MODIS
(Moderate Resolution Imaging Spectroradiometer)

CALIBRATION PEER REVIEW DATA PACKAGE

August 1995

DM VJ59-0238
CDRL 019

SANTA BARBARA RESEARCH CENTER

HUGHES AIRCRAFT

A HUGHES ELECTRONICS COMPANY

CAL PEER REVIEW AGENDA

Day 1, September 13, 1995

8:00 Program Status & Schedule (Tessmer)

8:15 Testing and Calibration Overview (Pagano/Young)
- Testing Compliance Matrix
- Algorithm Specification & TAC Usage
- Stategy for Budgets, Error Analysis and Trending

8:45 Testing Implementation (Bates/Koch)
- EM Testing vs PFM Testing
- Ambient Performance Testing
- Thermal Vacuum Performance Testing & Timeline
- Consent to Deconfigure Criteria

9:15 Ground Support Equipment (Alferd/Thompson)
- GSE Usage Matrix
- SIS, BCS/SVS, SpMA, IAC, ScMA, PSA, SBS's, MCC, etc.

9:45 Performance Predictions for PFM

9:45 Radiometric Sensitivity (Pagano/Bauer)
- EM SNR, NEΔTs
- Measurement Accuracies
  - Algorithm for Reduction
  - SNRs & Lamp Sequences
- LWIR Transmission & Noise
- Dynamic Range & Backgrounds

10:15 Break

10:30 Radiometric Accuracy (Pagano/Bauer))
- Accuracy Budget
- Traceability to NIST
- Predictions by Contributor
- EM Master Curve Results
- Linearity Measurement Issues
- Spatial Effects on Accuracy

11:15 Radiometric Stability (Pagano/Bauer))
- EM Stability Results
- PFM Stability Measurement Plans

11:30 Polarization (Young/Pellicori)
- Measurement Accuracy Budget
- PSA Anomalous Drift

12:00 Lunch

1:00 Near Field Response (Young/Pagano)
- Measurement Accuracy Budget
- Thermal Backgrounds Mitigation Plan
- AOA Results
- PFM Predictions

1:45 Spatial (Therrien/Lommen)
- Response vs Scan Angle
- FOV
- IFOV, MTF
  - Measurement Accuracy Budget
  - EM Results
  - AOA Results from PFM
- Registration
  - Measurement Accuracy Budget
  - EM Results
  - Revised Plan for Static/Dynamic
- Pointing
  - Measurement Accuracy Budget
  - VIS/NIR Test
  - SRCA Usage
- Light Leaks

2:15 Spectral (Young/Pellicori)
- Measurement Accuracy Budget
- Dry Nitrogen Purge Requirements
- SpMA Anomaous Spectral Response
- Out-of-Band Response

2:45 Stray Light (Young)
- Measurement Accuracy Budget
- Far Field Stray Light Test Plan
- Aperture Based Stray Light Test Plan

3:00 In-Flight Calibration

3:00 Blackbody (Bauer/Johnson)
- Performance Budget
- EM Test Results
- PFM Build
- Verification and Calibration Plan

3:30 Solar Diffuser (Young/Johnson)
- Performance Budget
- PFM Build
- Round Robin
- Stray Light Modeling (Fest)
- Verification and Calibration Plan

3:45 SDSM (Johnson)
Performance Budget
PFM Build
Verification and Calibration Plan

4:00 SRCA (Johnson)
Performance Budget
PFM Build
Verification and Calibration Plan

4:30 Adjourn

Day 2 September 14, 1995

Roll-over
Action Items
Discussions
Splinter Sessions

INTRODUCTION AND OVERVIEW

Lee Tessmer

INTRODUCTION

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- This is the third Calibration Peer Review of the MODIS instrument
- Two days have been allocated for the review: one day for presentations, and one day for wrap up, action items, and splinter sessions
- Amenities
- Agenda
- Protocols

PROGRAMMATIC OVERVIEW
(TOPICS)

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- EM testing a success
  - Extraordinary teamwork required
  - An abundance of meaningful test data
  - A sound basis for proceeding with the PFM
- PFM status
  - Schedule overview
  - Challenges

MODIS TEAMWORK

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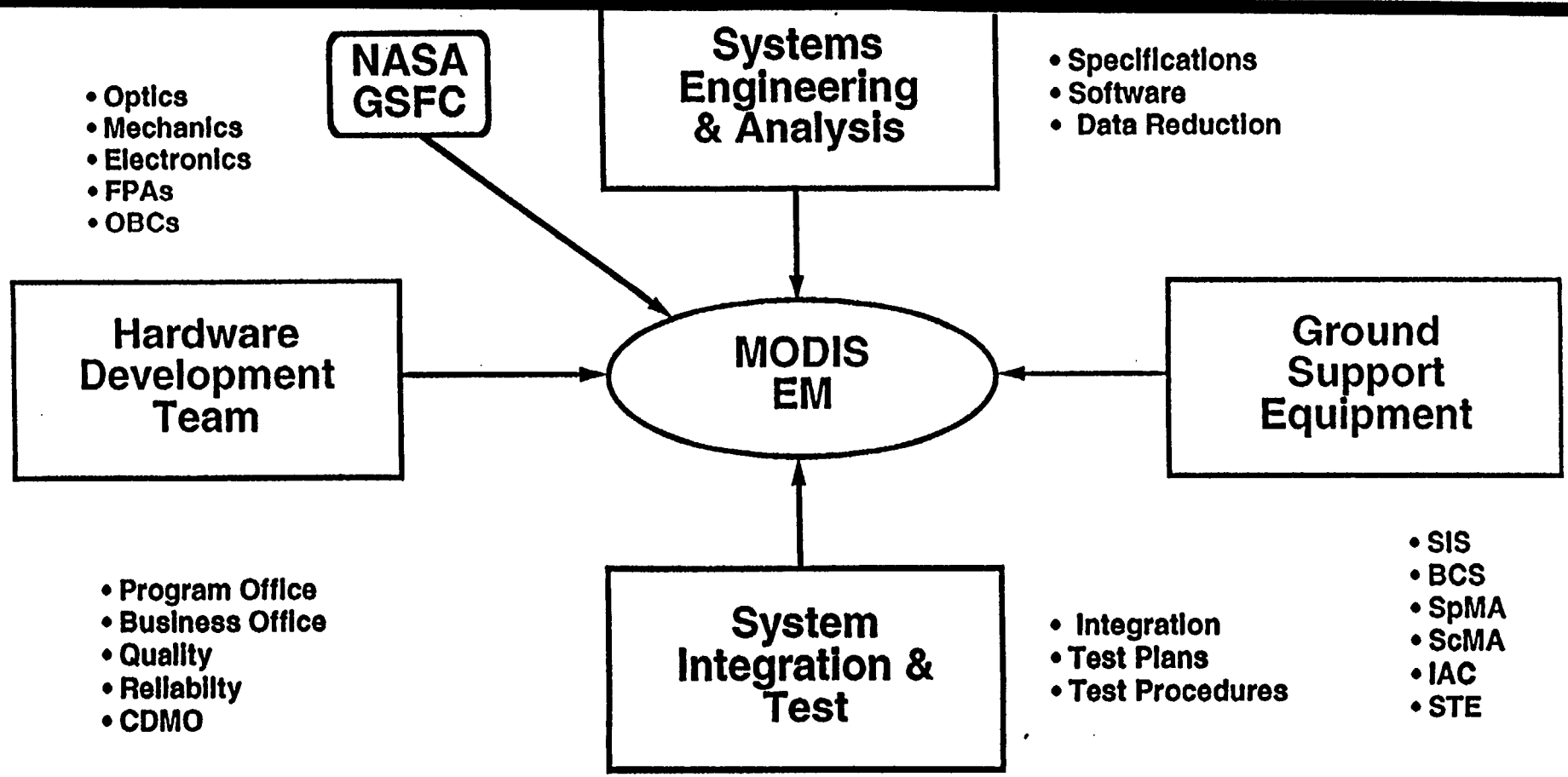

- The EM experience demonstrated that we have an able team, excellent GSE, and specialized facilities

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EM MODIS FULL BUILD-UP OF ESSENTIAL SUBSYSTEMS

MODIS
GSFC SBRC

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MODIS GROUND SUPPORT EQUIPMENT IN-PLACE

95-6-47

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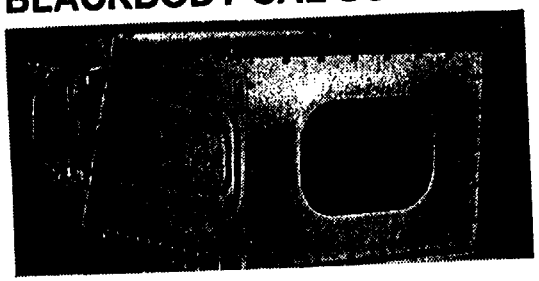
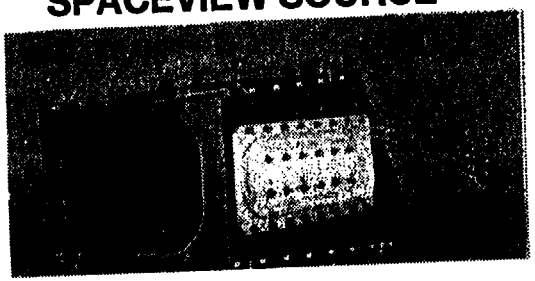
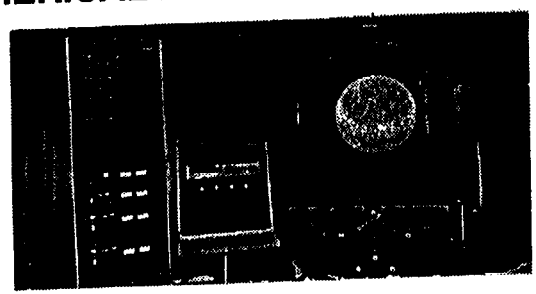
BLACKBODY CAL SOURCE



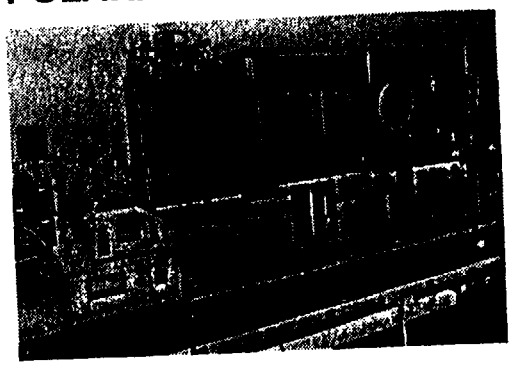
SPACEVIEW SOURCE



SPHERICAL INTEGRATOR SOURCE



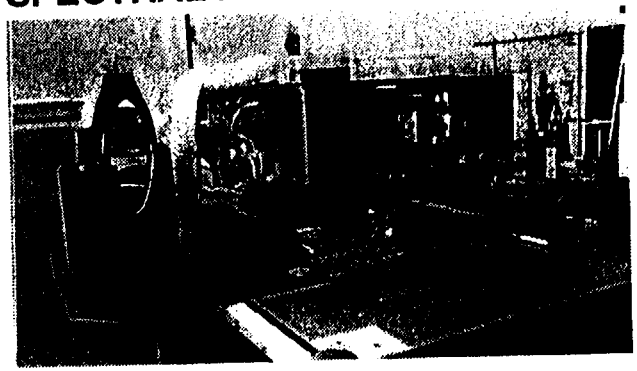
POLARIZED SOURCE ASSY



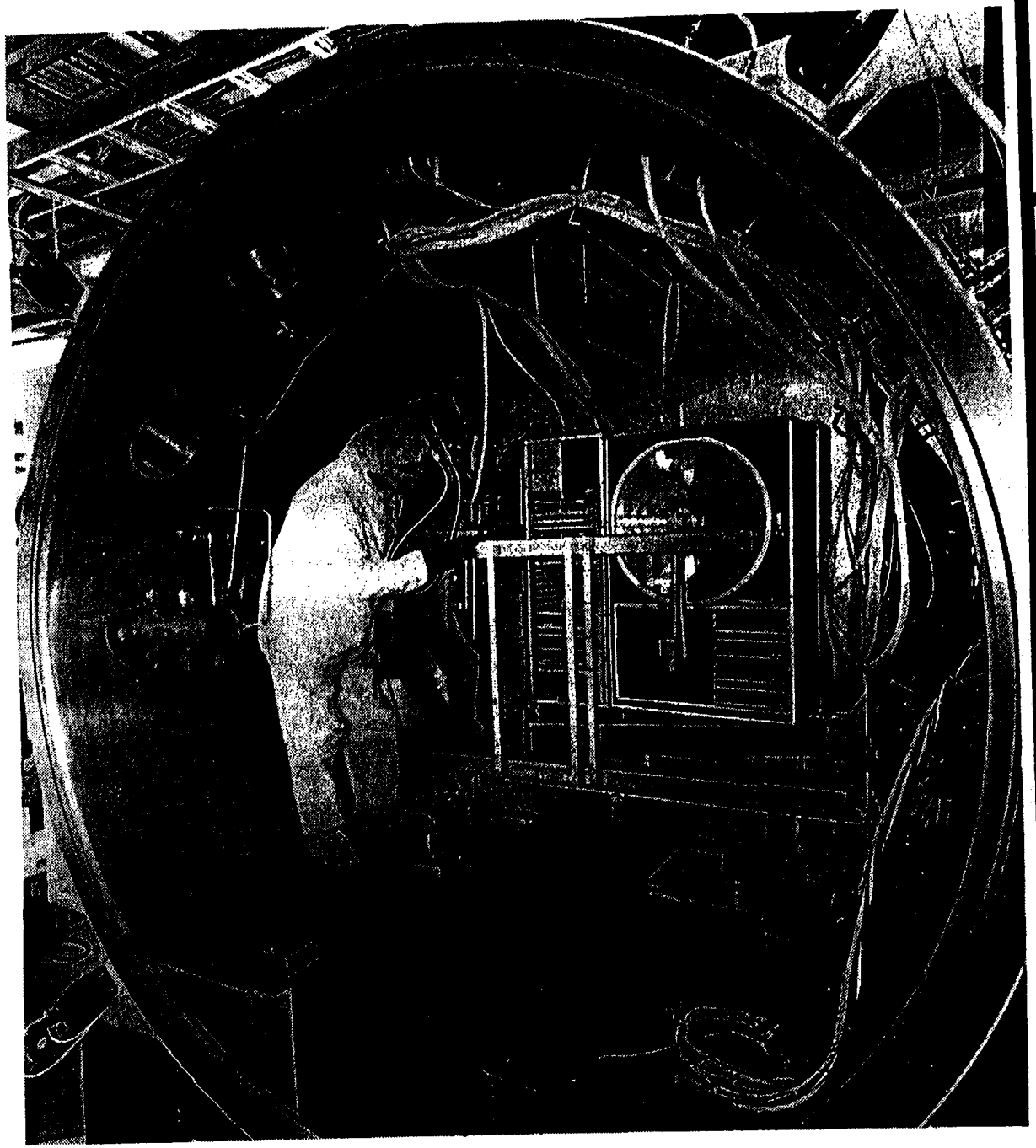
INTEGRATION AND ALIGNMENT COLLIMATOR

BENCHTEST COOLER SYSTEM TEST COMPUTERS

SPECTRAL MEASUREMENT ASSY



SCATTER MEASUREMENT ASSY



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MODIS CALIBRATION CHAMBER DEMONSTRATED ON MODIS EM

MODIS
GSFC SBRC

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EM HIGHLY SUCCESSFUL EFFORT

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Objectives: EM used for PFM:	Achieved
• To prove out instrument design	√
• To debug development and build cycle	√
• To demonstrate GSE and test method effectiveness	√
• To identify problem performance areas	√
• To develop an experienced instrument team	√

MODIS Design Robust

- No hard instrument failures during thermal vacuum
- No need to break vacuum; instrument functioned well

Note: Several EM subsystems reused PFM

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SCHEDULE OVERVIEW
PROTOFLIGHT MODEL

