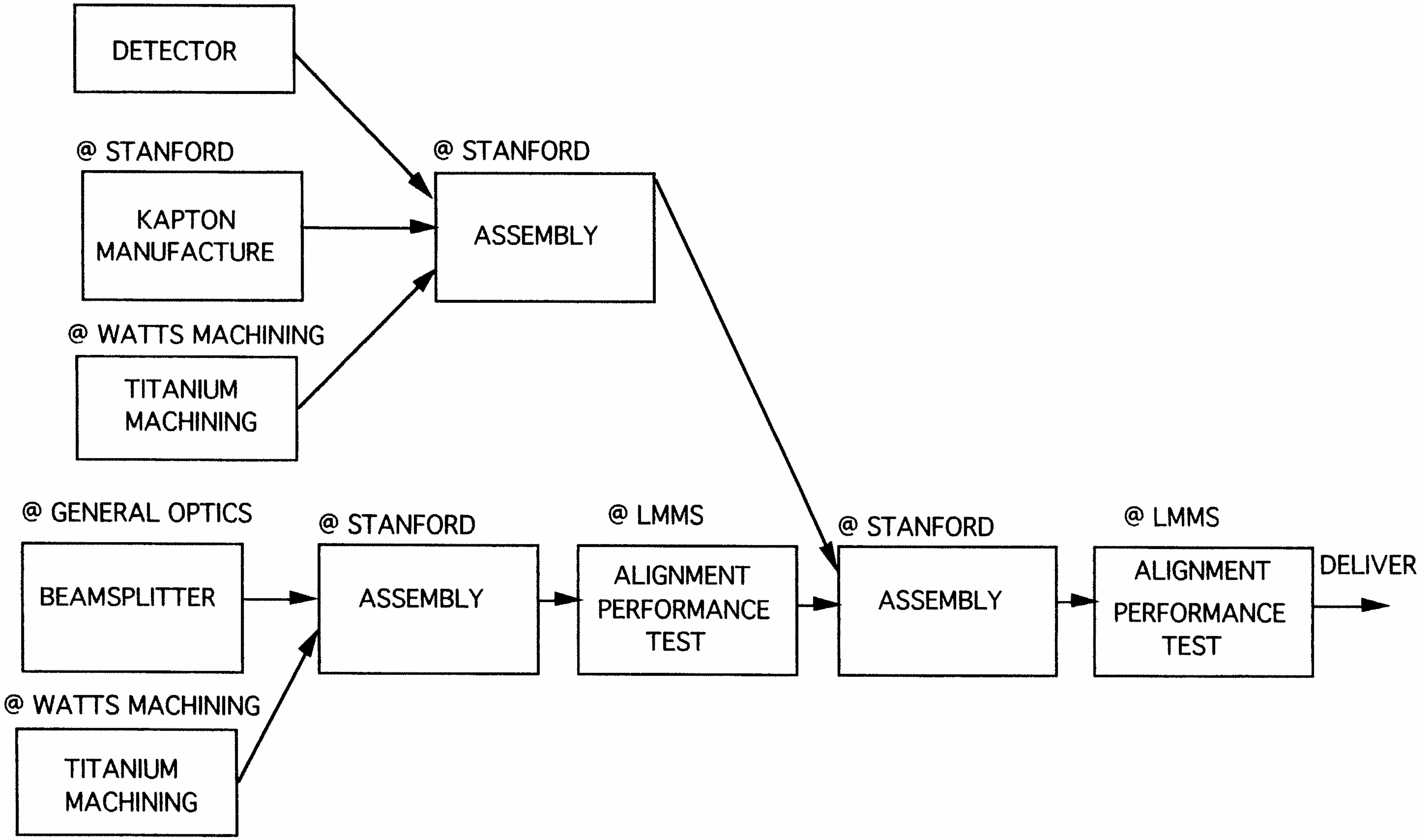
INSPECTION, PULL TEST

STANFORD

TRE DETECTOR & ASSEMBLY MANUFACTURING FLOW

STANFORD
LOCKHEED MARTIN

TRE CDR
8 MAY1996



DETECTOR

@ STANFORD
KAPTON MANUFACTURE

@ WATTS MACHINING
TITANIUM MACHINING

@ STANFORD
ASSEMBLY

@ GENERAL OPTICS
BEAMSPLITTER

@ WATTS MACHINING
TITANIUM MACHINING

@ STANFORD
ASSEMBLY

@ LMMS
ALIGNMENT PERFORMANCE TEST

@ STANFORD
ASSEMBLY

@ LMMS
ALIGNMENT PERFORMANCE TEST

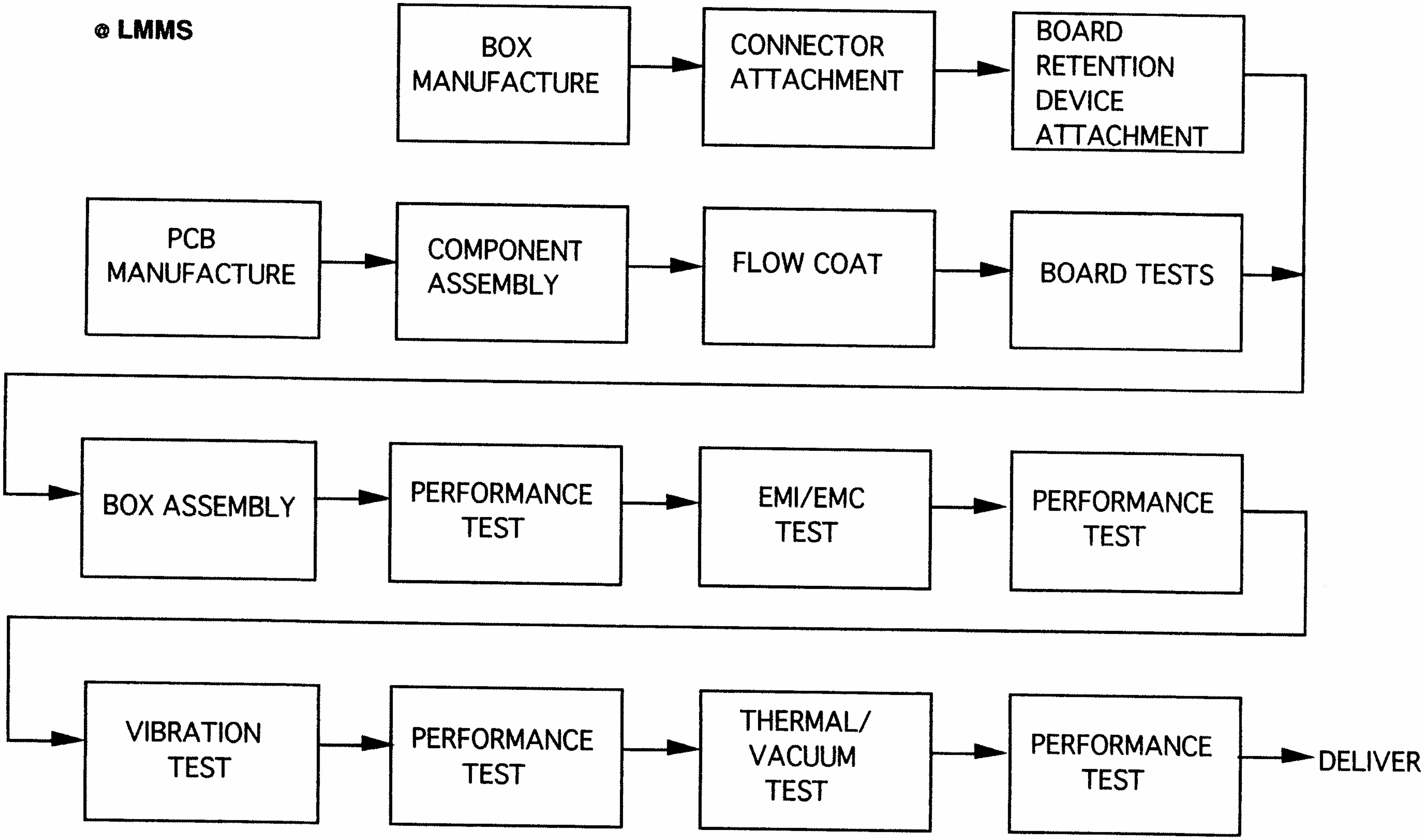
DELIVER

TRE WARM ELECTRONICS PACKAGE MANUFACTURING FLOW

STANFORD
LOCKHEED MARTIN

TRE CDR
8 MAY1996

@ LMMS



BOX MANUFACTURE → CONNECTOR ATTACHMENT → BOARD RETENTION DEVICE ATTACHMENT

PCB MANUFACTURE → COMPONENT ASSEMBLY → FLOW COAT → BOARD TESTS

BOX ASSEMBLY → PERFORMANCE TEST → EMI/EMC TEST → PERFORMANCE TEST

VIBRATION TEST → PERFORMANCE TEST → THERMAL/ VACUUM TEST → PERFORMANCE TEST → DELIVER

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

QUALITY ASSURANCE AND RELIABILITY FOR FORWARD ELECTRONICS

G. SWART

ELECTRONICS FABRICATION, ASSEMBLY, TEST OBJECTIVES

BUILD MISSION-CAPABLE ELECTRONICS HARDWARE

- PROVIDE OPERATIONAL MARGINS VERIFIED BY ANALYSIS OR TEST
- PROVIDE DOCUMENTATION PER APPLICABLE SPECIFICATIONS
- USE TAILORED MIL-SPEC AND NHB-5300.4 PROCESSES
- USE TAILORED CONFIGURATION CONTROL

FABRICATION & ASSEMBLY FACILITIES

The Space Payloads and Dynamics & Control Electronics Laboratories (buildings 255 / 250) are well qualified, experienced, certified and equipped for flight electronics hardware assembly, with over 5,000 square feet of process / test area.

✪ Workstations, ✪ Personnel, ✪ Certifications
✪ Equipment, ✪ Cleanliness , ✪ Electrostatic Discharge Protection

MANUFACTURING

CONFIGURATION CONTROL	MIL-STD-130, NHB5300.4 (1C),(3K) MSFC STD 506 C
HANDLING & STORAGE	JA-447B, MSFC-STD-506C, NHB5300.4 (1C)
ELECTROMAGNETIC COMPATIBILITY	MSFC-SPEC-461D
ELECTROSTATIC DISCHARGE PROTECTION	MSFC-STD-506C NHB5300.4 (3A-1)
CLEANING	MSFC-STD-506C
CERTIFICATIONS	NHB5300.4 (3H), (3A-1), MSFC STD 506 C
INSPECTION	NHB5300.4 (1C), (3A-1), (3H)
ELECTRONICS DOCUMENTATION	NHB5300.4 (3K)

MANUFACTURING

SPECIAL PARTS CONSIDERATIONS	MIL-STD-975, MIL-STD-883B
MATERIAL & PROCESSES	MSFC-STD-506C
BOARD FABRICATION	NHB 5300.4 (3I), MIL-P-55110C
CONFORMAL COATING	NHB5300.4 (3J)
BOARD ASSEMBLY	NHB5300.4 (3I), (3H), (3G),(1C), (3K), (3A-1)
VERIFICATION AND TEST	MSFC-SPEC-1198C, MSFC-SPEC-521 B MSFC-HDBK-1453
ENVIRONMENTAL TESTING	JA-418-A, MSFC-HDBK-1453

PRODUCT ASSURANCE

- **REQUIREMENTS:**
  PRODUCT ASSURANCE REQUIREMENTS HAVE BEEN TAILORED TO THE NEEDS OF THE GP-B PROGRAM DESCRIBED IN STU ELECTRONICS PRODUCT ASSURANCE PLAN, DATED 14 AUG 92

- **IMPLEMENTATION:**
  LMSC SAFETY, RELIABILITY, MAINTAINABILITY AND PRODUCT ASSURANCE PLAN, (F428533, FOR GP-B PROGRAM)

RELIABILITY

JA-447B,MIL-STD-975, NHB5300.4 (1C)

- Paragraphs 1C201 through 1C311 of NHB 5300.4 (1C) :
  ☆ Inspection System Plan, ☆ Handling, Packing, Packaging Procedures
  ☆ Government Property Records , ☆ Procurement Documents
  ☆ Raw Material Test Reports , ☆ Inspection and Test Procedures
  ☆ Inspection and Test Records , ☆ Process Control Procedure
  ☆ Process Control Records, ☆ Nonconformance Documentation
  ☆ Metrology System Procedures, ☆ Sampling Plans

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

VERIFICATION AND TEST PLAN FOR TRE

M. TAPLEY

Matrix
Environmental Tests
EMC
Radiation Tests
Subsystem Tests
Integrated Payload Tests
Space Vehicle Tests

VERIFICATION MATRIX

- Verification Matrix Integrated With Spec In Database
- Derived Performance Specs Have Driven Design Analyses;
  Critical Derivations (ie Annual Drift) Will Be Written Up As P-Documents
- T003 Flow-Down For Critical Parameters Captured In TRE Requirement Text Will Be Entered As Links In Database
- Complete Flow-Down Analysis (T003, Payload Spec, SIA Spec) Presented In Data Package This Review

TEST PLAN

General Environmental Compatibility

- Flight Unit Box Thermal Testing
  - Operation And Survival Ranges From FEE Thermal Specs
  - Variations At Roll And Orbital Rates Defined In FEE Thermal Specs
    - Test Will Include Detector Or Dummy Load (See Below)
  - Verifies Thermal Coefficients Computed From Part Data

- Flight Unit Vibration Testing

  Vibration Profile In Specification

- Meteoroid And Debris Specs Will Be Verified By Analysis

- Vacuum/Neutral Gas Environment

  Verified In Thermal-Vac Testing (Subsystem And Integrated SV)
  Plasma N/A Due To FEE Enclosure

Electromagnetic Compatibility

- EMI Tests On Box Will Be Carried Out According To EMI Test Plan
  - EMITP Modified From MIL-STD-461D (More Stringent For GP-B)
- Engineering Unit EMI Test Suite Approx. 1Q97
- EMI Effect On Detector - GTU2 EMI Tests And Bench Tests In LN_2 (1Q97)
  - Sunshade Attenuation Tested Seperately
- EMI / Grounding / Shielding Review May 14 Will Give More Details

Radiation Tests

- Parts Individually Tested Or Vendor Radiation Test Data Used
- Integrated Detector Package Exposed To Proton Bombardment 4Q96
- Charge Trapping, etc. Will Be Tested In Parts Tests

Subsystem Tests

- JFET Noise To Be Characterized In Dewar And RT Tests Down To 0.1 Hz

- Detector Testing In Test Dewar 2Q 1996
  - Verified Detector Functionality Cold
  - Verified Performance Against LED Light Source.

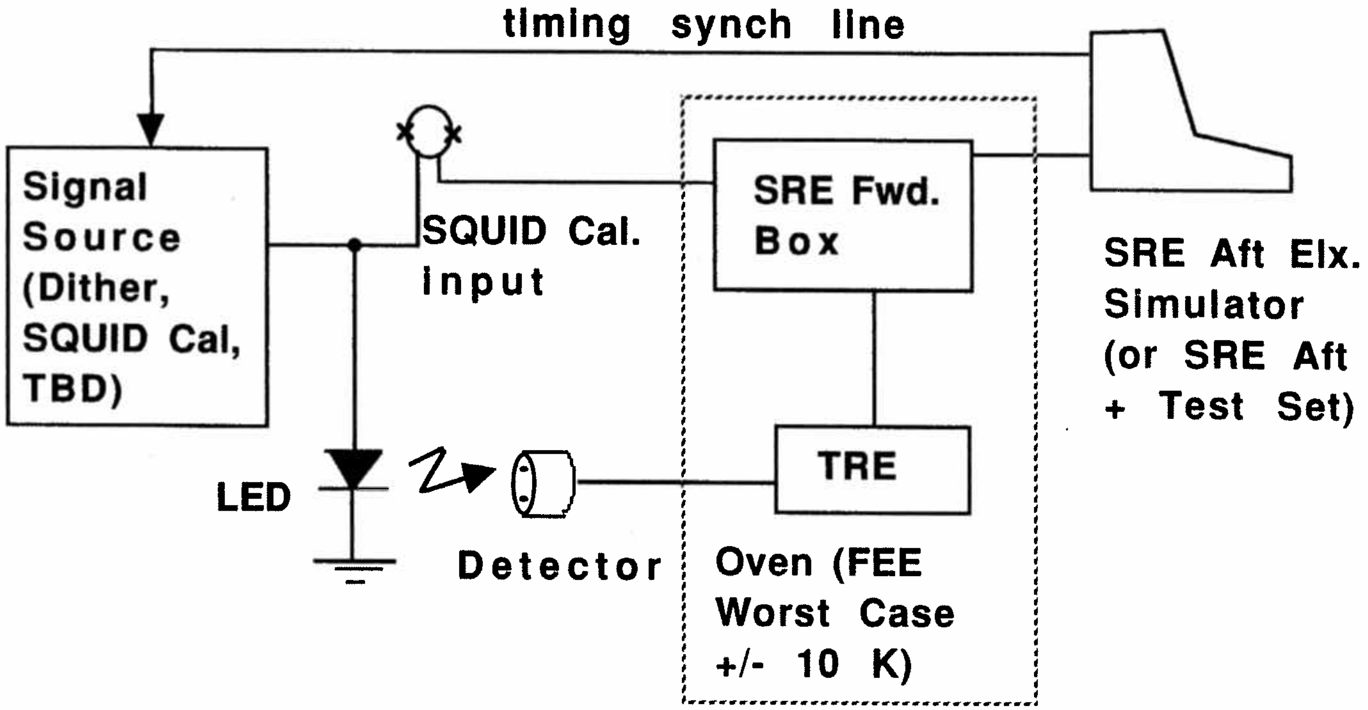
- Detector + Telescope 2 Testing 3Q 1996 With AS #2
  - Verify System Assembly/Alignment And Detector Performance (PDR 31)
  - Indicates Linearity. (IDR 18)

- Engineering Unit Box Testing 4Q 1996/1Q 1997

- Flight Unit Box Testing 4Q 1997

Subsystem Tests (cont.)