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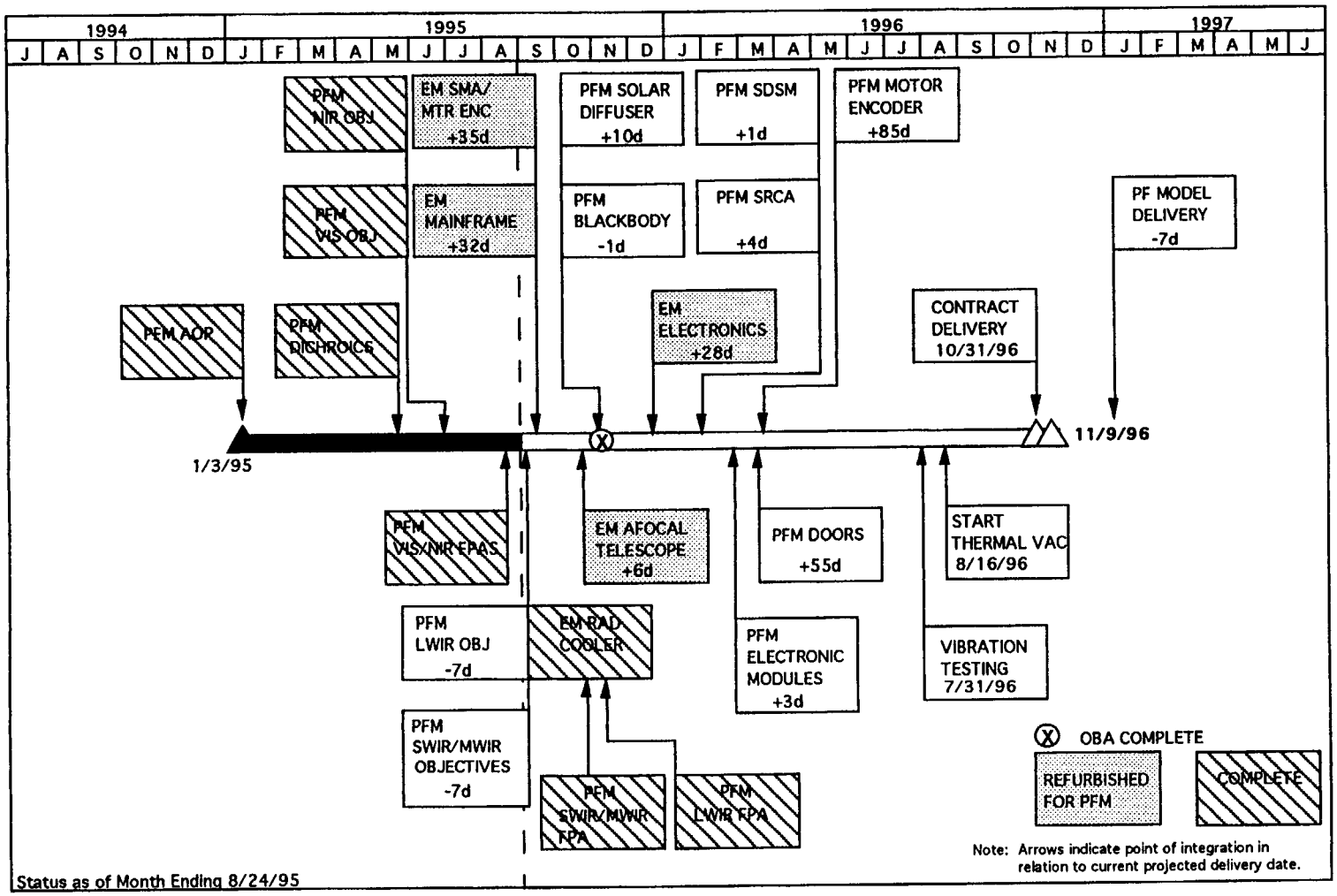

PFM CHALLENGES

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- Programmatic challenges
  - Holding to delivery schedule
  - Managing within available financial resources
  - Holding the team together
- Major technical challenges
  - Near field response

TESTING AND CALIBRATION OVERVIEW

Tom Pagano

GSFC REQUIREMENTS LEAD TO SYSTEM SPECIFICATIONS

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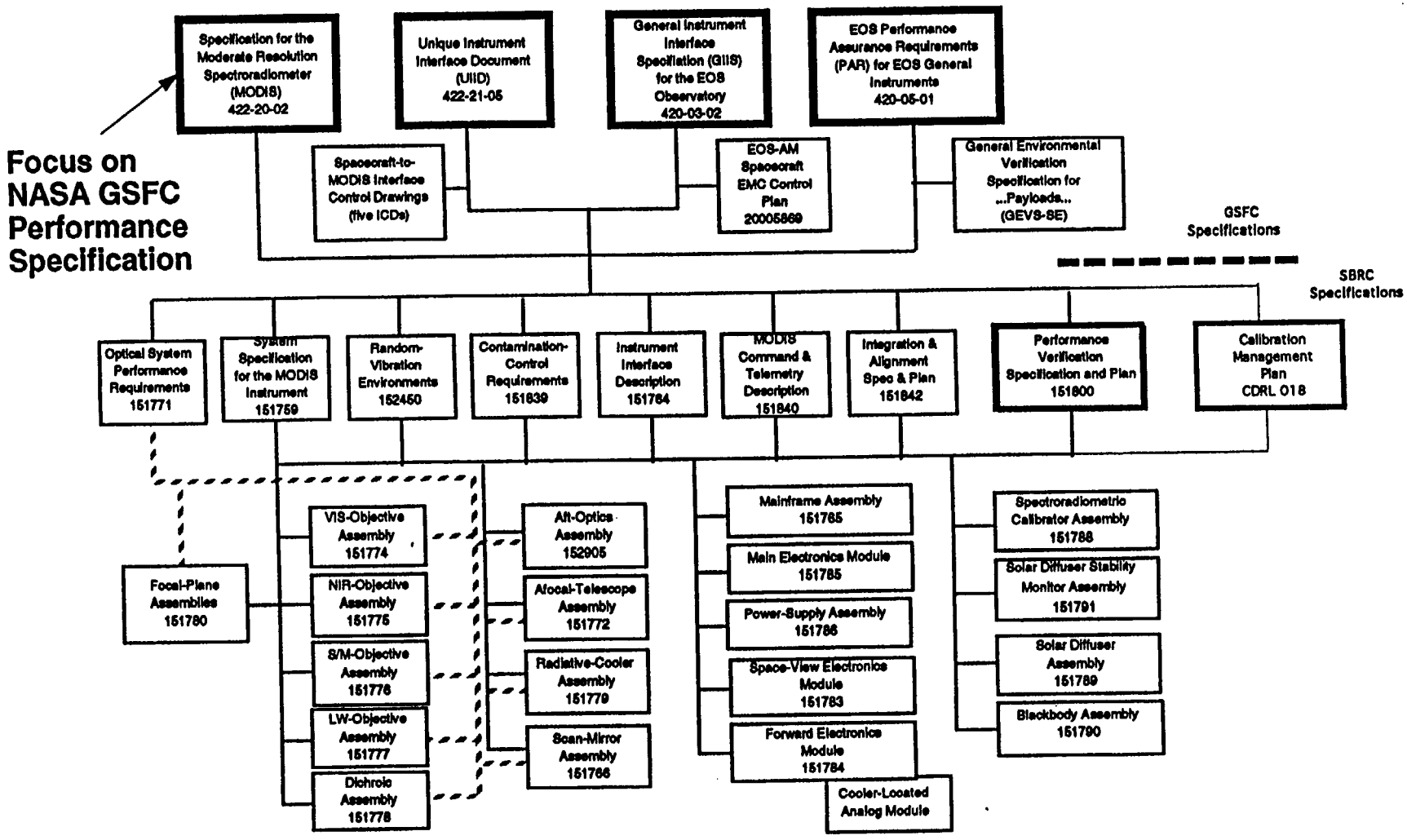

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INSTRUMENT REQUIREMENTS ARE CHALLENGING

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• Spectral Coverage	0.407 μm - 14.385 μm, 36 Bands
• Spectral Resolution	10 nm ≤ Δλ ≤ 500 nm
• Spectral Stability	λ & Δλ stable to ≤ 2 nm (VIS, NIR) λ & Δλ stable to ≤ 1% (all other bands)
• Spatial Coverage	±55°, 2330 km swath length at 705 km (contiguous scans at Nadir at the equator)
• Spatial Resolution	250m; 500m; 1000m at Nadir
• Spatial Registration	0.2 IFOV (0.1 IFOV goal)
• IFOV	0.354 mr, 0.709 mr, 1.418 mr (All ±6%)
• Radiometric Range	0.002% ≤ ρ ≤ 100%, 3K ≤ T ≤ 700K
• Dynamic Range	NEΔL to L_{max} (requires 12 bits)
• Radiometric Performance	≥ 57 to 1087, ≤ 5.0 to 0.05K
• Polarization Isolation	≤ 2%, 0.43 μm ≤ λ ≤ 2.2 μm
• Calibration Accuracy	Absolute Calibration: ±1% λ > 3 μm; ±5% λ < 3 μm; ±0.75 (Band 20), ±0.5% (Bands 31, 32) ±2% Reflectance (λ < 3 μm)

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PROTOFLIGHT MODEL TEST COMPLIANCE MATRIX FOR GSFC 422-20-02

Section	GSFC Specification 422-20-02	HI-BAY Pre-Env	AMB-MCC Pre-TV	T/V MCC 1st Cold	T/V MCC 1st Hot	T/V MCC 2nd Cold	T/V MCC 2nd Hot	T/V MCC Cal	AMB-MCC Post-TV
1	**Scope**								
2	**Applicable Documents**								
3	**Technical Requirements**								
3.1.	**Requirements Overview**								
3.2.	**Operational Requirements**								
3.3.	**Optical Requirements**								
3.3.1.	Instantaneous Field of View		PC-05						
3.3.2.	Field of View	FOV/RVS							
3.3.3.	Spectral Bands								
3.3.3.1	Definitions								
3.3.3.2	Edge Range		PC-07					PC-07	
3.3.3.3	Out-of-Band		PC-07					PC-07	
3.3.3.4	Ripple		PC-07					PC-07	
3.3.4.	Sensitivity Requirements								
3.3.4.1	VIS/NIR/SWIR			RC-01	RC-01			RC-01	
3.3.4.2	Thermal Emittance			RC-02	RC-02			RC-02	
3.3.5.	Polarization Insensitivity	PC-08							
3.4.	**System Performance**								
3.4.1.	Dynamic Range			RC-01,2	RC-01,2			RC-01,2	
3.4.2.	Modulation Transfer Function		PC05						
3.4.3.	Minimum Quantizing Resolution			RC-01,2	RC-01,2			RC-01,2	
3.4.4.	Transient Response	PC-04							
3.4.5.	Radiometric Performance								
3.4.5.1.	Spectral/Ampl Accy			RC-01,2	RC-01,2			RC-01,2	
3.4.5.2.	Absolute Rad Accy			RC-01,2	RC-01,2			RC-01,2	
3.4.5.3.	Relative Rad Accy								
3.4.5.3.1	RMS Deviation			RC-01,2	RC-01,2			RC-01,2	
3.4.5.3.2	Ch-to-Ch Uniformity			RC-01,2	RC-01,2			RC-01,2	
3.4.5.3.3	X-Talk, Fixed Pattern			MFI-10 FPN	MFI-10 FPN	MFI-10 FPN	MFI-10 FPN	MFI-10 FPN	
3.4.5.4.	IFOV Uniformity		PC-05						
3.4.5.5.	System Noise Meas.			RC-01,2	RC-01,2			RC-01,2	
3.4.6	Geometric Performance								
3.4.6.1	Pointing Knowledge	PC-06		PC-02	PC-02			PC-02	
3.4.6.2	Alignment Changes	PC-06		PC-02	PC-02			PC-02	
3.4.6.3	Registration	PC-02		PC-02	PC-02			PC-02	
3.4.7	Radio. Ampl. Stability and Repeat.								
3.4.7.1	Short Term Stability			RC-01,2	RC-01,2			RC-01,2	
3.4.7.2	Long-Term Stability			RC-01,2	RC-01,2			RC-01,2	
3.4.7.3	Spectral Band-to-Band Stab.			RC-01,2	RC-01,2			RC-01,2	
3.4.7.4	Wavelength Stability		PC-07					PC-07	
3.4.7.5	Wavelength Accy & Precision		PC-07					PC-07	
3.4.8	Stray Light								
3.4.8.1	Stray Light Rejection	PC12							
3.4.8.2	Bright Target ...	PC-09							
3.4.8.3	Dark Target ...	PC-09							
3.4.8.4	Warm Target ...	PC-11							
3.4.9	In-Flight Calibration								
3.4.9.1	In-Flight Radiometric	MFI-09		MFI-09				PC-17	
3.4.9.2	In-Flight Wavelength	MFI-15						PC-17	
3.4.9.3	In-Flight Reflectance	MFI14, PC-18							

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PROTOFLIGHT MODEL TEST COMPLIANCE MATRIX FOR GSFC 422-20-02

Section	GSFC Specification 422-20-02	HI-BAY Pre-Env	AMB-MCC Pre-TV	T/V MCC 1st Cold	T/V MCC 1st Hot	T/V MCC 2nd Cold	T/V MCC 2nd Hot	T/V MCC Cal	AMB-MCC Post-TV
3.4.9.4	In-Flight Lunar	No Test							
3.4.9.5	In-Flight Electronics	Ecal	Ecal						
3.4.10	Miscellaneous								
3.4.10.1	Passive Rad Cooler...	No Test							
3.4.10.2	Ambient Conditions Limits...	No Test							
3.4.10.3	Witness Mirrors	No Test							
3.4.10.4	Solar Flux	No Test							
3.5.	CCC and Telemetry								
3.5.1	Command & Control	MFI-07							
3.5.2	Instrument Data Stream								
3.5.2.1	Data Rates	MFI-10							
3.5.2.2	Data packet	MFI-10							
3.5.3	Instrument Health & Status								
3.5.3.1	Command Status	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07
3.5.3.2	Houskeeping ...	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07	MFI-07
3.6.	Interface Requirements								
3.6.1	General								
3.6.2	Unique								
3.6.2.1	Power Consumption	MFI06, MFI12,MFI13		MFI-06	MFI-06				
3.6.2.2	Mechanical Dimensions	PC-14							
3.6.2.3.	Deleted								
3.6.2.4.	View Factors								
3.6.2.4.1.	Ground View	No Test							
3.6.2.4.2.	Sun View	No Test							
3.6.2.4.3.	Space View	No Test							
4	Software Requirements	See Software Management Plan							
5	Verification and CAL Reqmts.	See Performance Verification Plan and Calibration Management Plan							
6	Ground Support Equipment								

Test ID	Title
MFI-06	Electronics Grounding and Power Verifications
MFI-07	Commands and Telemetry
MFI-09	Blackbody Operation and DC Restore
MFI-10	Data Stream Verification and Fixed Pattern Noise
MFI-12	Power Profile
MFI-13	Input Current Transients
MFI-14	SDSM Functional
MFI-15	SRCA Functional

Test ID	Title
RC-01	Radiometric Cal Reflective Bands
RC-02	Radiometric Cal Emissive Bands
PC-02	Spatial Performance: Dynamic
PC-05	Spatial Performance: Static
PC-04	Near Field Response
PC-06	Pointing Knowledge
PC-07	Spectral Coverage

Test ID	Title
PC-08	Polarization Insensitivity
PC-09	Bright/Dark Target...Stray Light
PC-11	Warm Target...Stray Light
PC-12	Stray Light Rejection
PC-13	S/C Mounting Template Cal
PC-14	Mass Properties
PC-15	Magnetic Mapping
PC-16	EMI/EMC
PC-17	In-Flight Calibrator Stimulation
PC-18	Solar Calibrator Functional

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TEST ANALYSIS CONTROLLER
PROGRAM STRUCTURE AND DATA FILES

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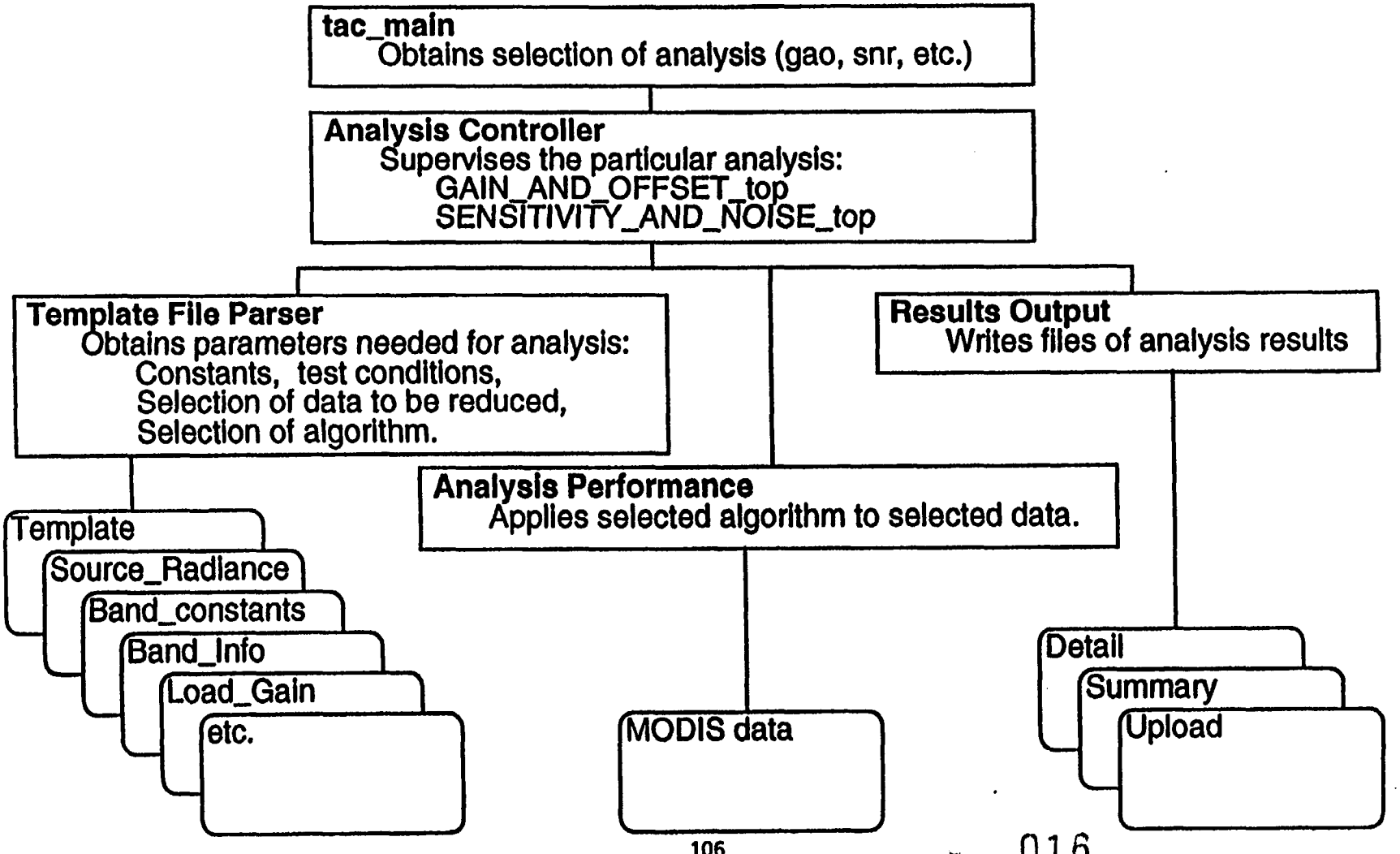