- Phase Delay As A Function Of Temperature
  - Precisely Quantify Delays (Phase Shifts) In TRE Data System



Integrated Payload Tests

- Artificial Star 3 Tests In SP Integrated Testing
- Box Fuctionality Testing 2Q97 (Engineering Unit) 1Q98 (Flight Unit)

Space Vehicle Tests

- Integrated Space Vehicle Testing Confirms Box And Detector Aliveness
- On-Orbit Verification Confirms Noise Numbers
- On-Orbit Dither Against Rate Gyros
  - Provides Additional Data And Confirms Pointing Simulations
- GS-Invalid Periods During SM
  - Dark Signal Calibrates Radiation Influence On Detectors And Elx.

TELESCOPE READ-OUT ELECTRONICS CRITICAL DESIGN REVIEW

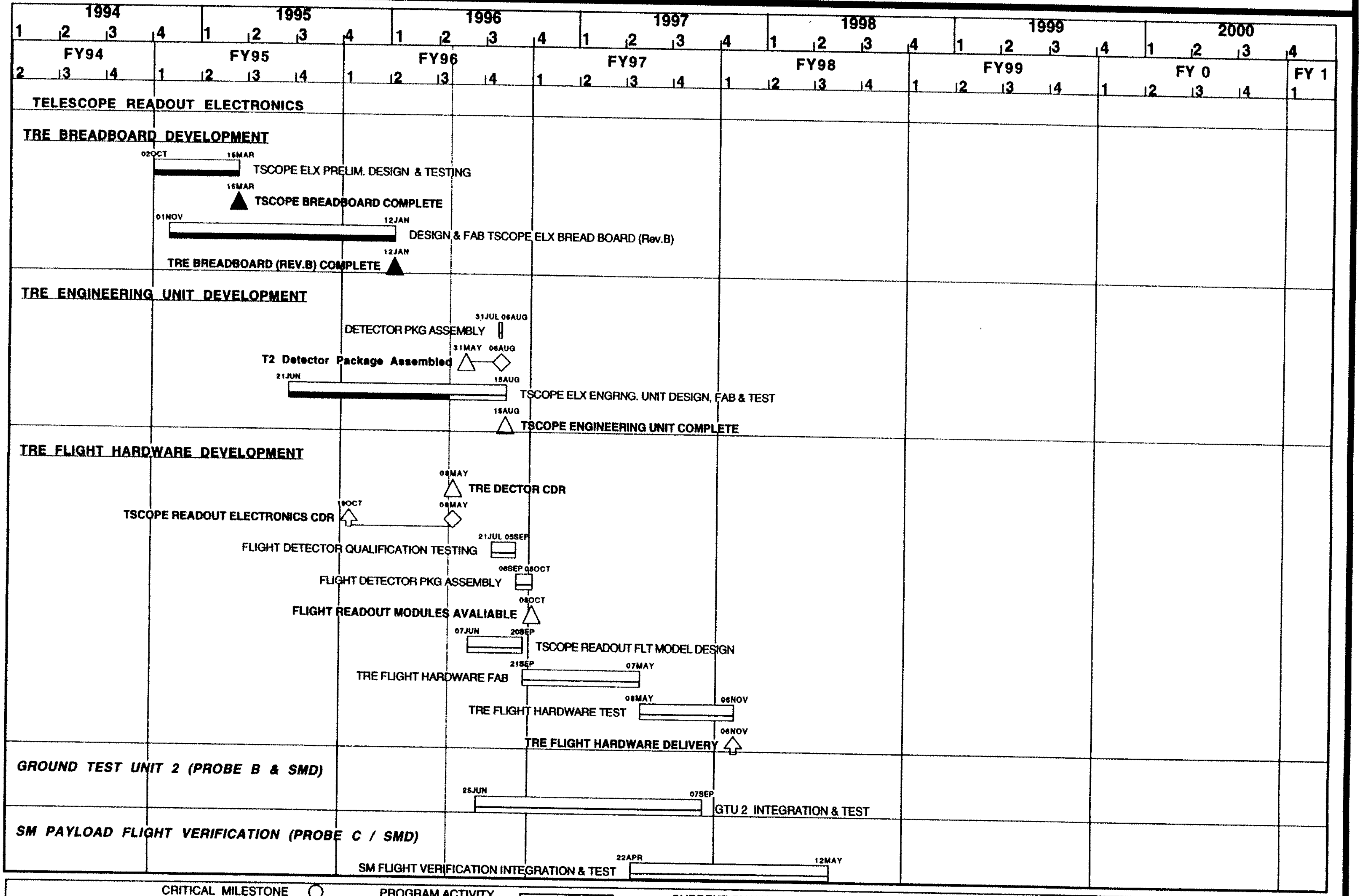
SCHEDULE

J. BURNS

Stanford University

TELESCOPE ELECTRONICS
OVERVIEW SCHEDULE

RELATIVITY MISSION



LEGEND

CRITICAL MILESTONE ○
MAJOR MILESTONE
TECHNICAL MILESTONE △

PROGRAM ACTIVITY
PROGRESS ON ACTIVITY

CURRENT CHANGES TO START OR COMPLETE DATES

Rev. Number: R-8

Data Date: 29APR96

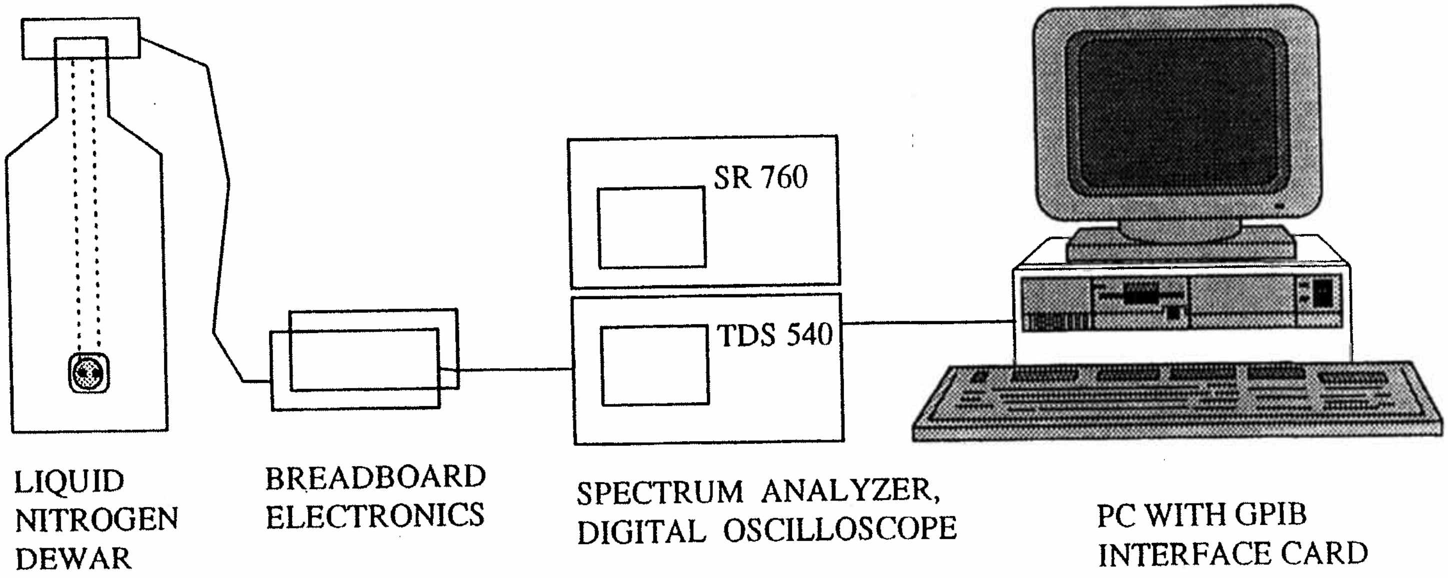
FRM File SKD122F.FMT SCH File: GP-B DATA.34: Sch:GPB MASTER NET (R-8)

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

DEVELOPMENT TESTS

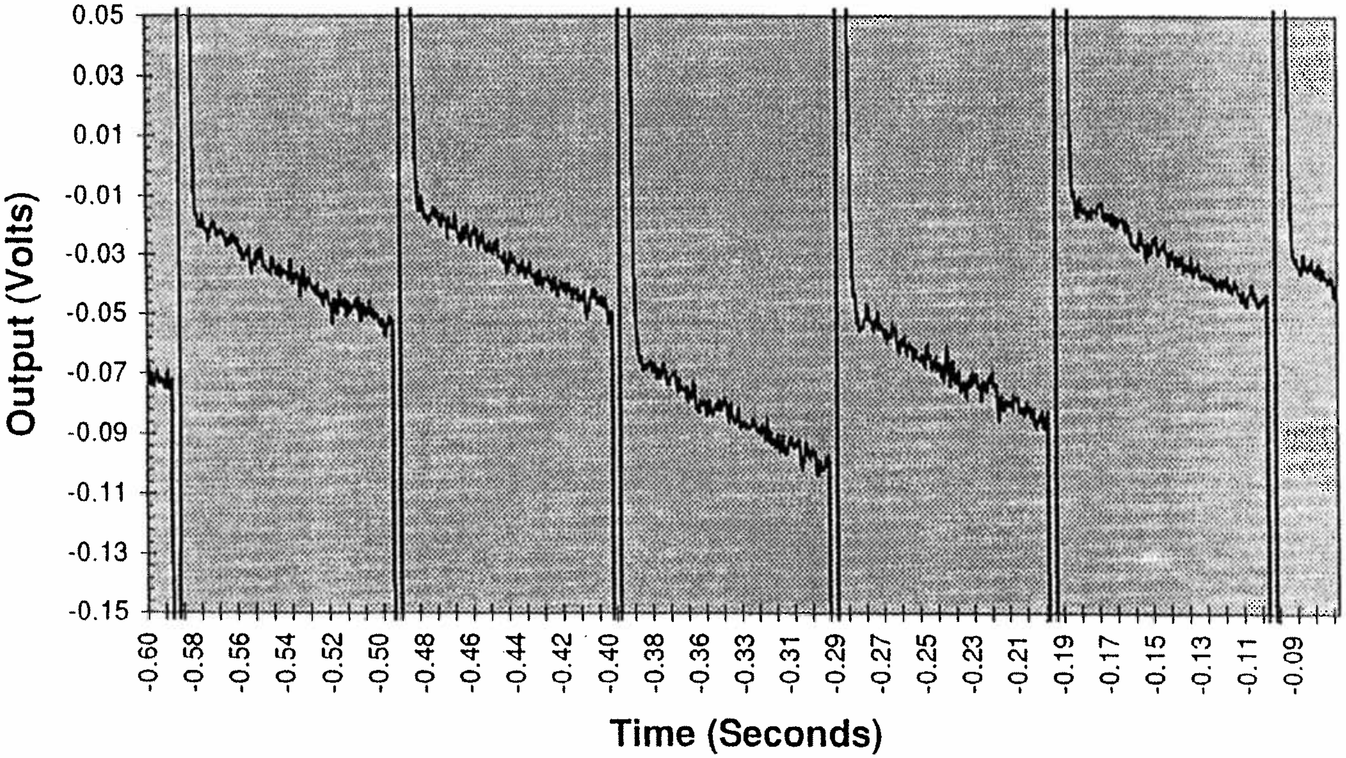
H. DEMROFF

DATA ACQUISITION SYSTEM

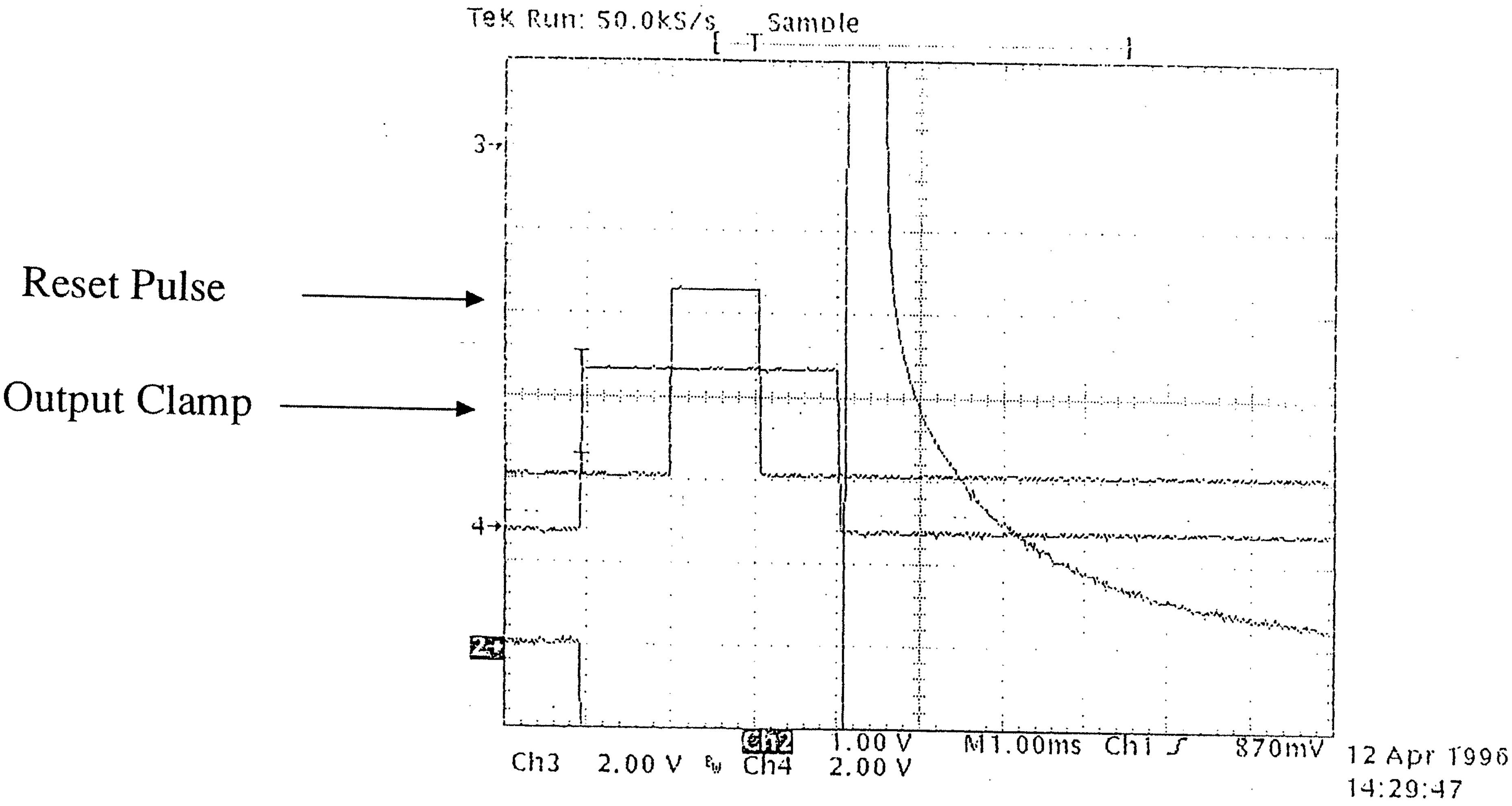


1) LIQUID NITROGEN DEWAR 4 LITER
2) BREADBOARD ELECTRONICS
    A) TEMPERATURE SENSE AND BIAS CARD
    B) TIMING AND RESET CARD
    C) 2 DETECTOR AMPLIFIER CARD FOR X+ AND X-, Y+ AND Y-
3) SR 760 FFT SPECTRUM ANALYZER
4) TEKTRONIX TDS 540 FOUR CHANNEL DIGITAL SCOPE WITH 15 BIT RESOLUTION
5) GPIB INTERFACE CARD (IEEE 488.2) FOR AUTOMATED DATA ACQUISITION