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PLANS IDENTIFIED FOR CALIBRATION AND CHARACTERIZATION OF MODIS

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- Extensive preflight calibration and characterization of all key performance indicators in current test plan
- Preflight Ground Support Equipment linked to NIST traceable sources
- MODIS Calibration Chamber on-line. Enhances model-to-model uniformity of calibration
- Preflight and On-orbit calibration linked via On-board Calibrators Blackbody, Solar Diffuser, SDSM, SRCA
- On-orbit ground truth, lunar, and solar calibration essential to complete calibration methodology
- This review will only cover pre-flight calibration/characterization and on-board calibrators

MULTIPLE SOURCES USED TO CALIBRATE MODIS

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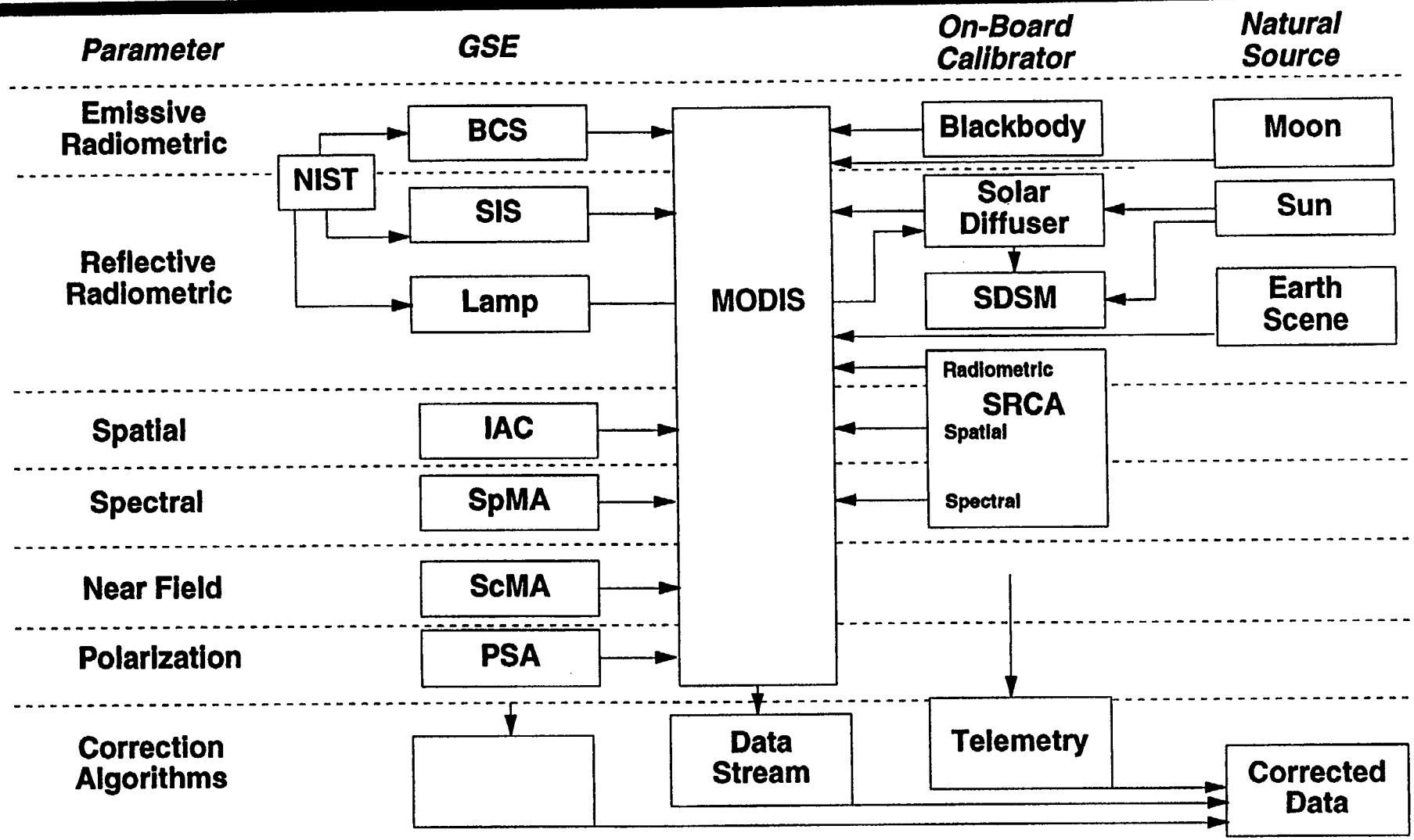

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INTEGRATION AND TEST

D. Bates / T. Koch

PFM SYSTEM INTEGRATION & TEST

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- System Integration and Test Process
- PFM Test Procedure Development Plans and Status
- Test Procedure Close-Out Process
- Test Procedure Close-Out Status
- Special Test Request Close-Out Status

PFM SYSTEM INTEGRATION & TEST PROCESS

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- Plans Based On Released PVS/PVP
  - Customer Comments in Review
  - Schedule Implications in Review
- Weekly Summary Meetings with Task Leaders and Line Mgmt
  - Summarize last week's accomplishments, future plans
  - Ensure adequate manpower coverage
- Daily Coordination Meetings with Task Leaders
  - Twice daily during 2- and 3-shift operations
- Consent-to-Proceed Meetings at key junctures
  - Ensure all actions complete before changing set-up and/or instrument configuration
  - Best effort to ensure data validity before proceding
  - Avoid delay and expense of repeating any set-up
- Formal documentation approach used to ensure highest quality
  - Released Test Procedures, Planning, EOs, Emergency EOs
  - Formal Anomaly Reporting

PFM TEST PROCEDURE DEVELOPMENT PLANS

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Protoflight Model Instrument Test Phase	Total TPs	Revisions from EM	New Procedures	Number Released
Aft Optics Integration	13	12	1	10
Mainframe Integration	19	9	10	0
System Level	20	9	11	1

PROTOFLIGHT PROCEDURE DEVELOPMENT SCHEDULE

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EDCC Number	Test ID	TEST PROCEDURE NAME	Author	Activity #	Procedure Release Need Date	Planned First Use
152751	AOI-01	Cooled Spectral-Bands Eye-Lens Alignment	Chirra	F0-30-03a	Released	1/3/95
152752	AOI-02	Dichroic-Assembly Alignment	Chirra	F0-30-03b	Released	2/27/95
152756	AOI-15	Cooled Spectral Bands Vignetting Check	Chirra	F0-30-03e	Released	5/15/95
152764	AOI-SU	Aft-Optics-Integration Test-Equipment Setup	Chirra	(F0-30-03d,04)	Released	6/1/95
152753	AOI-03	Ini- Align of NIR-OBJ to AOP Mech-Datums	Chirra	F0-30-03c	Released	6/1/95
152754	AOI-04	Ini- Align of VIS-OBJ to AOP Mech-Datums	Chirra	F0-30-03d	Released	6/1/95
152760	AOI-SOP	BAEM/IAC/BTC Operating Procedure	Franco	(F0-30-03d,04)	Released	6/1/95
152757	AOI-07	NIR FPA Alignment	Franco	F0-30-04a	Released	6/26/95
152758	AOI-08	VIS FPA Alignment	Franco	F0-30-04b	Released	6/26/95
152759	AOI-09-13	Cooled-Spectral-Bands Alignments	Koch	F0-30-04c,d,e,f	Released	7/25/95
152766	MFI-02	Alignment of Reference Cube to S/C Interface	Luke	F0-30-05	8/2/95	9/1/95
152765	MFI-01	SMA Alignment to S/C Interface	Luke	F0-30-05	8/8/95	9/7/95
152783	MFI-SU	Mainframe Integration Test Equipment Setup	Kus	(F0-30-04,...)	8/13/95	9/12/95
152768	MFI-21	Solar Diffuser Pointing Verificaiton	Luke	F0-30-05	8/14/95	9/13/95
152795	AOI-14	OBA Spatial Verifications	Kent	F0-30-04.5	9/9/95	10/9/95
152803	AOI-Vibe	Aft Optics Assembly Random Vibration Exposure	Luke	F0-30-05.10	9/16/95	10/16/95
152791	ALPC06	Determining Pointing Knowledge	Franco	F0-30-13	9/27/95	10/27/95
152773	MFI-09	BB Operation & DC-Restore Function Check	Vanstone	F0-30-08d	10/10/95	11/9/95
152767	MFI-03	OBA Alignment to Scan Mirror	Kent	F0-30-05	10/14/95	11/13/95
152778	MFI-14	Alignment and Functional Check of the SDSM	De Loo	F0-30-07	10/16/95	11/15/95
152786	AL-SU	Ambient-Lab Test-Equipment Setup	Kus	(F0-30-10)	11/7/95	12/7/95
152770	MFI-06	Electronics Grounding & Power Verifications	Glick	F0-30-08a	11/7/95	12/7/95
152792	ALPC07	Measurement of Spectral Coverage	Vanstone	F0-30-13	11/9/95	12/9/95
152793	ALPC08	Measurement of Polarization Insensitivity	Parker	F0-30-13	11/10/95	12/10/95
152761	MFI-19	Gravity Release Assessment	Kent	F0-30-07	11/22/95	12/22/95
152787	ALPC2/3/5	System Spatial Performance	Kent	F0-30-13	12/13/95	1/12/96
152779	MFI-15	Alignment and Functional Check of the SRCA	Rodil	F0-30-07	12/26/95	1/25/96

PROTOFLIGHT PROCEDURE DEVELOPMENT SCHEDULE

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EDCC Number	Test ID	TEST PROCEDURE NAME	Author	Activity #	Procedure Release Need Date	Planned First Use
152771	MFI-07	MODIS Commands and Telemetry Verifications	Glick	F0-30-08b	1/3/96	2/2/96
152776	MFI-12	Power Profile Measurements	Glick	F0-30-08g	1/3/96	2/2/96
152777	MFI-13	Input Current Transient Measurements	Glick	F0-30-08h	1/3/96	2/2/96
152774	MFI-10	Data Stream Verification and Pattern Noise	Kus	F0-30-08b	1/3/96	2/2/96
152935	MFI-20	System Software Verification	Auchter	F0-30-08	1/24/96	2/23/96
152782	MFI-18	Scan Mirror Encoder Readout Perf. Tracking	Glick	F0-30-08	1/31/96	3/1/96
152787	ALPC04	Transient Response Measurement	Kent	F0-30-13	2/4/96	3/5/96
152772	MFI-08	Scene/OBC Stimuli Frame Number Determination	Vanstone	F0-30-08c	2/5/96	3/6/96
152781	MFI-28	Mechanical Function Test	Luke	F0-30-08	2/6/96	3/7/96
152785	ALRC02	...MWIR & LWIR Spectral-Bands Responsivities	De Loo	F0-30-11	2/7/96	3/8/96
152784	ALRC01	Rad-Cal of VIS, NIR, & SWIR Spectral Bands	Franco	F0-30-10	2/7/96	3/8/96
152755	AOI-05/06	Ini- Align of SW/MW/LWIR-OBJs to AOP Mech-Datums	Chirra	F1-30-03e	2/24/96	3/25/96
152788	AOI-17	NIR FPA Alignment with IAC2	Chirra	F1-30-04a	3/5/96	4/4/96
152790	AOI-18	VIS FPA Alignment with IAC2	Chirra	F1-30-04b	3/5/96	4/4/96
152794	ALPC09	Eval of Brt&Dk Targets w/in Field, Stray Lt.	De Loo	F0-30-12	3/20/96	4/19/96
152796	ALPC11	Eval of Warm Target Within Field Diff. Light	De Loo	F0-30-12	3/21/96	4/20/96
152797	ALPC12	Evaluation of Stray Light Rejection	De Loo	F0-30-12	3/22/96	4/21/96
152780	MFI-16	Transfer of MODIS Alignment to the Ref. Cube	Luke	F0-30-05	4/23/96	5/23/96
152808	TV-SU	Thermal Vacuum Test Equipment Setup	TBD	(F0-30-16)	4/24/96	5/24/96
152798	ALPC13	S/C Mounting Template Pointing Calibration	Franco	F0-30-14	5/6/96	6/5/96
152799	ALPC14	Mass Properties Measurements	Rodil	F0-30-15	5/18/96	6/17/96
152120	ALPC16	EMI/EMC Measurements	Glick	F0-30-15	5/25/96	6/24/96
152802	ALLE02	Structural Loads & Random Vibration Exposures	Luke	F0-30-16	6/8/96	7/8/96
152804	ALLE04	Acoustics Eposure	Rodil	F0-30-16	6/15/96	7/15/96
152800	ALPC15	Magnetic Mapping	Rodil	F0-30-16	6/16/96	7/16/96
152807	TV-TP	Thermal Vacuum Test Procedure - MODIS	Brown	F0-30-16	6/24/96	7/24/96
152805	ALLE05	Mechanical Shock (N/A. Deviation authorized to defer to S/C test.)				

PFM TEST PROCEDURE CLOSE-OUT FLOWCHART

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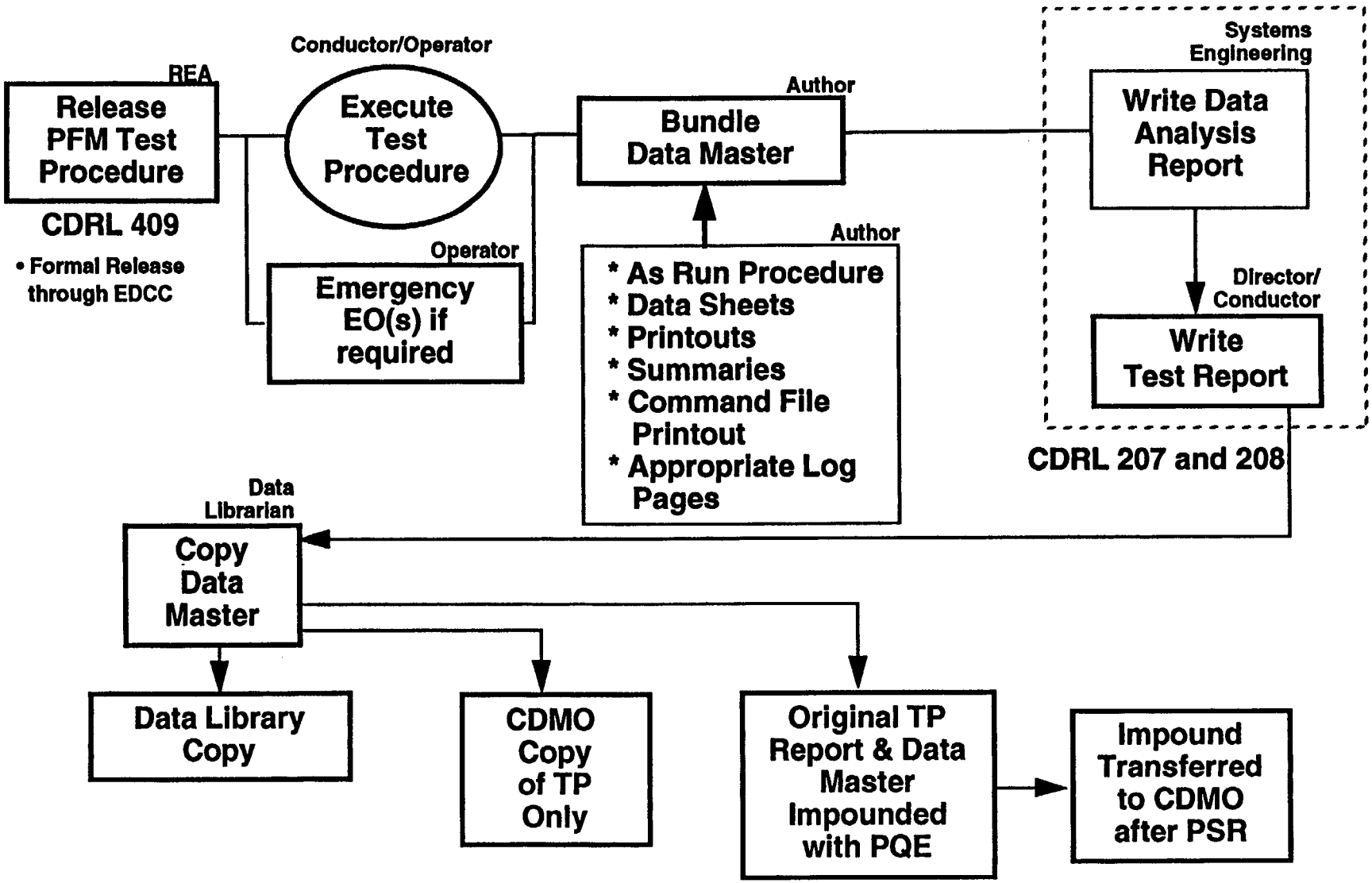

Test Phase: PFM Aft Optics Integration

Procedure No. & Name	Test Execution Completed	Run-Time EO's Required	Data Master(1) Bundled For Review	Data Analysis Report Complete (PL3095-)	Test Report Complete (PL3095-)	Data Master Impounded	Consent-to-Proceed Completed
AOI-01 ELMP Align	2/13/95		2/13/95		Y048089/003	8/30/95	
AOI-02 Dichr. Assy Align	6/6/95		6/6/95		Y04089	8/30/95	
AOI-03 NIR Objective	7/5/95		7/5/95		Y04089/001	8/30/95	
AOI-04 VIS Objective	6/23/95		6/23/95		Y04089/002	8/30/95	
AOI-15 Vignetting Margin	6/1/95				Y04089/004		
AOI-07 NIR FPA Align							
AOI-08 VIS FPA Align							
AOI-09-13 S/M/L FPA Align							
AOI-14 OBA Spatial Perf							
AOI-SU AOI Set-Up							
AOI-SOP Std. Oper. Proced.							
AOA-Vibe Vibration Expos.							