TRE OUTPUT FOR EXPECTED MINIMUM LIGHT INTENSITY

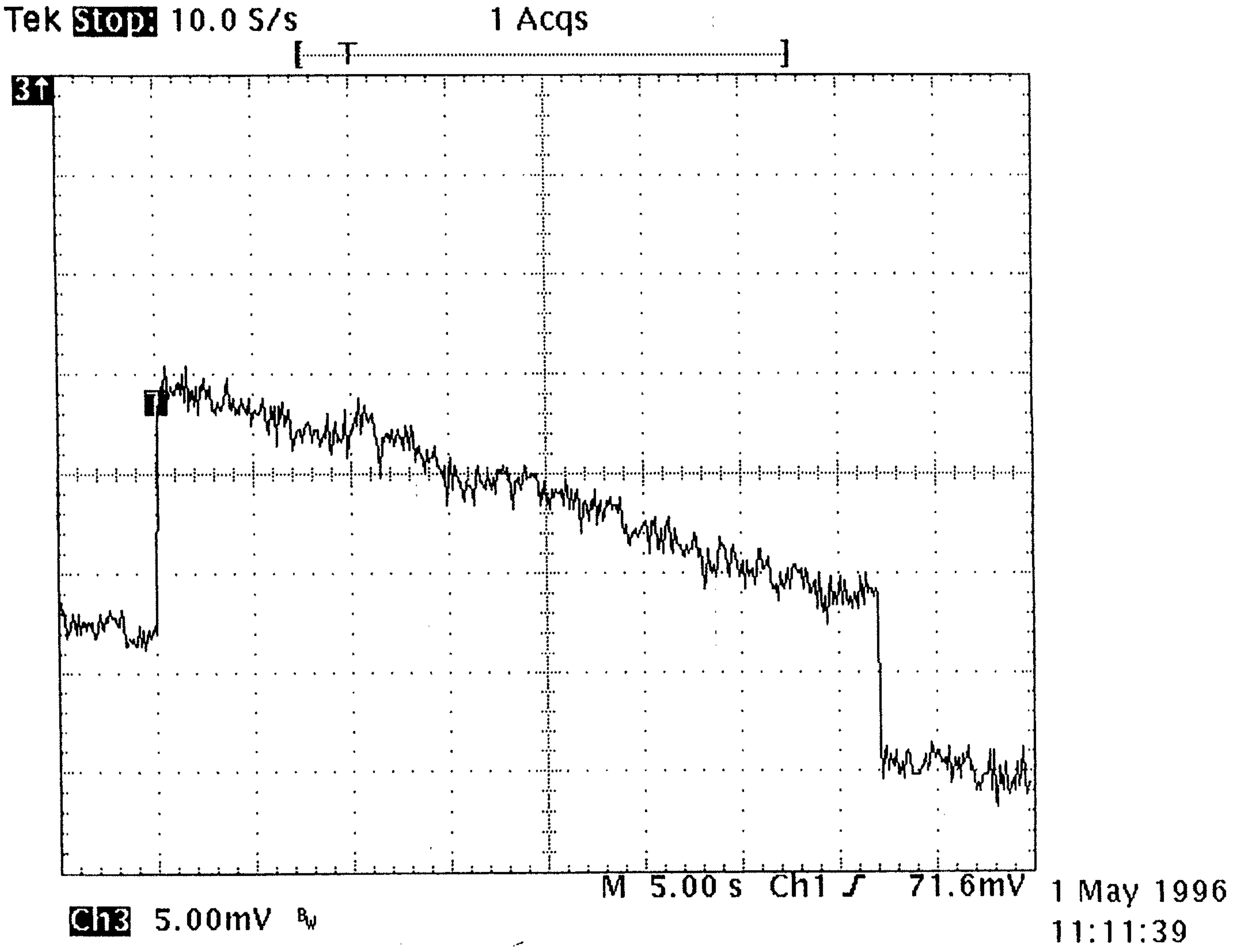


A DETAILED LOOK AT THE RESET AND OUTPUT PULSE



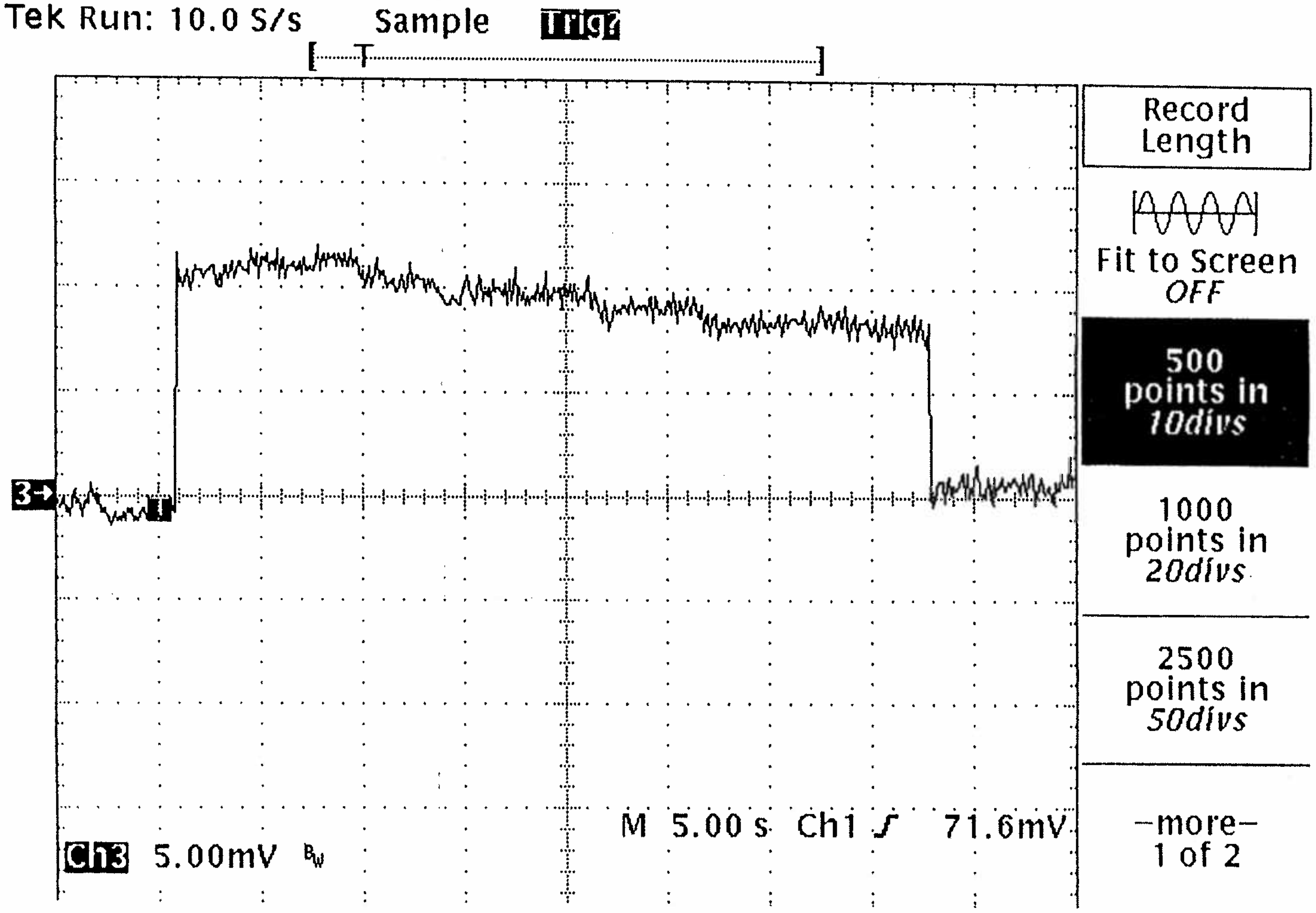
These oscilloscope traces show the reset pulse occuring within the output clamp.

Measured Leakage Current .01fA Photodiode Bias 4.1 volt



Meets Requirement TRE PLSE-13, Pt 3.2.18.3

Measured Leakage Current < .005 fA   Photodiode Bias 0 volt



Tek Run: 10.0 S/s Sample Trig?

Ch3 5.00mV B_W

M 5.00 s Ch1 ƒ 71.6mV

TELESCOPE READ-OUT ELECTRONICS
CRITICAL DESIGN REVIEW

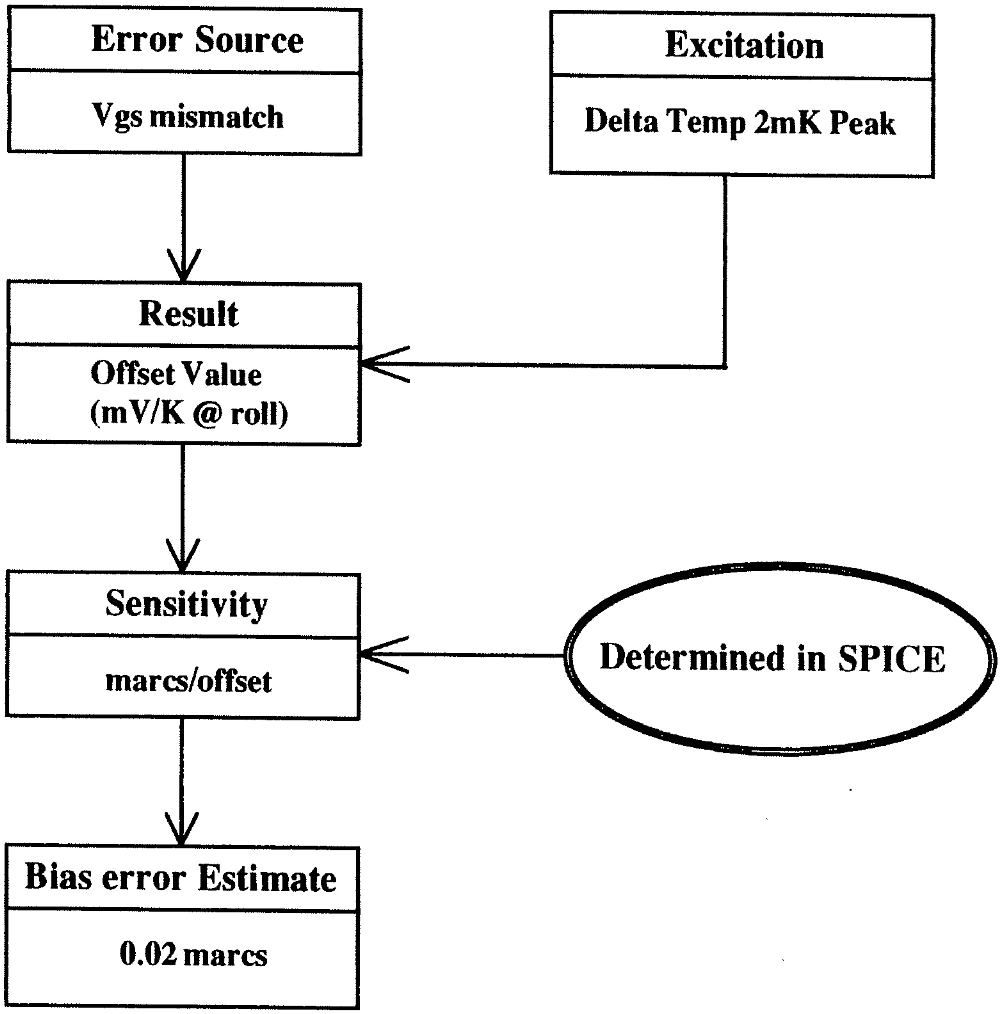
ERROR BUDGET AND PERFORMANCE PREDICTION

K. COLEMAN

Bias Variation Estimation
SPICE Model
Error Tree

TRE BIAS VARIATION ESTIMATE

Example:



Error Source

Vgs mismatch

Excitation

Delta Temp 2mK Peak

Result

Offset Value
(mV/K @ roll)