(1) Includes:
A-Procedure As-Run
B-Data Sheets & Printouts
C-Hardcopy of Command File
D-Appropriate Logbook Pages
E-List of Relevant Event Log Start Times
F-List of Relevant UAIDS

PFM Hibay STRs

Number	Originator	Description	Date Approved	Report Complete (PL3095-)	Impounded(1)
STR-044	Pagano	Radiometric Test of VIS/NIR FPA			
STR-046	Pagano	Optical Crosstalk Evaluation	8/1/95		
STR-047	Bell	Aft Optics Thermal Vacuum (Background)			

TOPICS
PFM SI&T

TLK - 2
8/30/95

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- SYSTEM INTEGRATION & TEST OBJECTIVES
- SI&T PLAN & FORMAT
- PFM SI&T TEST FLOW PLAN
- PFM THERMAL-VACUUM TEST PLAN
- SUMMARY

MODIS PFM SI&T OBJECTIVES

TLK - 3
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SI&T OBJECTIVE 1

- INTEGRATE, CHARACTERIZE AND CALIBRATE THE MODIS INSTRUMENT AND ON-BOARD CALIBRATORS TO ENSURE THE PROTOFLIGHT MODEL MEETS AND/OR EXCEEDS GSFC REQUIREMENTS.

SI&T OBJECTIVE 2

- COMPLETE OBJECTIVE 1 WITHIN THE COST AND SCHEDULE BUDGETS OF THE MODIS PROGRAM.

PFM SI&T PLAN

TLK - 4
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- INITIAL SI&T TEST PLANS INDICATED ≈282 TESTS WOULD BE REQUIRED FOR COMPREHENSIVE & LIMITED PERFORMANCE TESTING THE PFM INSTRUMENT, INCLUDING:
  - 12 - AFT-OPTICS ASSEMBLY TESTS
  - 66 - AMBIENT TESTS IN THE HI-BAY CLEAN ROOM
  - 75 - OFFSITE ENVIRONMENTAL TESTS/RETESTS
  - 23 - AMBIENT TESTS IN MODIS CALIBRATION CHAMBER
  - 82 - THERMAL-VACUUM PERFORMANCE TESTS IN MCC
  - 14 - POST-THERMAL VACUUM RETESTS
- @ 2.1-DAYS/TEST (≈EM AVERAGE), REQUIRES ≈2.4 WORKING YEARS (≈29 MO) TO COMPLETE MODIS PFM
- TESTS 9-13 PRESENTLY IN WORK; LEAVES 269 TESTS INDICATING PFM DELIVERY 1 NOV 1997
- <u>CLEARLY UNACCEPTABLE TO BOTH SBRC & GSFC</u>

PFM SI&T TEST REPLAN

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- A TEST REPLAN IS IN PROGRESS - THE INTENT:
  - REDUCE THE NUMBER AND SCOPE OF TESTS TO THOSE REQUIRED TO MEET PERFORMANCE SPECIFICATIONS AND PRESERVE THE INTEGRITY OF THE TEST SYSTEM & ITS CALIBRATION
  - I.e., TEST WHEN NECESSARY, NOT - TEST FOR THE SAKE OF TESTING
- PRESENTLY REDUCED TO 190 TESTS, INCLUDING :
  - 12 - AFT-OPTICS ASSEMBLY TESTS
  - 62 - AMBIENT TESTS IN THE HI-BAY CLEAN ROOM
  - 23 - OFFSITE ENVIRONMENTAL TESTS/RETESTS
  - 25 - AMBIENT TESTS IN MODIS CALIBRATION CHAMBER
  - 59 - THERMAL-VACUUM PERFORMANCE TESTS
  - 9 - POST-THERMAL VACUUM RETESTS
  - 190 - TOTAL TESTS REQUIRED
- @ 2.1-DAYS/TEST = 19.3 MONTHS OR 21 APRIL 1997
- STILL UNACCEPTABLE - THUS, REPLAN IS CONTINUING

PFM SI&T REPLAN
- CONTINUED -

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- TEST REPLAN EFFORT ADDRESSING MEANS TO FURTHER REDUCE TEST COMPLEXITY:
  - SPECIFICALLY CLASSIFY EACH TEST
    - + COMPREHENSIVE PERFORMANCE TEST (CPT)
      Required to Meet all System Performance Specifications
    - + LIMITED PERFORMANCE TEST (LPT)
      Verify Performance, Subset of "CPT"
      For Specific Instances When "CPT" Not Required
    - + FUNCTIONAL PERFORMANCE TEST (FPT)
      Verify Functionality of Subsystem in Test
  - 190 TESTS INCLUDE:
    - + 108 - COMPREHENSIVE PERFORMANCE TESTS
    - + 53 - LIMITED PERFORMANCE TESTS
    - + 29 - FUNCTIONALITY TESTS
    - + 190 - TOTAL TESTS
  - MEANS TO FURTHER REDUCE TEST TIME
    MULTIPLE SHIFT WORK, VERIFY BY ANALYSIS, AUTOMATION, REQUEST FOR WAIVERS, etc.

MODIS PROTOFLIGHT MODEL SI&T FLOW PLAN

TLK - 7
8/30/95

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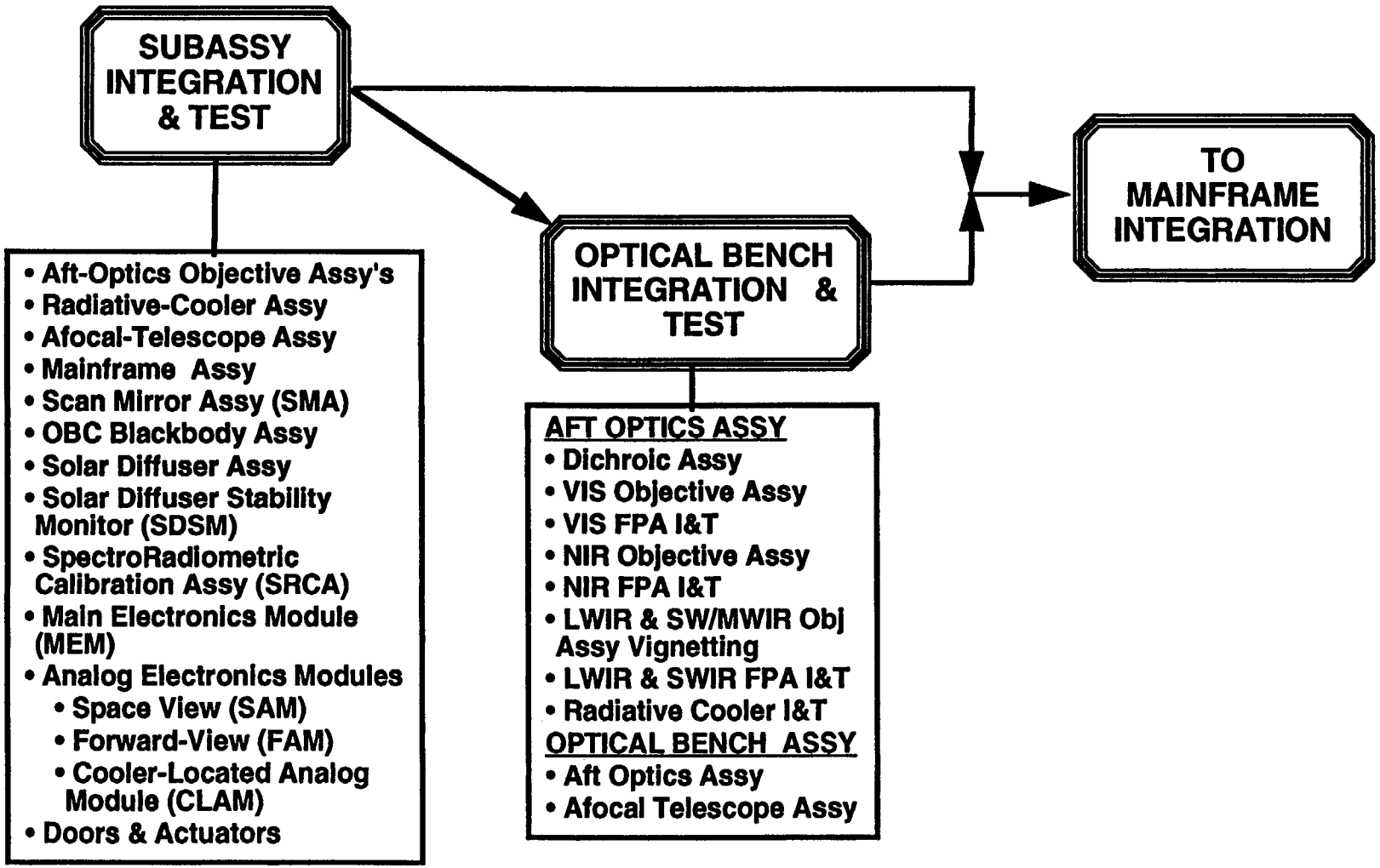

PFM SI&T AMBIENT LAB TEST FLOW PLAN

TLK - 8
8/30/95

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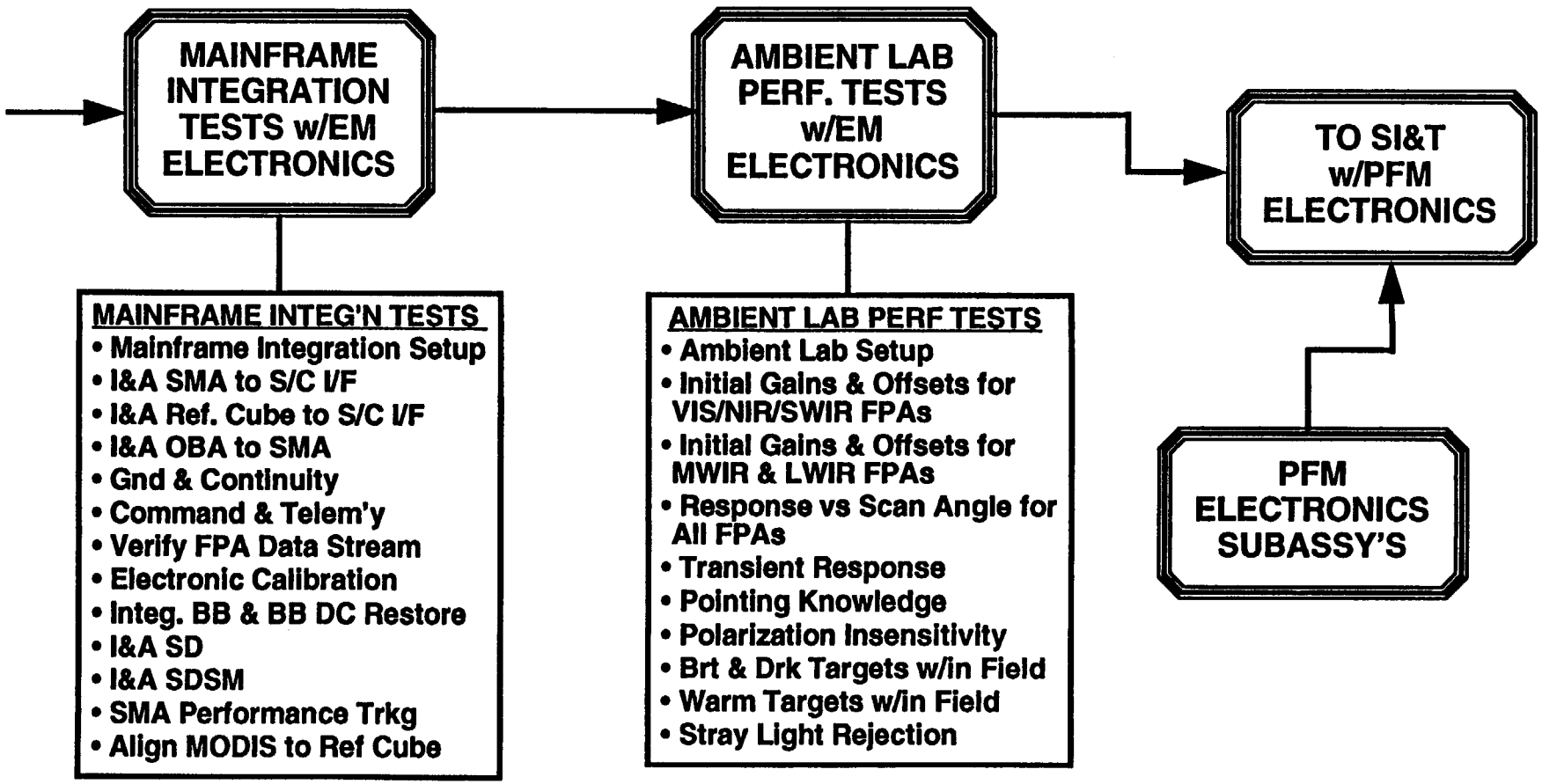

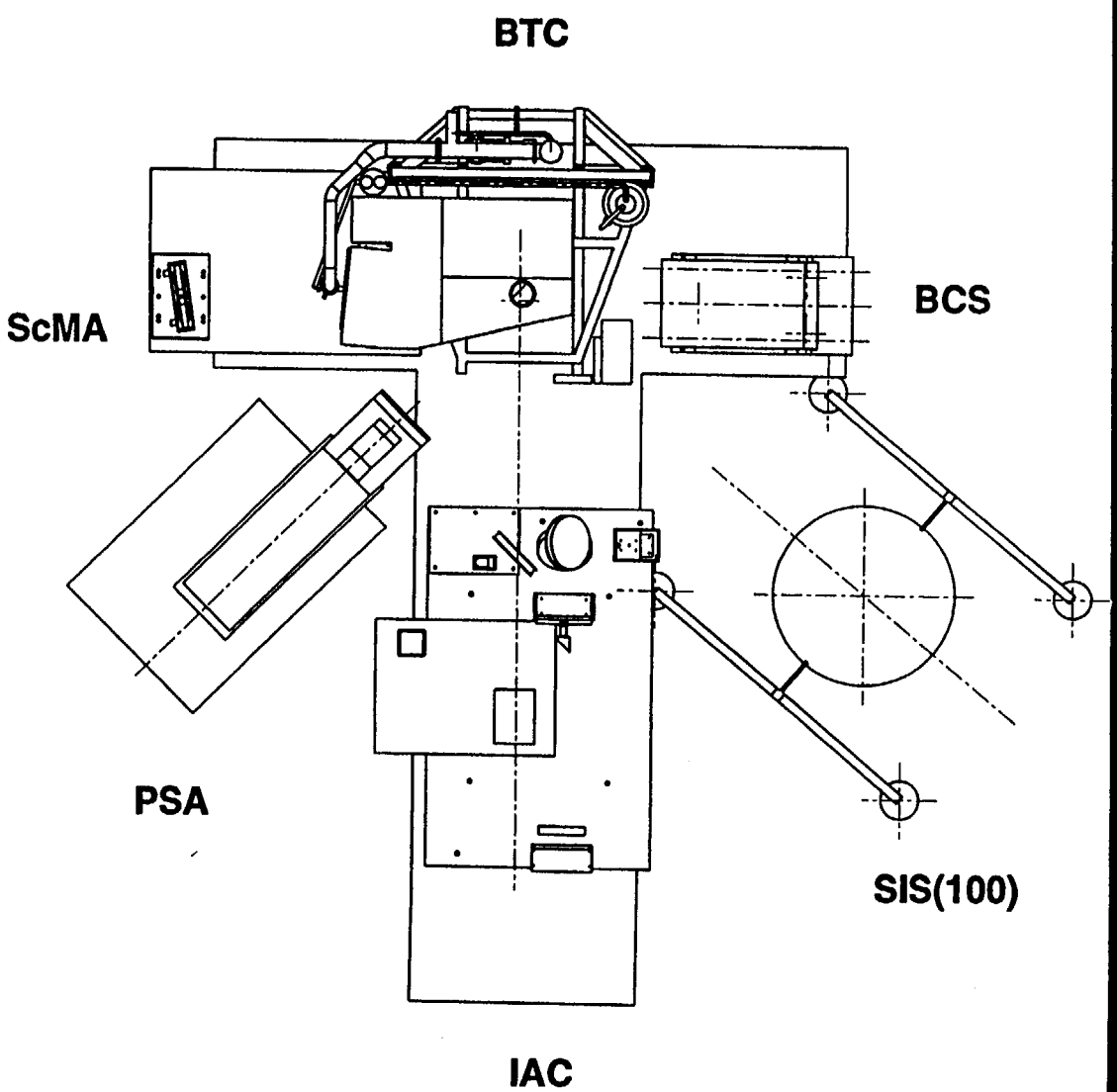

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PROPOSED TEST AREA SET-UP FOR TESTING MODIS PFM UNDER AMBIENT CONDITIONS

Photo: 95-3-80 (12)

TLK - 09
8/30/95

035

PFM SI&T AMBIENT LAB TEST FLOW PLAN - CONTINUED -

TLK - 10
8/30/95

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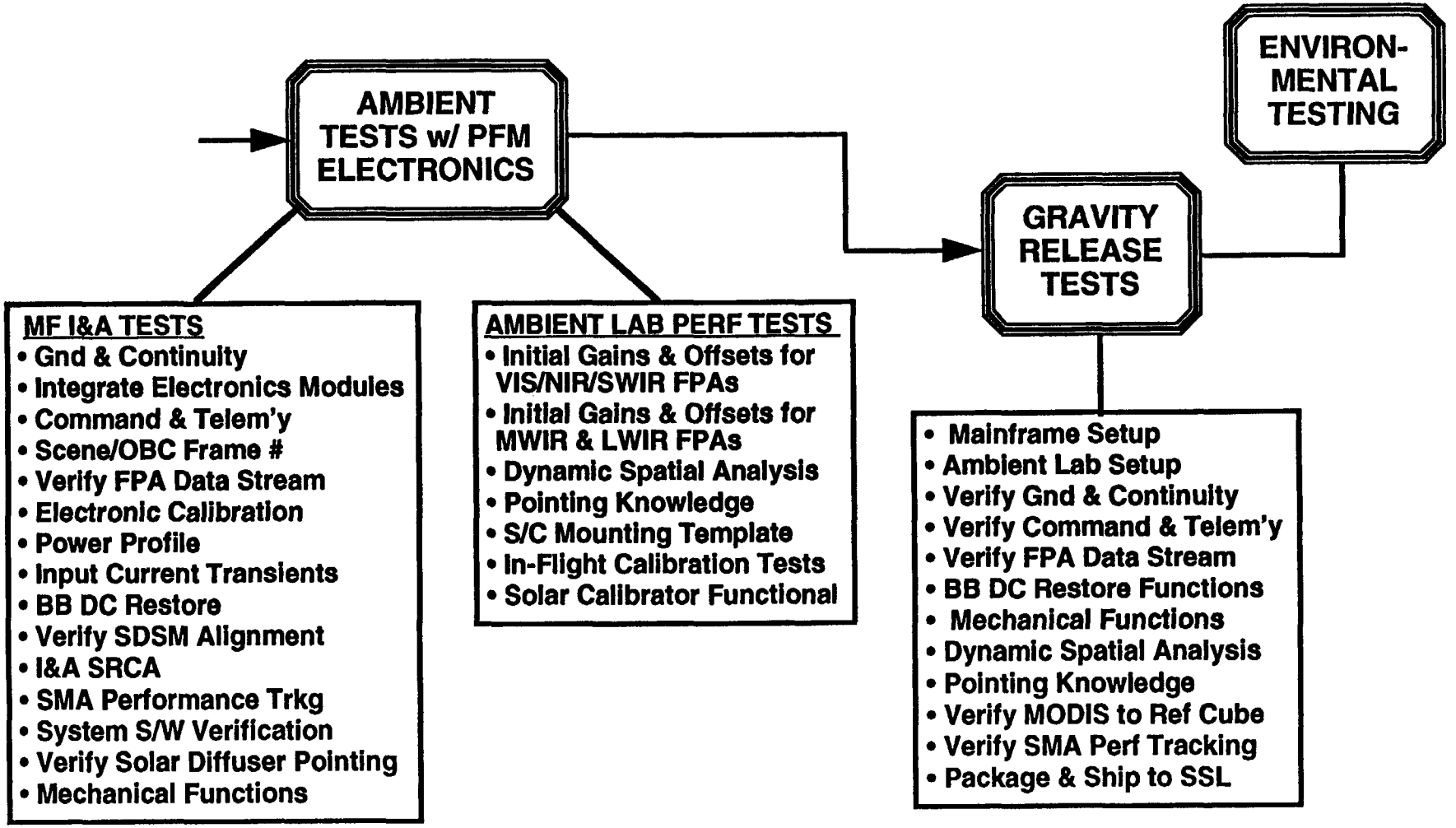

PFM SI&T OFFSITE ENVIRONMENTAL TEST FLOW PLAN

TLK - 11
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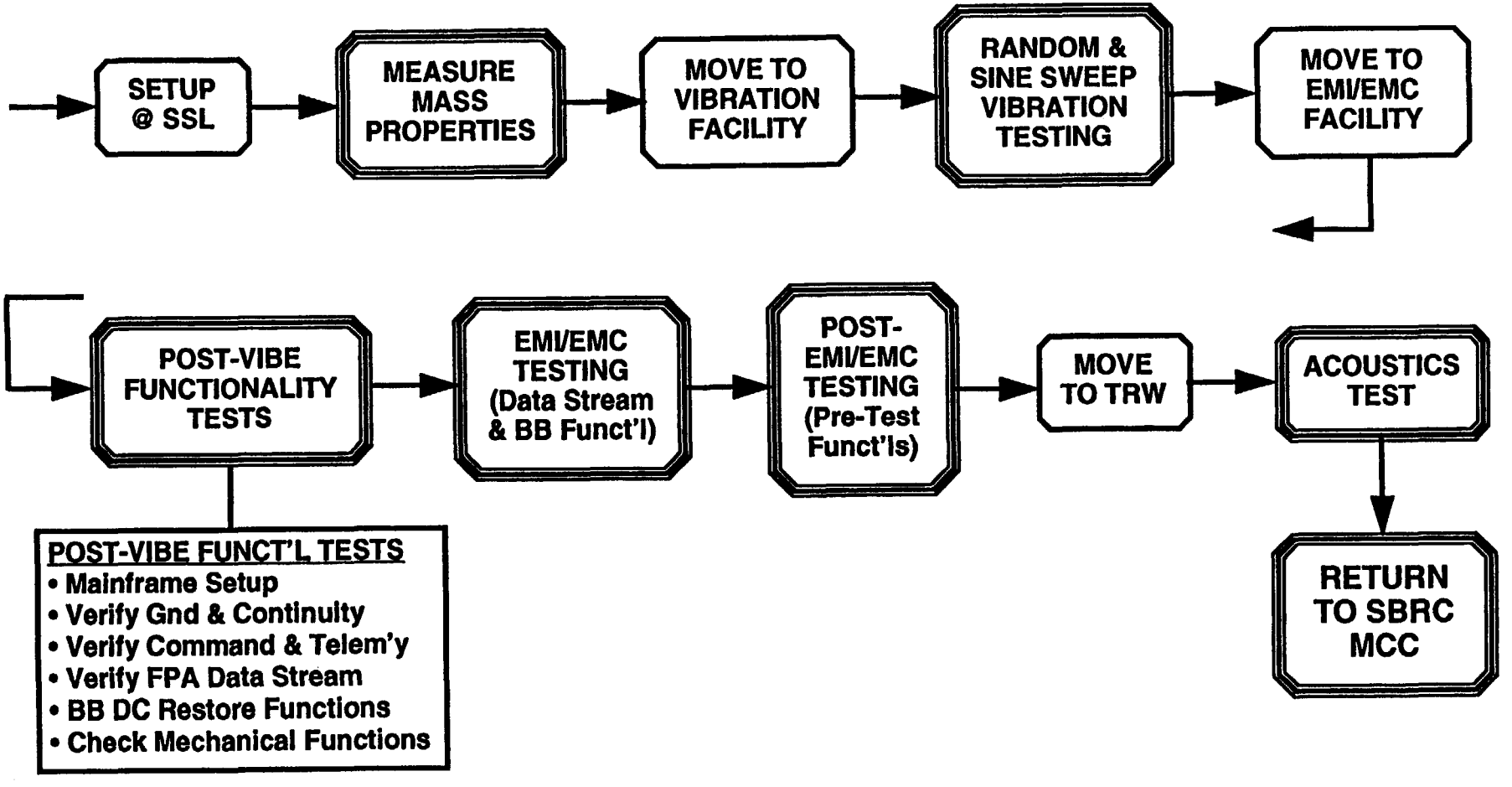

MODIS PFM MCC SI&T AMBIENT TEST FLOW PLAN

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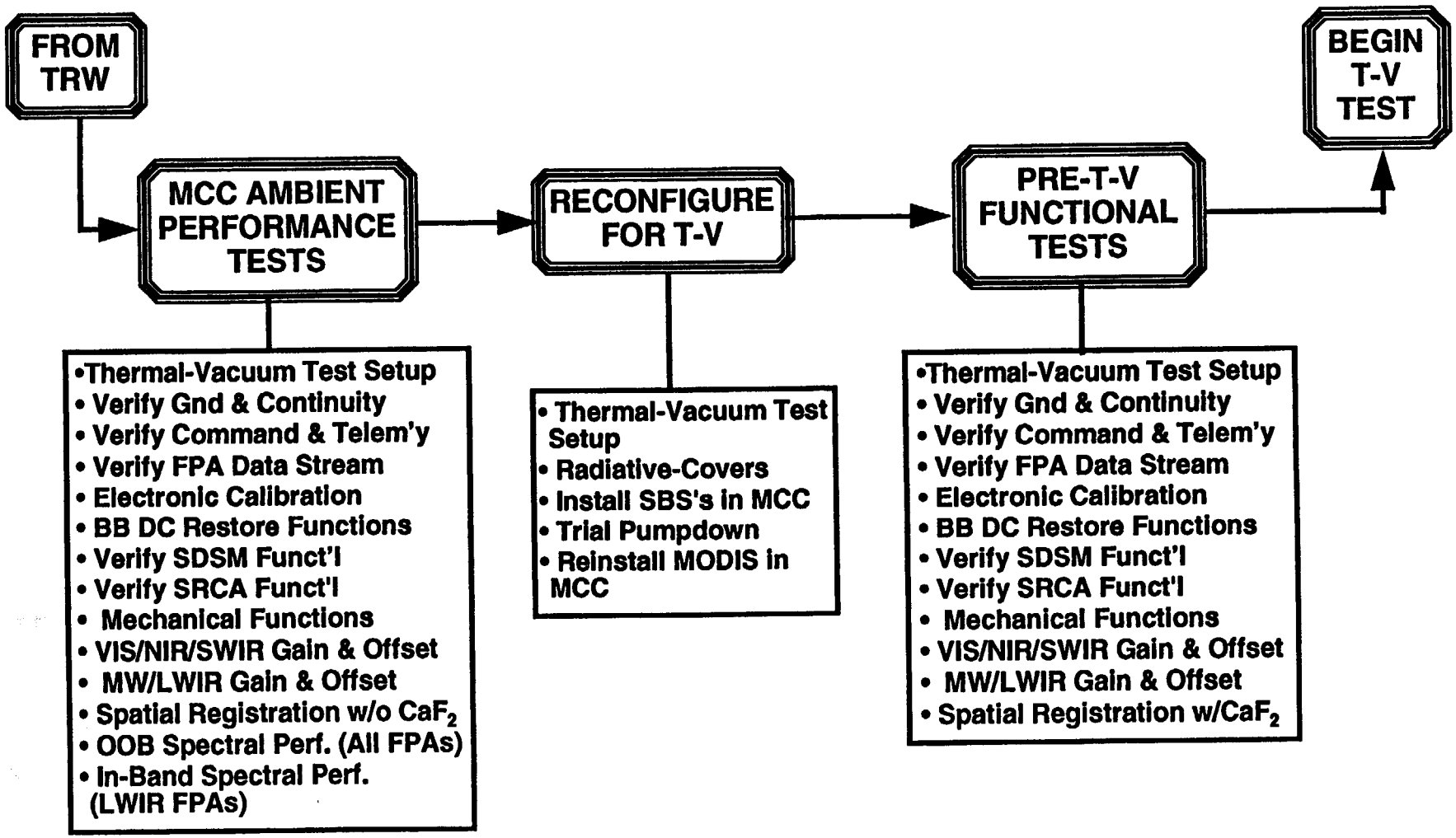

MODIS PFM SI&T THERMAL-VACUUM TEST FLOW PLAN

TLK - 13
8/30/95

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PRE-PERFORMANCE TESTS

- Pumpdown to Hi-Vacuum
- Acquire Telemetry
- Hot-Survival Thermal-Cycle
- Outgas Radiative Cooler
- Cold-Survival Thermal-Cycle
- Cooldown Radiative Cooler
- Transition to Cold Temp (0°C)
- Stabilize 16 Hours
- Cold Turn-On

COLD-TEMP PERFORMANCE TEST

- All Commands & Telemetry
- Verify FPA Data Stream
- BB DC Restore
- Verify SDSM Funct'l
- Ltd SRCA Performance
- Mechanical Functions
- VIS/NIR/SWIR Gain & Offset
- VIS/NIR/SWIR Radiometric Calib.
- MW/LWIR Gain & Offset
- MW/LWIR Radiometric Calib.
- Spatial Registration w/CaF_2

HOT TRNSTN FUNCTIONAL TEST

- Transition to Hot Temp (42°C)
- Command & Telemetry
- Verify FPA Data Stream
- BB DC Restore Funct'l
- Ltd VIS/NIR/SWIR Radiometrics
- Ltd MW/LWIR Radiometrics
- Stabilize 16 Hours
- Hot Turn-On

HOT TEMP TESTS

MODIS PFM SI&T THERMAL-VACUUM TEST FLOW PLAN

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HOT-TEMP PERFORMANCE TEST

- All Commands & Telemetry
- Verify FPA Data Stream
- BB DC Restore
- Verify SDSM Funct'l
- Ltd SRCA Performance
- Mechanical Functions
- VIS/NIR/SWIR Radiometric Calibration
- MW/LWIR Radiometric Calibration
- Spatial Registration w/ CaF_2

TRANSITION TO COLD TEMP

- Transition to Cold Temp (0°C)
- Command & Telemetry
- Stabilize 16 Hours
- Cold Turn-On

2ND COLD TEMP PERFORMANCE TEST

- All Commands & Telemetry
- Ltd FPA Data Stream
- BB DC Restore Funct'l
- Verify SDSM Funct'l
- Ltd SRCA Performance
- Mechanical Functions

HOT TEMP TRANSI TION

MODIS PFM SI&T THERMAL-VACUUM TEST FLOW PLAN

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2ND HOT-TEMP PERFORMANCE TEST

- Transition to Hot Temp (42°C)
- Stabilize 16 Hours
- Ltd Command & Telem'y
- Verify FPA Data Stream
- Verify SDSM Funct'l
- Verify SRCA Funct'l
- Mechanical Functions
- Transition to Ambient Temp
- Stabilize 16 Hours
- Set CFPAs to 83K Set Point

AMBIENT TEMP PERFORMANCE TESTS

- <u>83K FPA TEMP TESTS</u>
- Ltd Commands & Telem'y
- Verify FPA Data Stream
- BB DC Restore
- Ltd VIS/NIR/SWIR Radiometric Calibration
- Ltd MW/LWIR Radiometric Calibration
- (Repeat Above @ 88K Set Point Following 85K Tests)
- Transition CFPAs to 85K Set Point

- <u>85K FPA PERF TESTS</u>
- All Commands & Telem'y
- Full FPA Data Stream
- Full BB DC Restore
- Electronic Calibration
- Verify SDSM Funct'l
- Full SRCA Performance/Calib.
- Scan Mirror Encoder Trkg
- Mechanical Functions
- VIS/NIR/SWIR Radiometric Calib.
- MW/LWIR Radiometric Calib.
- Full Spatial Registration (except LWIR)
- VIS/NIR/SWIR Spectral
- In-Flight Calibrator Stimulation
- Transition CFPAs to 88K Set Point

END T-V, TRANSITION TO ROOM AMBIENT

PROPOSED PFM MODIS THERMAL-VACUUM TIMELINE

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PFM SI&T POST- T-V TEST FLOW PLAN