Sensitivity

marcs/offset

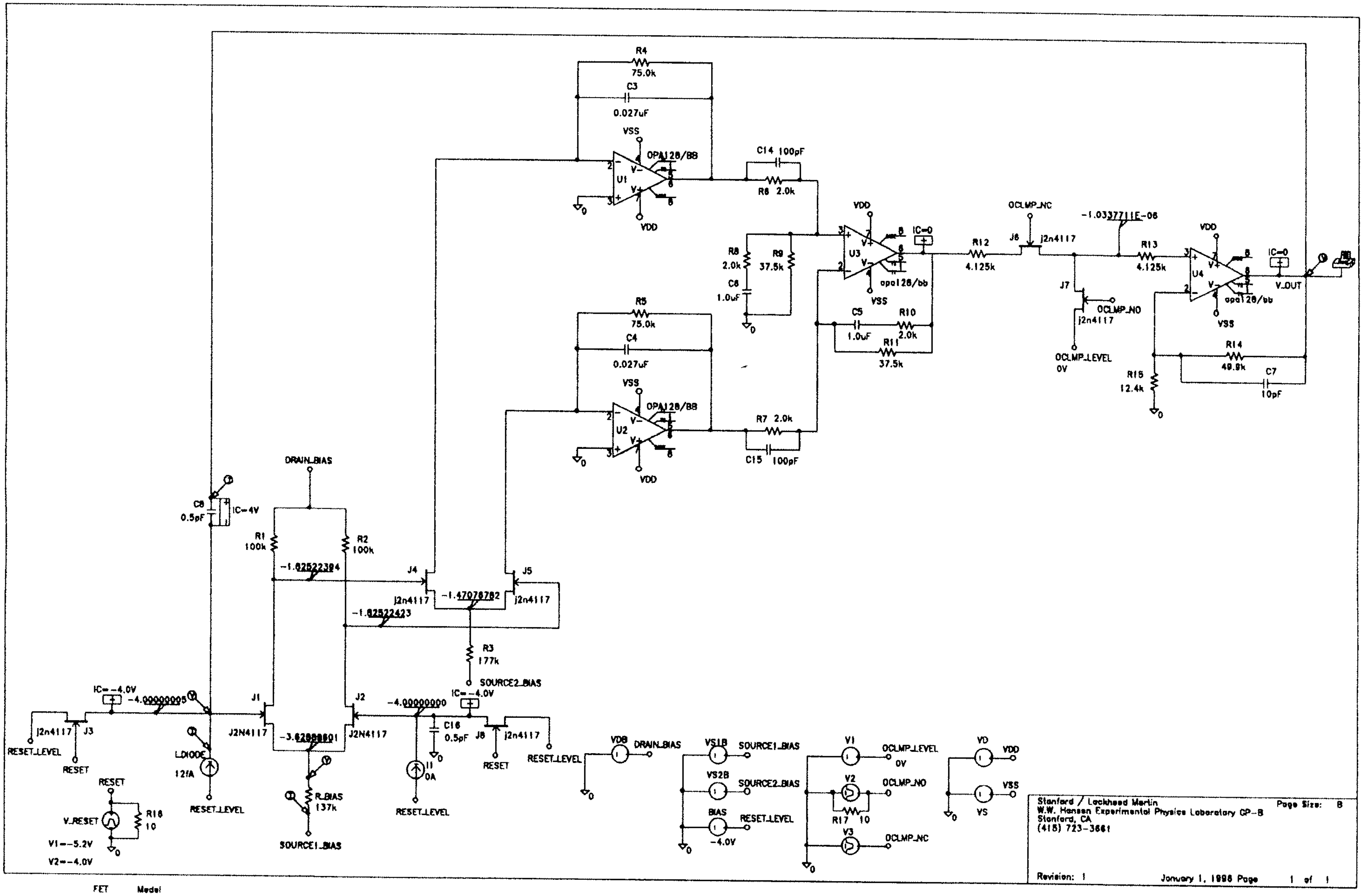
Determined in SPICE

Bias error Estimate

0.02 marcs

* ERRORS ARE WORST CASE AT ROLL

* TRE CIRCUIT SENSITIVITIES ARE DETERMINED IN SPICE



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Page Size: B

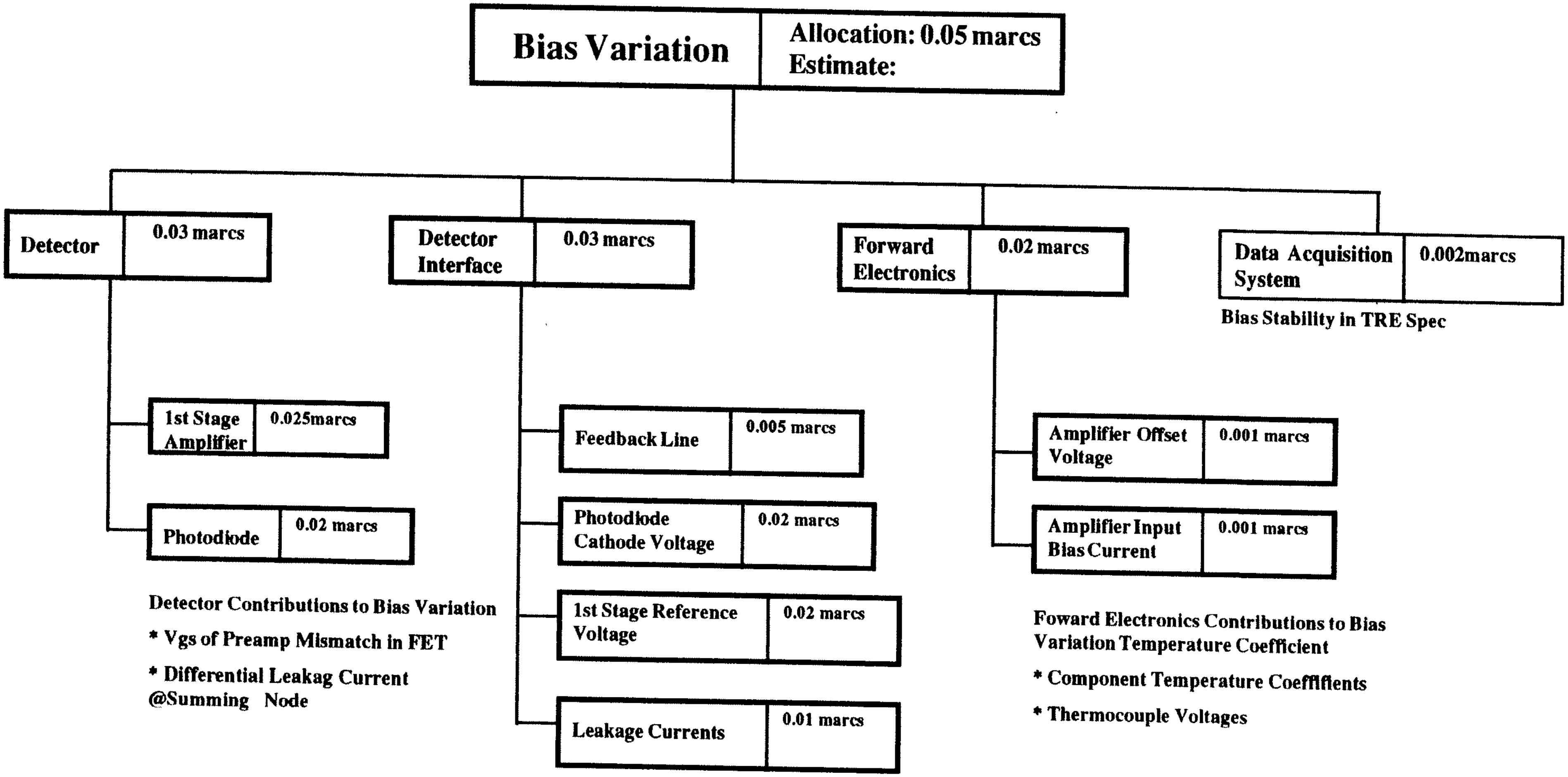
Revision: 1

January 1, 1998 Page 1 of 1

FET	Model
J1	J2N4117-X3
J2	J2N4117-X3
J3	J2N4117-X3
J8	J2N4117-X3
J4	J2N4117-X1
J5	J2N4117-X1

OCLMP_NO	OCLMP_NC
V1=-2.25V	V1=-0.5V
V2=-0.5V	V2=-2.25V

BIAS VARIATION ERROR TREE



- **Bias Variation** — Allocation: 0.05 marcs; Estimate:
  - Detector — 0.03 marcs
    - 1st Stage Amplifier — 0.025marcs
    - Photodiode — 0.02 marcs
  - Detector Interface — 0.03 marcs
    - Feedback Line — 0.005 marcs
    - Photodiode Cathode Voltage — 0.02 marcs
    - 1st Stage Reference Voltage — 0.02 marcs
    - Leakage Currents — 0.01 marcs
  - Forward Electronics — 0.02 marcs
    - Amplifier Offset Voltage — 0.001 marcs
    - Amplifier Input Bias Current — 0.001 marcs
  - Data Acquisition System — 0.002marcs