TLK - 17
8/30/95

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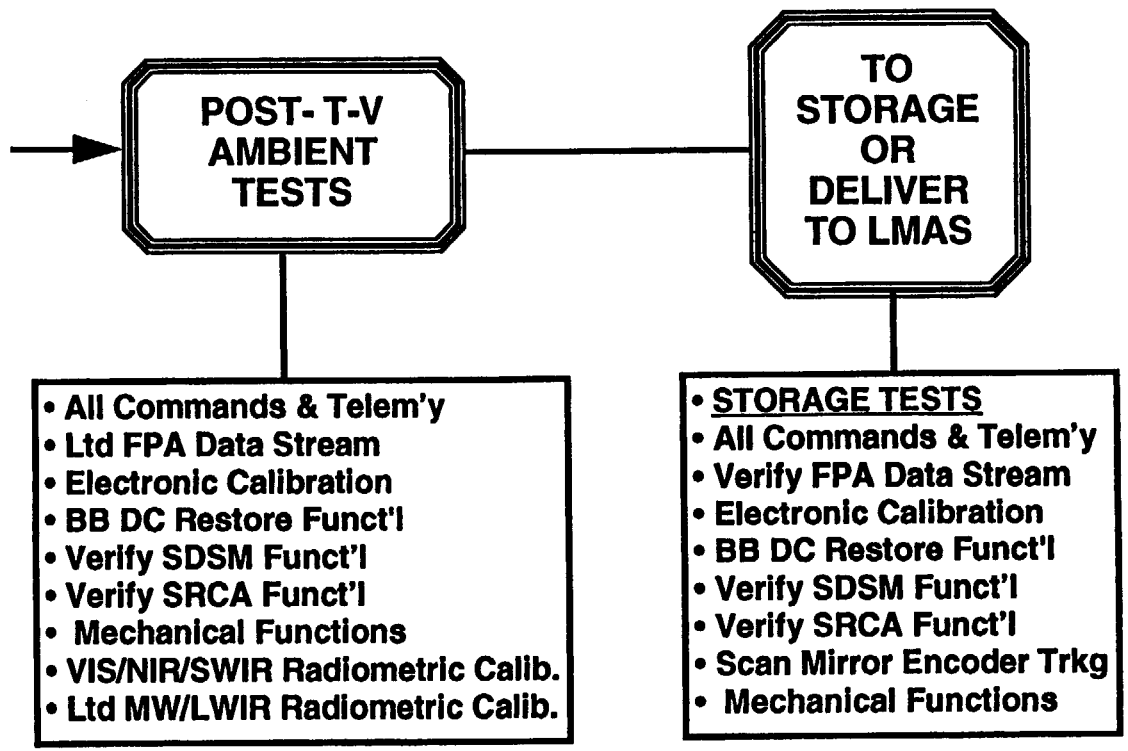

PFM SI&T SUMMARY

TLK - 18
8/30/95

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- SBRC SI&T TEAM'S OBJECTIVES: TO PRODUCE A MODIS INSTRUMENT THAT MEETS ALL COST, SCHEDULE AND SPECIFICATION REQUIREMENTS
- SI&T TEAM IS DEDICATED TO ACHIEVING THOSE OBJECTIVES
- DEDICATED TEAM IS COMING ON-LINE FOR MULTI-SHIFT WORK EFFORT TO REDUCE SCHEDULE
- COMPREHENSIVE TEST PLAN ADDRESSES ALL SYSTEM REQUIREMENTS
- PFM TEST PLAN IS BEING REPLANNED WITH INTENT TO MAINTAIN SYSTEM SPECIFICATION INTEGRITY AND MEET ABOVE REQUIREMENTS

GROUND SUPPORT EQUIPMENT

Vern Alferd

AGENDA

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- Polarized Source Assembly (PSA)
- Scatter Measurement Assembly (SCMA)
- 100 cm. Spherical Integrating Source (SIS)
- Blackbody Calibration Source (BCS)
- Space View Source (SVS)
- Integration and Alignment Collimator (IAC)
- Spectral Measurement Assembly (SPMA)
- MODIS Calibration Chamber (MCC)

MODIS POLARIZED SOURCE ASSEMBLY

94-12-30

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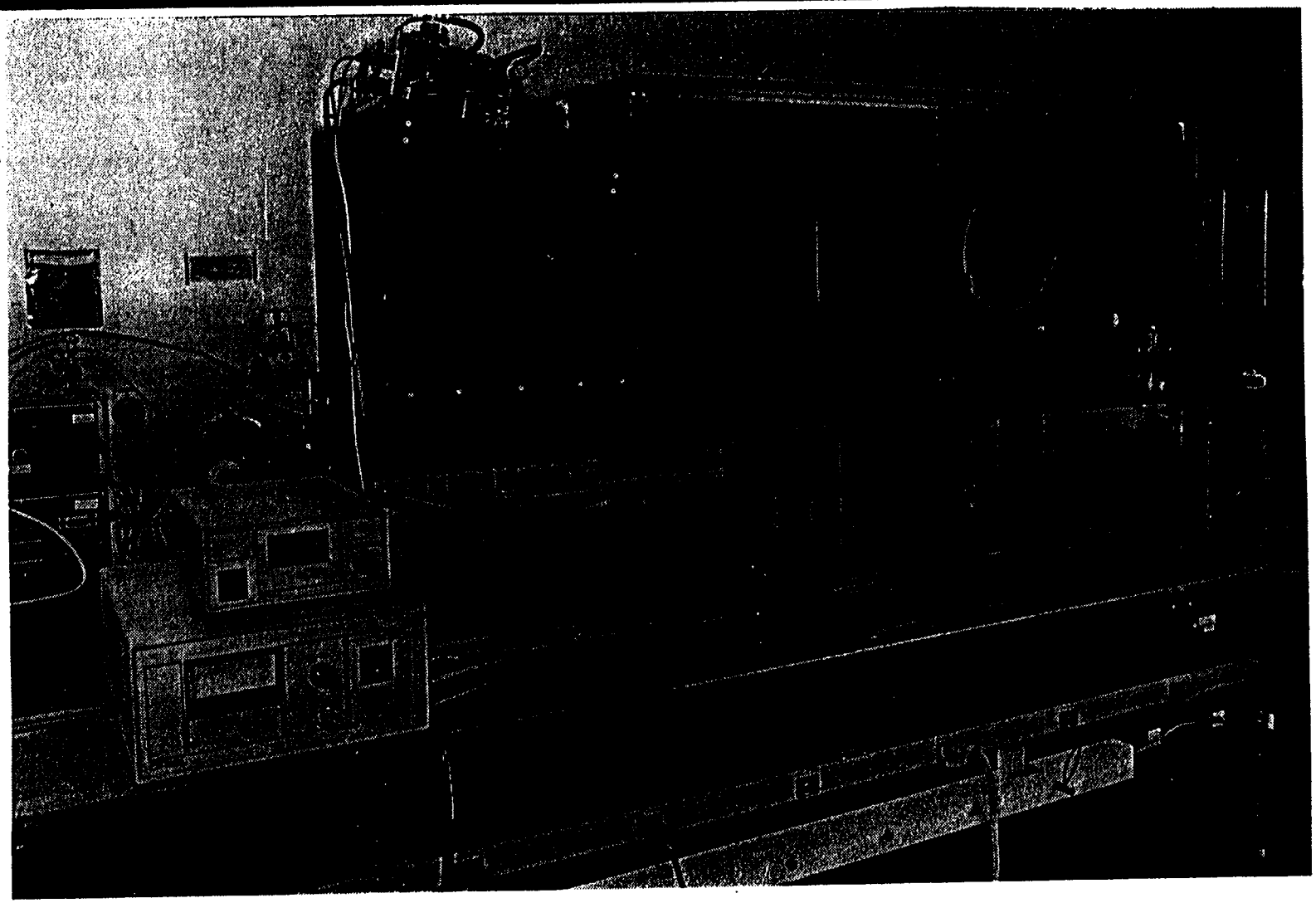

POLARIZED SOURCE ASSEMBLY REQUIREMENTS & PERFORMANCE

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PARAMETERS	REQUIREMENTS	PERFORMANCE
• Wavelength Range	0.43μm to 2.2μm	0.43μm to 2.2μm
• Polarizance over Scan Angles of ± 45°	> 99.8%	> 99.8% ±0.2%
• Uniformity of Polarizance over Exit Pupil	< 1%	< 1%
• Radiance Stability	±0.1% of steady state level	< ±0.05%
• Field of view coverage	1°	1° Circular
• Rotation range	0° to 360° in 15° steps	0° to 360° in 15° steps

MEASUREMENT OF KEY PSA PARAMETERS

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- **Polarizance**

  A laboratory polarimeter with a Wollaston prism, which allowed simultaneous measurement of S and P polarized energy values, was used to establish the polarizance of the PSA. Polarimeter accuracy was established at ±0.1% from measurements of surfaces with known Fresnel reflection values.

- **Uniformity of Polarizance over Exit Pupil**

  The laboratory polarimeter with a 1-inch aperture was positioned at multiple locations over the exit pupil of the PSA to provide a map of polarizance. At each location, the PSA's Ahrens polarizing prism was rotated at 15 degree intervals from 0 to 360 degrees.

- **Radiance Stability**

  PSA irradiance was monitored with a Si photodiode over an 8-hour period.

PSA FUNCTIONAL BLOCK DIAGRAM

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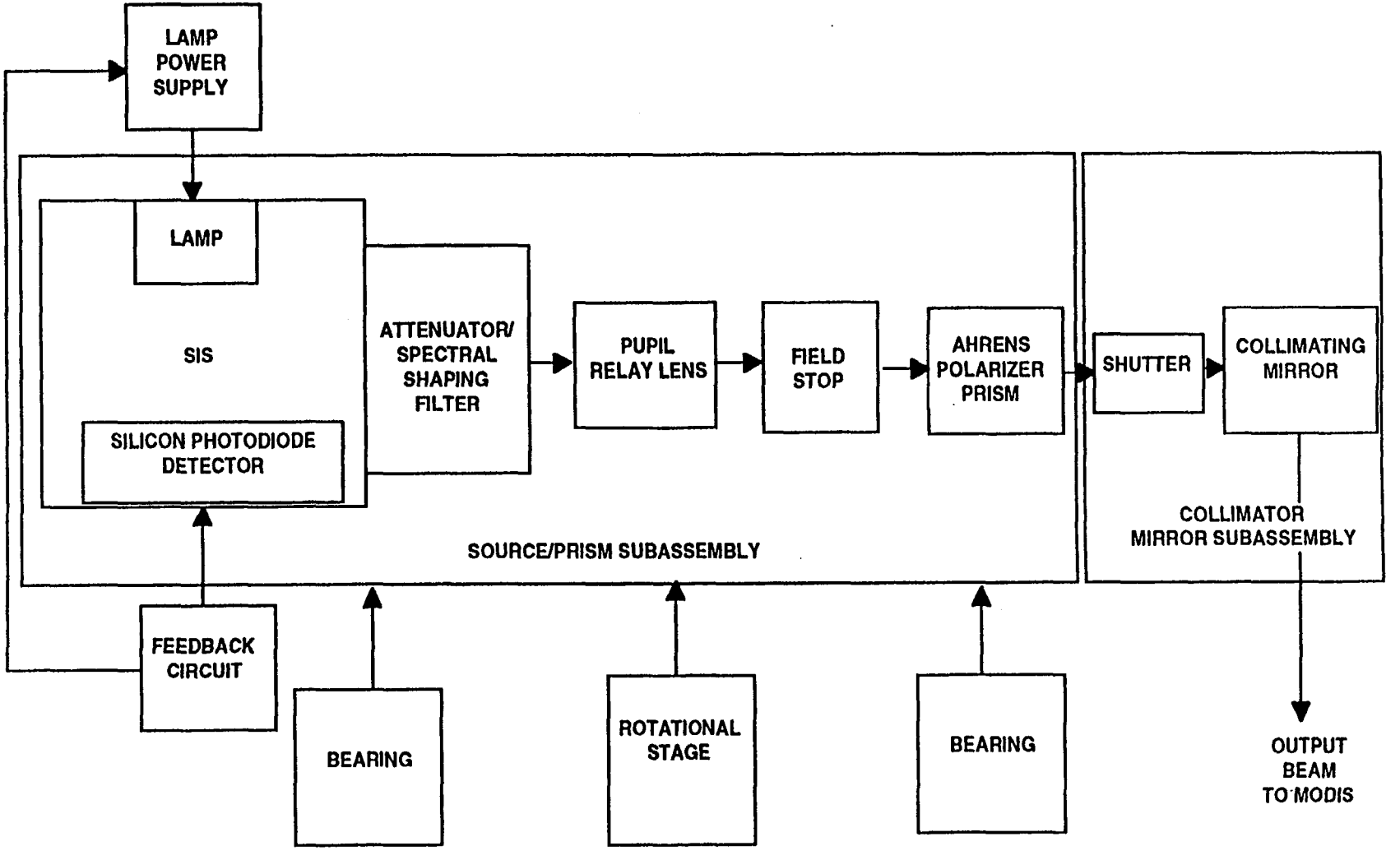

PSA PERFORMANCE EVALUATION & PROPOSED SYSTEM MODIFICATIONS

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- **Performance Evaluation**
  - The Polarized Source Assembly performed as per specifications with one possible problem during testing.
  - Possible misalignment of the PSA with respect to MODIS may have caused an output polarization intensity fall-off as a function of rotation angle.
- **Proposed System Modifications**
  - The Macintosh PC with Labview software will be replaced by OASIS control via the STE Stimulus Controller Workstation.
  - Alignment fixturing to allow angular pointing adjustment of the entire PSA will be developed.

SCATTER MEASUREMENT ASSEMBLY

95-5-162

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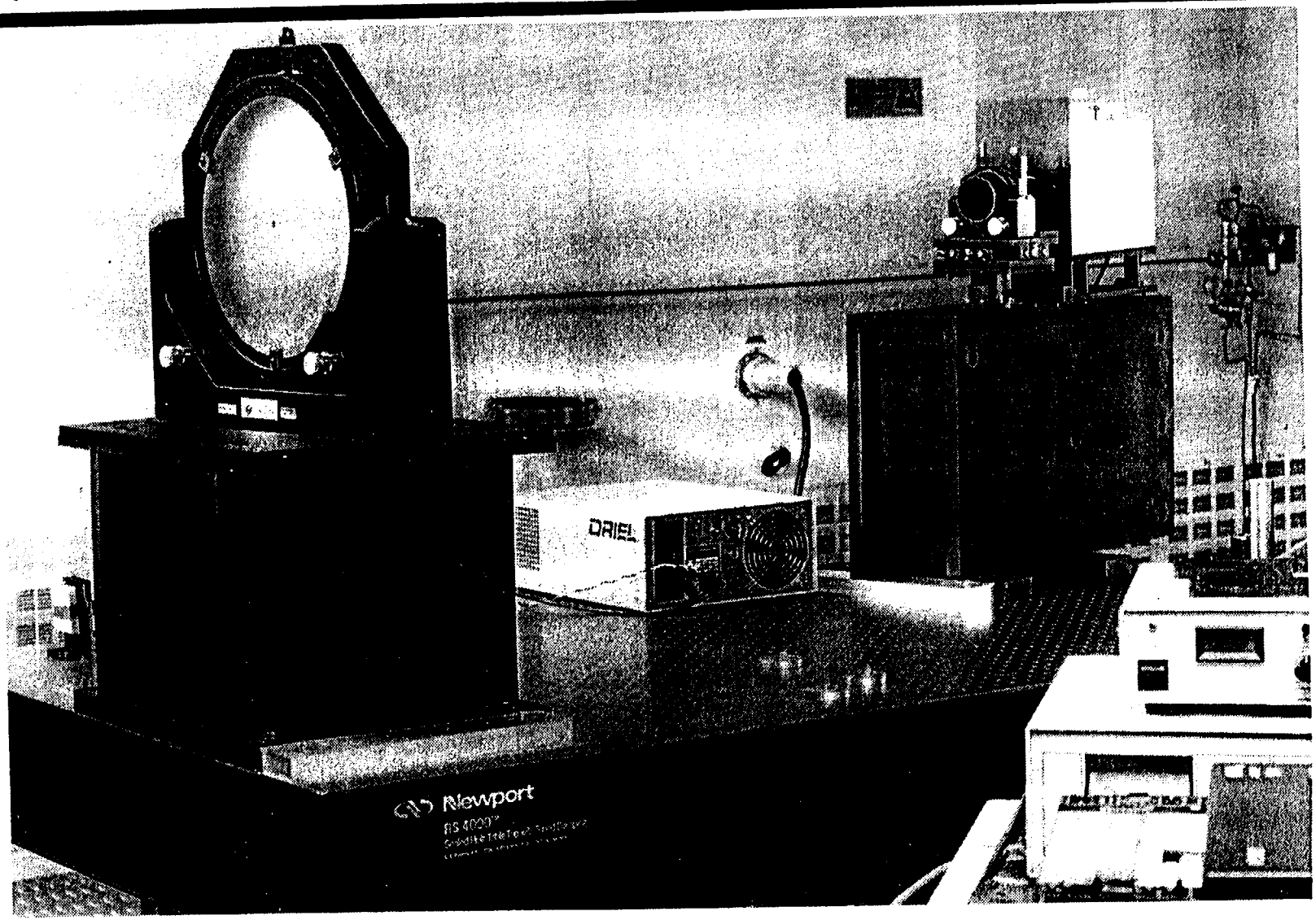

SCATTER MEASUREMENT ASSEMBLY REQUIREMENTS AND PERFORMANCE

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PARAMETERS	REQUIREMENTS	PERFORMANCE
• Wavelength Range	0.43μm to 14.3μm	0.43μm to 14.3μm
• Geometric Projected Image Size	1 to 1.5 pixels Scan 10 pixels min. Track	1.5 pixels Scan 11 pixels Track
• Collimator Mirror Surface Roughness	< 7 Angstroms RMS	3.75 Angstroms RMS
• Collimator Beam Size	> 7-inch diameter	11.25-inch diameter
• Radiance Non-uniformity	< 5%	< 3%
• Radiance Stability over Exit Pupil	±0.1% of steady state level	< ±0.05%

MEASUREMENT OF KEY SCMA PARAMETERS

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- **Collimator Mirror Surface Roughness**

  Roughness measurements were made with a non-contact profilometer by the mirror vendor Tinsley Labs. The profilometer was a state-of -the-art instrument which has been cross-checked against other leading instruments such as the Wyko, Zygo, Photographic Sciences MP-2000, and an atomic force microscope.

- **Spectral and Neutral Density Filters**

  Spectral transmittances were measured by a Cary 14 spectrometer in the visible region and by a Nicolet 7000 FTIR in the infrared from 2.0μm to 20.0μm.

- **Slit Reflectance**

  The BRDF of the surface surrounding the slit was measured at SBRC with a scatterometer measurement system developed by Breault Research Organization.

SCMA FUNCTIONAL BLOCK DIAGRAM

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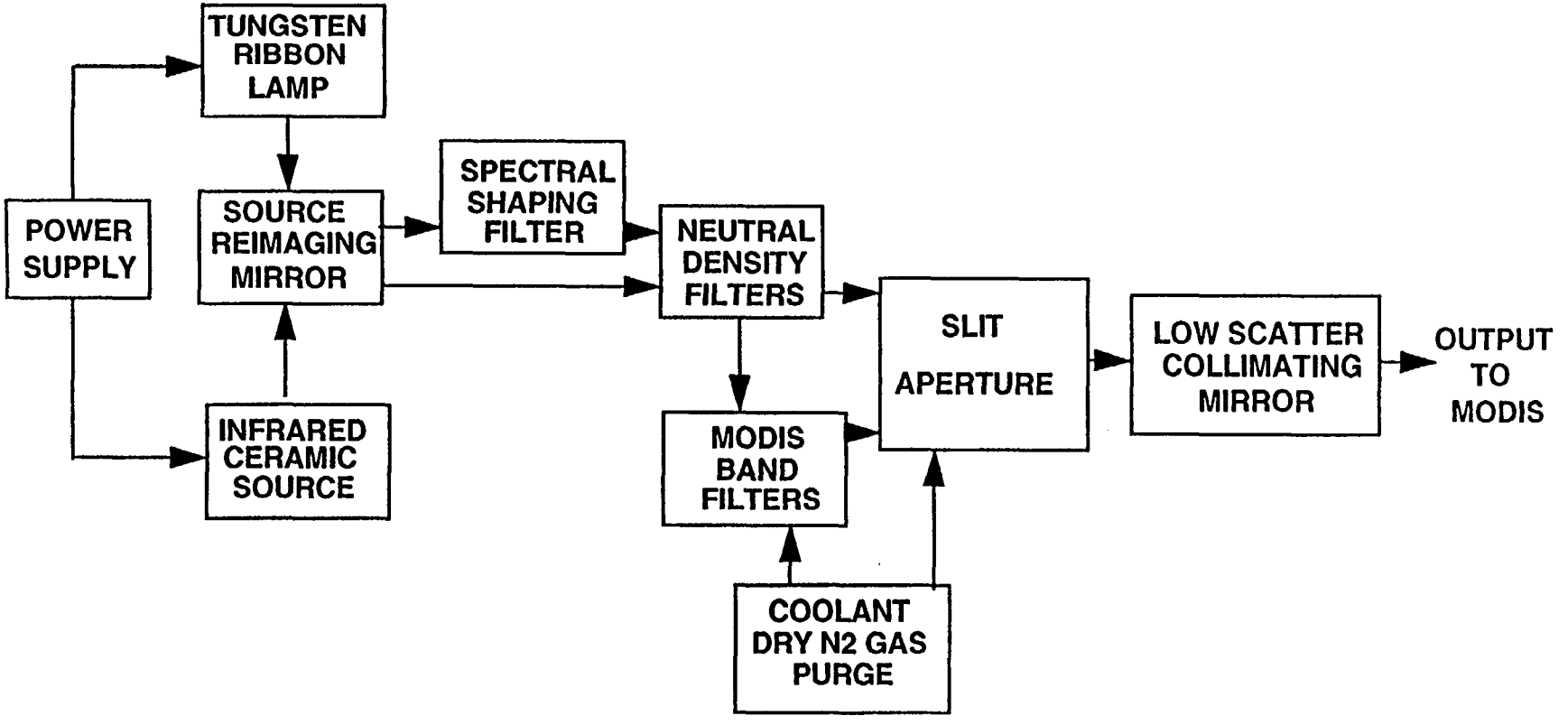

SCMA PERFORMANCE EVALUATION & PROPOSED SYSTEM MODIFICATIONS

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- **Performance Evaluation**
  - The Scatter Measurement Assembly performed to specifications with no functional problems during testing.
  - Realignment of the slit was required after switching between sources.

- **Proposed System Modifications**
  - A shutter system is to be added to the source assembly for IR band collects.
  - Filter wheels are to be added to the system to accommodate spectral band and neutral density filters.
  - The problem of slit realignment after source changes will be addressed.
  - Automatic control via the Stimulus Controller Workstation will be added for shutter and filter selection.

100 cm SIS

93-12-184

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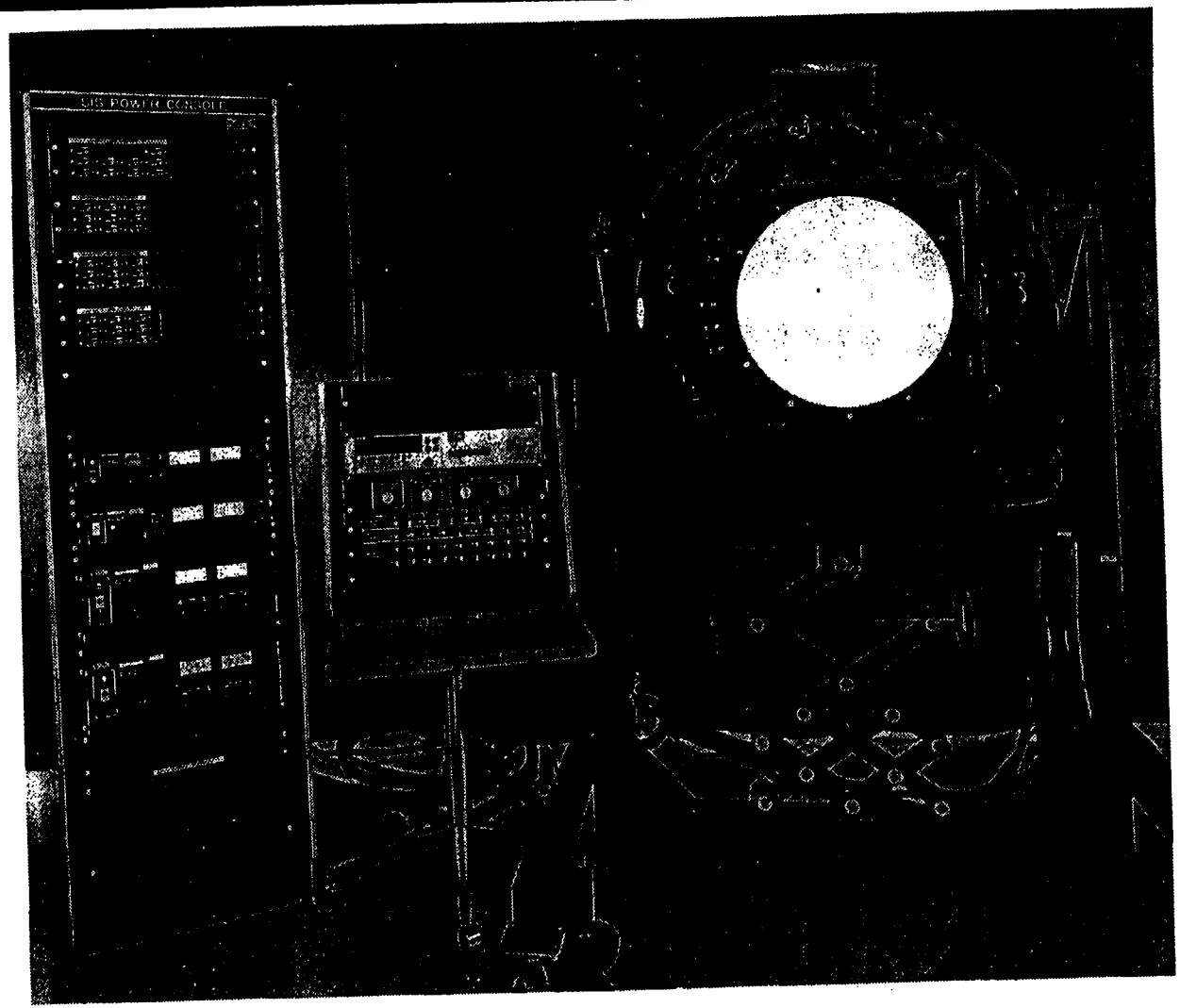

SIS(100) REQUIREMENTS

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TESTS

SNR	STRAY LIGHT	DYNAMIC RANGE	RADIOMETRIC CALIBRATION	RADIOMETRIC STABILITY	CHANNEL TO CHANNEL UNIFORMITY

REQUIREMENTS

TYPE OF REQUIREMENT	MODIS PRIME ITEM REQUIREMENT	SIS(100) DERIVED REQUIREMENT	SIS(100) PREDICTED PERFORMANCE
• RADIOMETRIC ACCURACY @ Ltyp BANDS 1-19,& 26 (<3.0μm).	5%, 1 SIGMA	< 3.4%, 1 SIGMA	< 3.0%, 1 SIGMA
• RADIOMETRIC ACCURACY BETWEEN 0.3Ltyp & 0.9Lmax	<6%, 1 SIGMA	< 3.9%, 1 SIGMA	< 3.5%, 1 SIGMA
• RADIOMETRIC STABILITY (short term: < 2 weeks)	<+/- 1.0%	<+/- 1.0%	<+/- 1.0%
• RADIOMETRIC STABILITY (long term: 2 weeks to 5 yrs.)	<+/- 2.0%	<+/- 2.0%	<+/- 2.0%
• RADIANCE UNIFORMITY		< 0.3%	< 0.25%

MEASUREMENT OF KEY SIS(100) CALIBRATION PARAMETERS

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- **Absolute Spectral Radiance**

  Intercomparison via a Cary 14 Double monochromator of SIS(100) spectral radiance with a Spectral Irradiance Standard Lamp plus Halon diffuser traceable to NIST.

- **Radiometric Stability**

  Voltage across a shunt was monitored to measure SIS(100) source current as a function of time and also as a function of small changes applied to the spectral radiance amplitude. Stability was better than 0. 03% over the period of calibration.

- **Radiance Uniformity**

  7-inch diameter sample areas at the SIS(100) aperture are mapped via the Cary 14 double monochromator to give better than a 0.25% uniformity.

- **Monochromator Spectral Calibration**

  Wavelength calibration employed line standard lamps of Hg and Krypton.

- **Monochromator System Linearity**

  Signal output from the Cary 14 system was plotted as a function of exit slit area.

SIS(100) FUNCTIONAL BLOCK DIAGRAM

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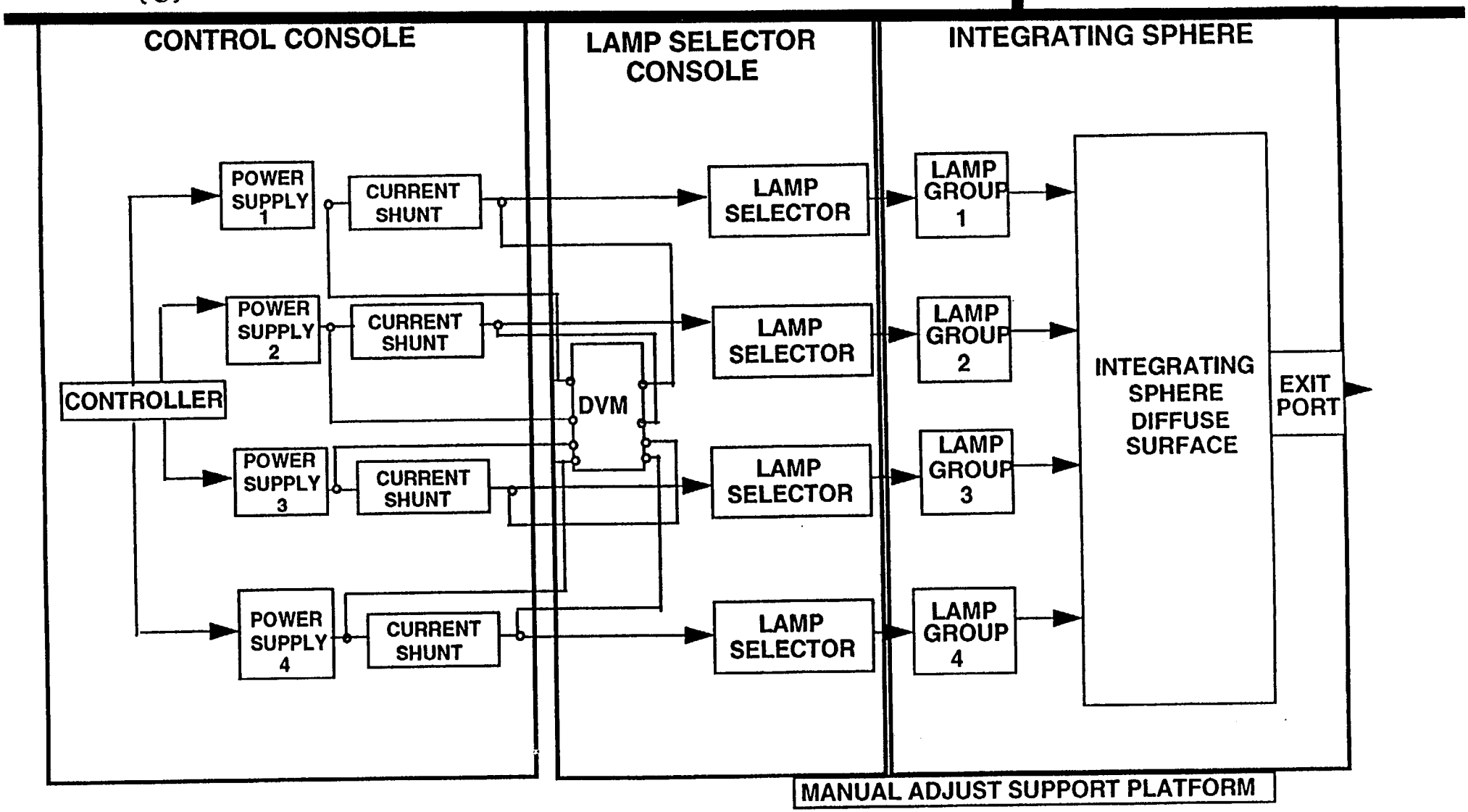

SIS(100) CALIBRATION PLAN

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CALIBRATION PATH

SBRC NIST TRACEABLE CALIBRATION

OPTRONICS IRRADIANCE STANDARD → WORKING IRRADIANCE STANDARD → SIS(100)

CROSS CALIBRATION

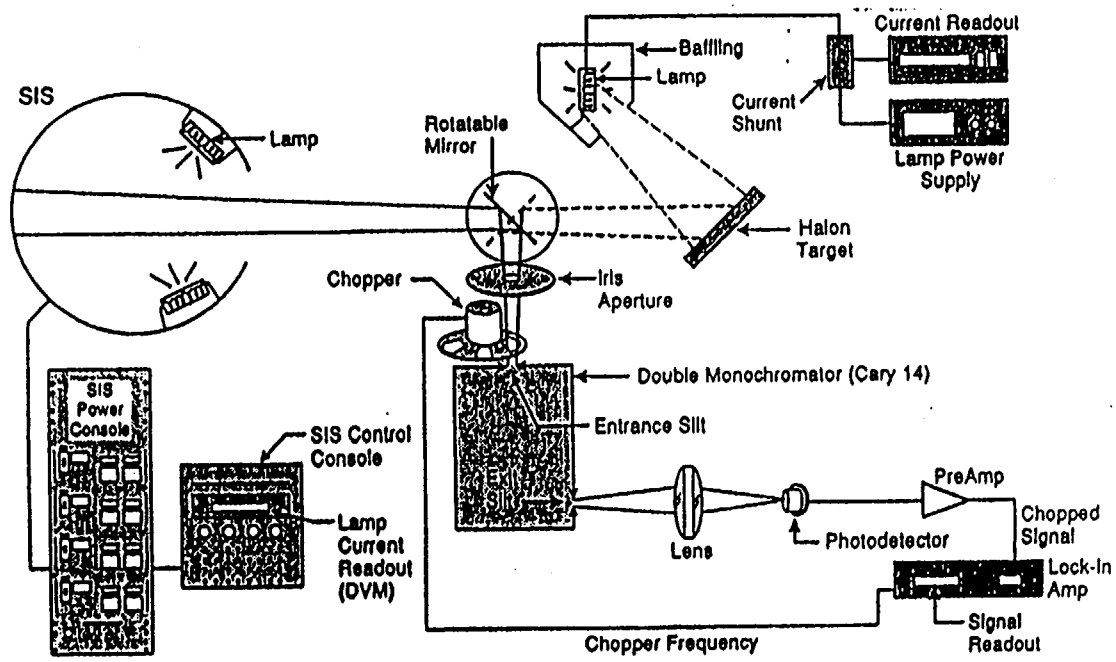
U OF A DETECTOR BASED RADIOMETERS → SIS(100)