Bias Stability in TRE Spec

Detector Contributions to Bias Variation

* Vgs of Preamp Mismatch in FET

* Differential Leakag Current @Summing Node

Interface Contributions to Bias Variation Temperature Coefficient

* Thermocouple Voltages

* Filter Attenuation

* Leakage Currents

* EMI Rectification

Foward Electronics Contributions to Bias Variation Temperature Coefficient

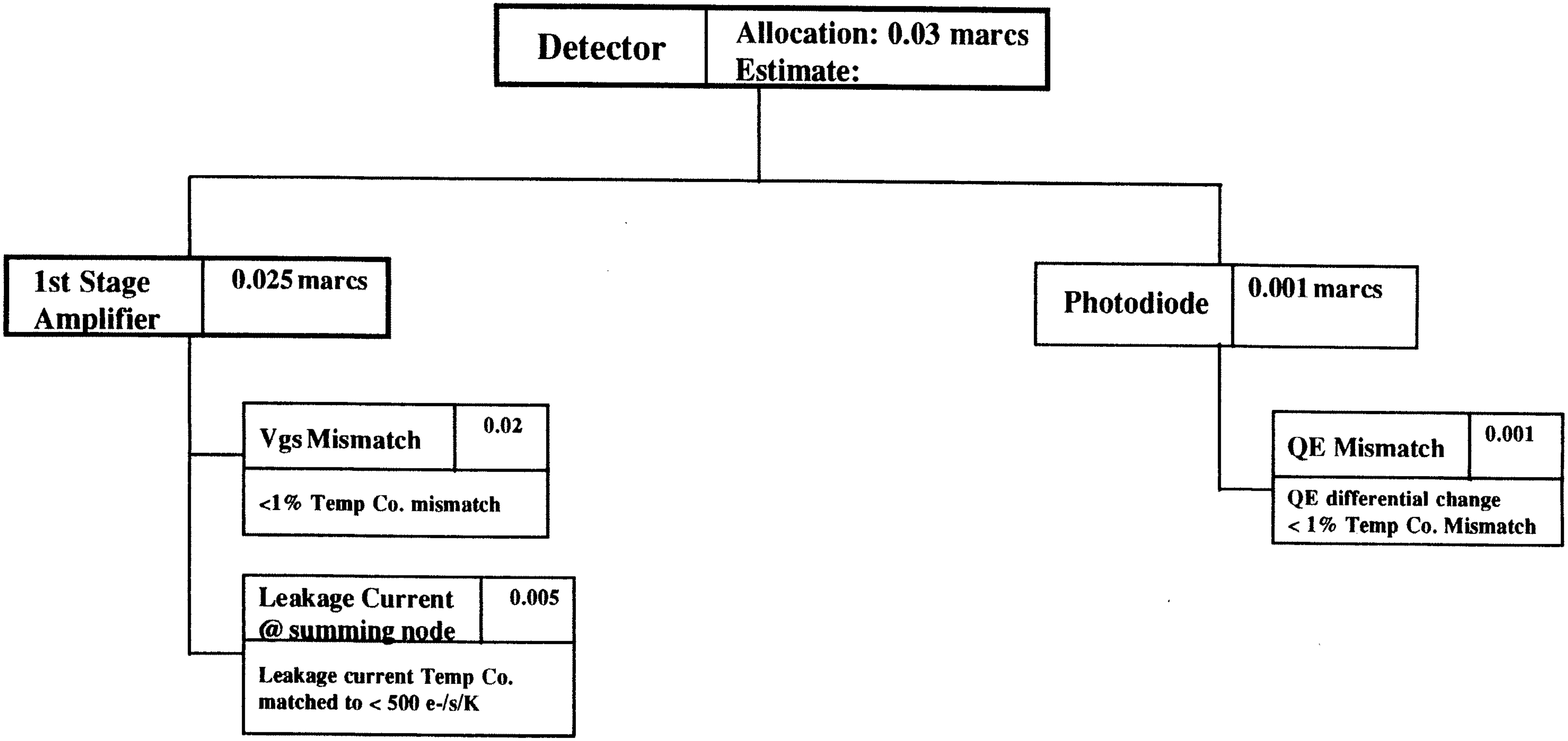
* Component Temperature Coeffifients

* Thermocouple Voltages

* ERRORS ARE WORST CASE AT ROLL

* TRE CIRCUIT SENSITIVITIES ARE DETERMINED IN SPICE

BIAS VARIATION ERROR TREE



Detector | Allocation: 0.03 marcs
Estimate:

- **1st Stage Amplifier** | 0.025 marcs
  - **Vgs Mismatch** | 0.02
    <1% Temp Co. mismatch
  - **Leakage Current @ summing node** | 0.005
    Leakage current Temp Co. matched to < 500 e-/s/K
- **Photodiode** | 0.001 marcs
  - **QE Mismatch** | 0.001
    QE differential change
    < 1% Temp Co. Mismatch

* ERRORS ARE WORST CASE AT ROLL
* TRE CIRCUIT SENSITIVITIES ARE DETERMINED IN SPICE

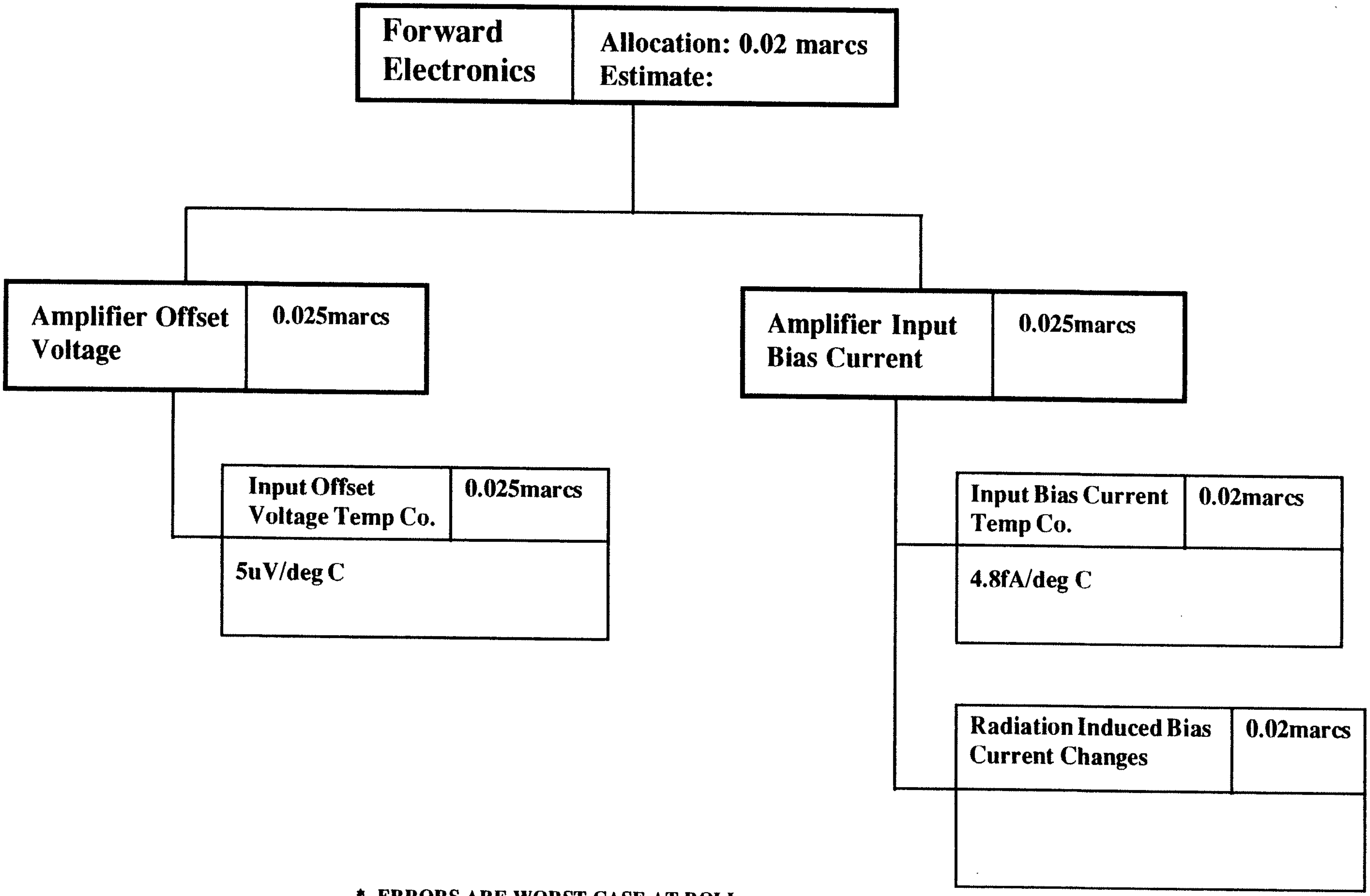
BIAS VARIATION ERROR TREE

- **Detector Interface** | Allocation: 0.03 marcs | Estimate:
  - **Feedback Line** | 0.005
    - Filter Attenuation | 0.005 | 0.001% Stability
    - Thermocouple Voltages | 0.001 | Peak Thermocouple voltage @ roll ~ 10uV/K
  - **Photodiode Cathode Voltage** | 0.02
    - Filter Attenuation | 0.01 | 0.001% Stability
    - Thermocouple Voltages | 0.01 | Peak Thermocouple voltage @ roll ~ 10uV/K
    - EMI Rectification | 0.005 | Peak Thermocouple voltage @ roll ~ 10uV/K
    - TRE Electrical Temp Co | 0.01 | < 1% Temp Co. mismatch
  - **1st Stage Reference Voltage** | 0.02
    - Filter Attenuation | 0.01 | 0.001% Stability
    - Thermocouple Voltages | 0.01 | Peak Thermocouple voltage @ roll ~ 10uV/K
    - TRE Electrical Temp Co | 0.01 | < 1% Temp Co. mismatch
  - **Leakage Current** | 0.01
    - Probe Cables | 0.005 | 300pA @ Roll
    - Top Hat Connector | 0.005 | 300pA @ Roll
    - Filter Attenuation | 0.005 | 300pA @ Roll
    - FEE Cable | 0.005 | 300pA @ Roll
    - TRE Connector | 0.005 | 300pA @ Roll

* ERRORS ARE WORST CASE AT ROLL

* TRE CIRCUIT SENSITIVITIES ARE DETERMINED IN SPICE

BIAS VARIATION ERROR TREE



Forward Electronics

Allocation: 0.02 marcs
Estimate:

Amplifier Offset Voltage

0.025marcs

Input Offset Voltage Temp Co.

0.025marcs

5uV/deg C

Amplifier Input Bias Current

0.025marcs

Input Bias Current Temp Co.

0.02marcs

4.8fA/deg C

Radiation Induced Bias Current Changes

0.02marcs

* ERRORS ARE WORST CASE AT ROLL
* TRE CIRCUIT SENSITIVITIES ARE DETERMINED IN SPICE

TELESCOPE READ-OUT ELECTRONICS CRITICAL DESIGN REVIEW

WRAP-UP

P. EHRENSBERGER

On-orbit Verification
Mission Time Line

ON ORBIT VERIFICATION

Pre-mission:

Large and small amplitude dither operations - scale-factor measurement and look for anomalous response.

Detector thermal control evaluation - test thermal control modes for detector and select one.

Observation of guide star and neighbors - verify calibration of magnitude signal

Monitor redundant electronics during roll-up - study temp coef of bias in forward electronics.

Sunshade performance evaluation - verify that sunshade is performing adequately. (method not identified to date)

Mission:

Guide Star Invalid mode provides data to verify bias variation in TRE (detector and fwd).

Redundant channel read out provides a way to evaluate bias variation due to temperature and/or or radiation effects in forward electronics during Guide Star Valid.

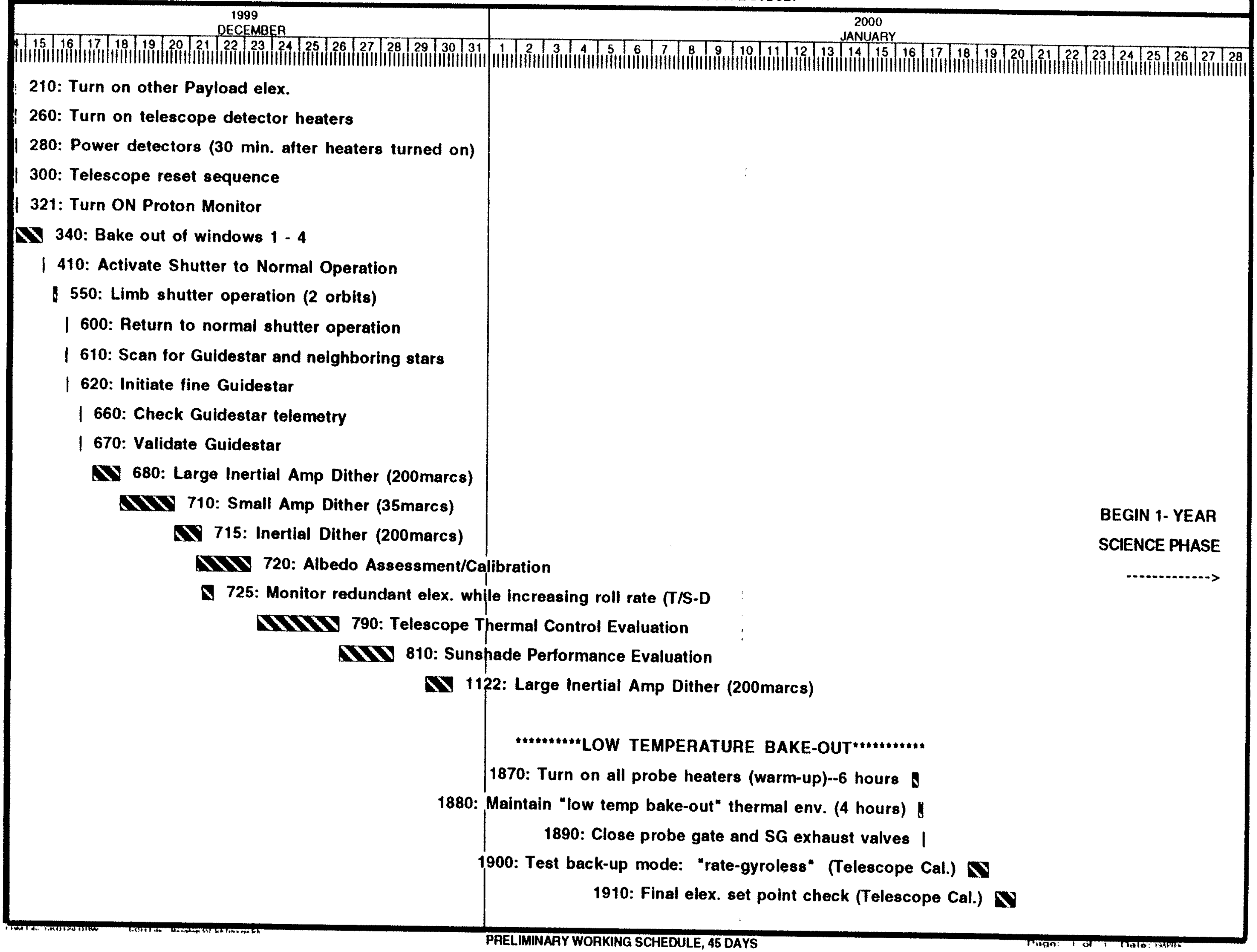
Monitor magnitude signals to verify sunshade performance.

Post-mission:

Enhance temperature variation in forward electronics to verify temperature coef (no method identified to date).

Enhance temperature variation in detector to verify temperature coef.

RELATIVITY MISSION TIMELINE: TELESCOPE SUBSET



PRELIMINARY WORKING SCHEDULE, 45 DAYS

RELATIVITY MISSION TIMELINE DATASET - TELESCOPE SUBSET (COMMANDS AND TELEMETRY)

Event #	Associated Commands:	Associated Telemetry:	Event #	Associated Commands:	Associated Telemetry:
210	HLD from CCCA to Alt SRE A		680	SF DITHERAMP,	Detector signals: (as in 410)
260	Set x detector heater A,	TRE A x DTemp,		SF DITHERFREQ,	
	Set x detector heater B,	TRE B x DTemp,		SF DITHERRATE,	
	Set y detector heater A,	TRE A y DTemp,		SF DITHER	
	Set y detector heater B	TRE B y DTemp	710	SF DITHERAMP,	Detector signals; (as in 410)
280	Power x detector A,	TRE A x DTemp,		SF DITHERFREQ,	
	Power x detector B,	TRE B x DTemp,		SF DITHERRATE,	
	Power y detector A,	TRE A y DTemp,		SF DITHER	
	Power y detector B	TRE B y DTemp	715	SF DITHERAMP,	Detector signals: (as in 410)
300	asynchronous reset, set snapshot monitor mode	Snapshot- detector signal telemetry		SF DITHERFREQ,	
321	PDU: Proton Monitor On			SF DITHERRATE,	
340				SF DITHER	
410	Remove power to shutter to disable closed	Detector signals: TRE A (+x) (-x),	720	set snapshot monitor mode	Detector signals: (as in 410)
	(TBD) - Lim Mar	TRE B (+x) (-x), TRE A (+x)DET,		open and close shutter to given angle	Shutter Open/close detectors
		TRE B (+x)DET, TRE A (-X)DET,	725		
		TRE B (-X)DET, TRE A (+Y) (-Y),	790		
		TRE B (+Y) (-Y), TRE A (+Y)DET,	810	Switch to gyro pointing	Std Tlm - TBD
		TRE B (+Y)DET, TRE A (-Y)DET,		Point Telescope at large star-free area of space	
		TRE B (-Y)DET		Return to Guidestar pointing	
		Shutter tlm (TBD)		TBD	
550	set snapshot monitor mode	Detector signals: (as in 410)	1122	SF DITHERAMP,	Detector signals: (as in 410)
	open and close shutter to given angle	Shutter Open/close detectors		SF DITHERFREQ,	
600	set snapshot nominal mode	Detector signals: (as in 410)		SF DITHERRATE,	
	open and close shutter to given angle	Shutter Open/close detectors		SF DITHER	
610		Detector signals: (as in 410)	1870		
620	Initiate guidestar acquisition		1880		
660		Detector signals: (as in 410)	1890		
670		FF GSVALID	1900	Change mode to gyroless	
			1910		