NASA 42" DIAMETER SIS → SIS(100)

CALIBRATION PLAN

- CROSS-CALIBRATION WITH NASA SIS — NOV'92
- SEAWIFS CALIBRATION 0.4 TO 0.9μm — MAR'93
- CROSS- CALIBRATION WITH U OF A DETECTOR — JUN'93
- INITIAL EM CALIBRATION RANGE 0.4 TO 1.8μm — NOV'94
- FIRST CALIBRATION FULL RANGE 0.4 TO 2.2μm — OCT'95

SIS(100) CALIBRATION SCHEMATIC



SIS(100) CALIBRATION HISTORY

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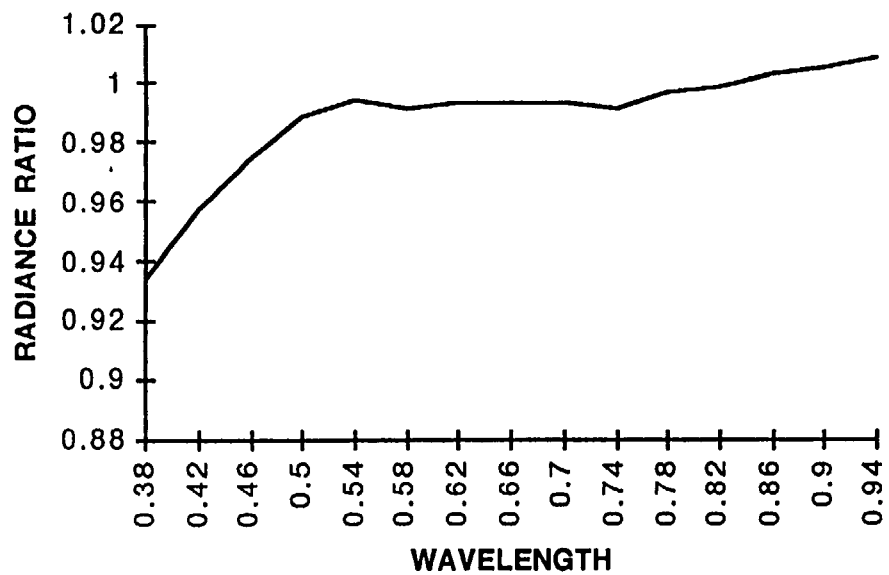
COMPARISON OF SEPT 93 DATA TO OCT 92 DATA



- SEAWIFS DATA COLLECTED FROM SIS(100) SINCE MARCH 93 HAS BEEN STABLE TO APPROXIMATELY ±1%
- COMPARISON TO NASA SIS IN NOV 92 GAVE AGREEMENT WITHIN APPROXIMATELY ±2%
- CALIBRATION OVER FULL WAVELENGTH RANGE TO COMMENCE IN AUGUST 1995

SIS(100) PERFORMANCE EVALUATION & PROPOSED SYSTEM MODIFICATIONS

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- **Performance Evaluation**
  - SIS(100) performed as per expectations for the Engineering Model with no problems encountered.

- **Proposed System Modifications**
  - An InSb detector will be added to the SIS(100) calibration equipment and optimized prior to Protoflight.
  - A real-time current read out will be added to the SIS(100) control system.
  - Software will be upgraded to improve data handling and analysis.

BLACKBODY CALIBRATOR SOURCE

95-1-47

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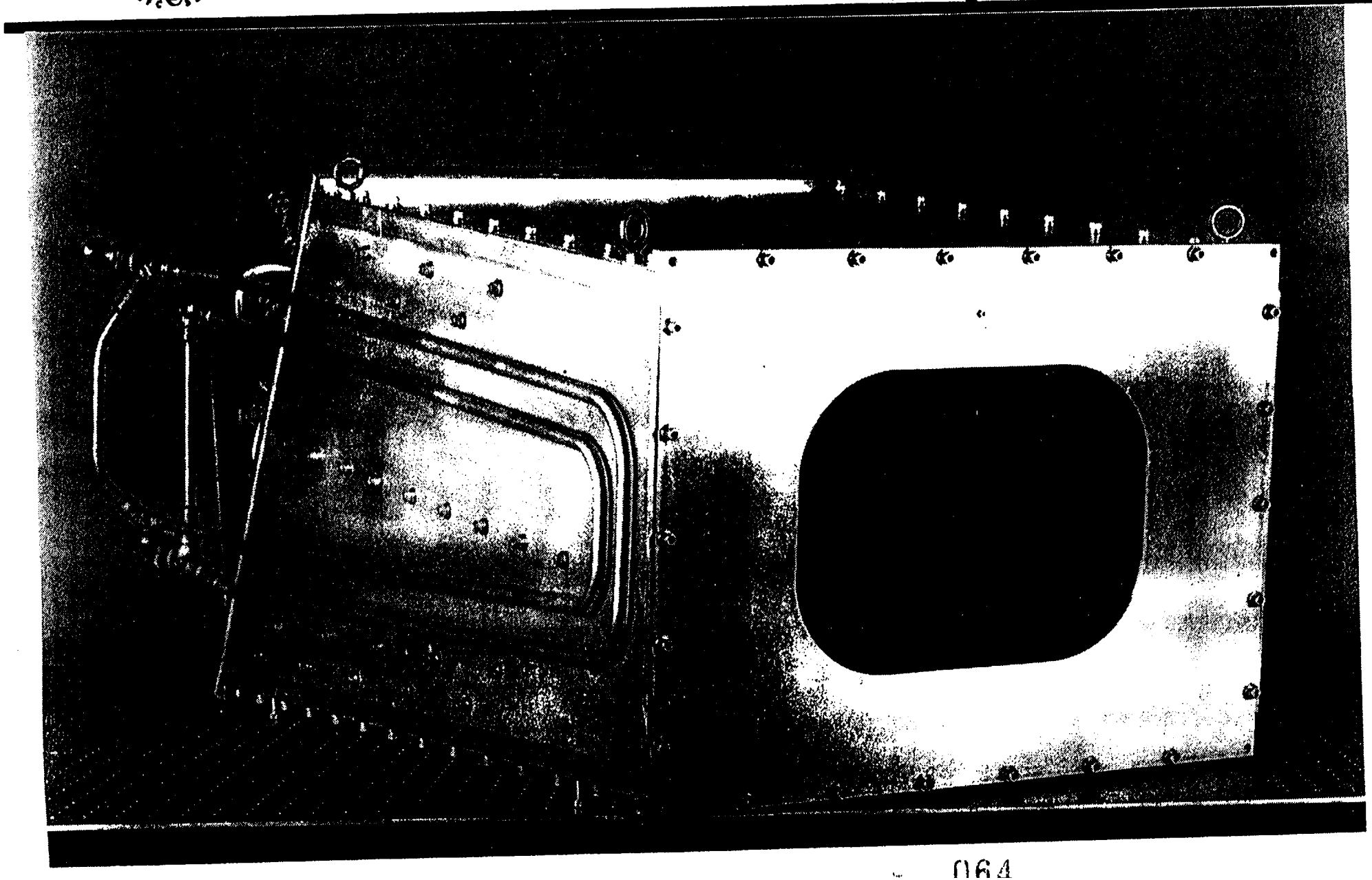

BLACKBODY CALIBRATION SOURCE REQUIREMENTS AND PERFORMANCE

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PARAMETER	REQUIREMENT	PERFORMANCE
• Temperature Range (Vacuum)	170K - 340K	170K - 340K
• Temperature Range (Ambient)	295K - 340K	295K - 340K
• Temperature Accuracy(Vacuum)	±0.040K	±0.025K
• Temperature Accuracy(198K-248K)	±0.040K	±0.055K*
• Temperature Accuracy(Ambient)	±0.040K	±0.040K
• Effective Cavity Emittance	>0.999	0.999845±4E-6
• Temperature Uniformity	<±0.1K	<±0.020K
• Temperature Repeatability	±0.1K	±0.1K
• Temperature Transition Times	< 30 min for 10K	11 to 27 minutes

* Out-of-spec due to calibration methodology ; will be corrected before Protoflight.

MEASUREMENT OF KEY BCS PARAMETERS

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- **Absolute Temperature**

  Temperature was measured with a square grid of nine PRTs calibrated by Rosemount. Each PRT temperature was traceable to NIST with a worst case value of ±0.016K. An overall "effective" temperature was calculated from an algorithm which employs a weighted contribution from the first, second, and third bounce surfaces.

- **Temperature Uniformity**

  Temperature gradients over the each of the cavity plates were measured by in-place PRTs .

- **Effective Cavity Emittance**

  BRDFs and Reflectances of cavity surfaces were measured by scatterometer and spectrometer systems at Hughes EOS. A proprietary computer program, OARDAS, modeled the BCS cavity and used measurement data to calculate effective emittance.

BCS FUNCTIONAL BLOCK DIAGRAM

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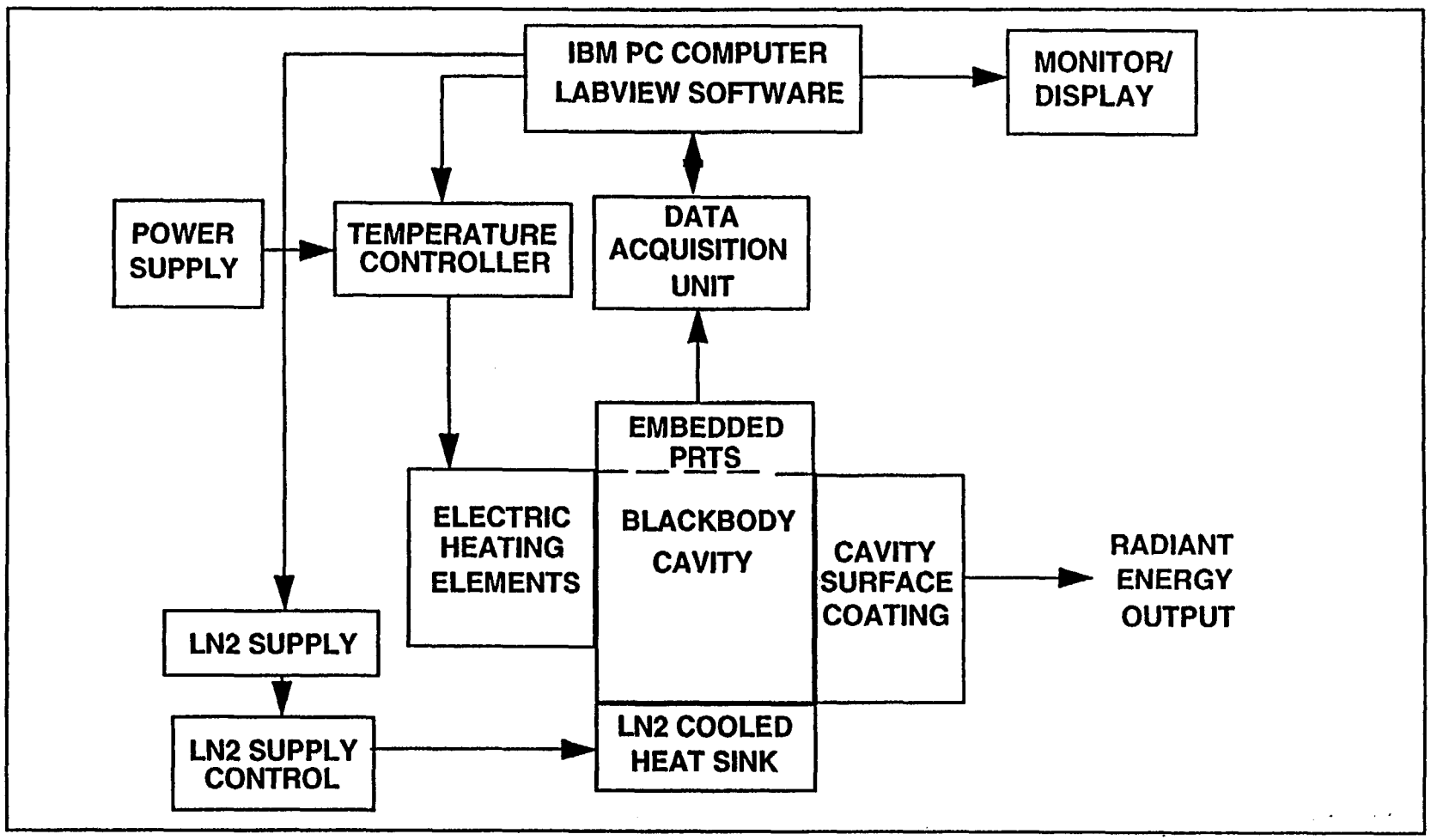

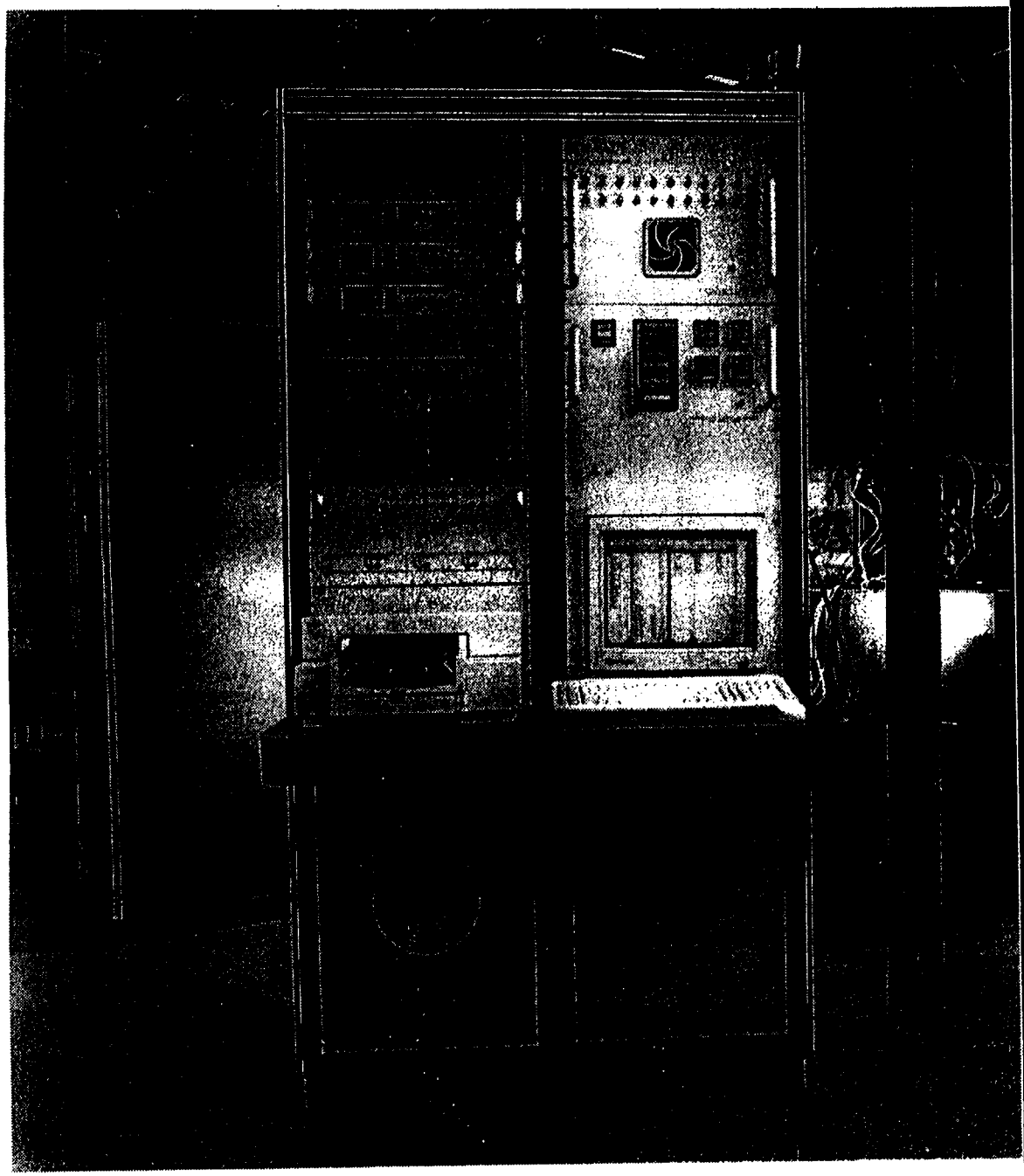

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BCS / SVS CONTROLLER

MODIS
GSFC SBRC

068

SPACE VIEW SOURCE

95-1-48

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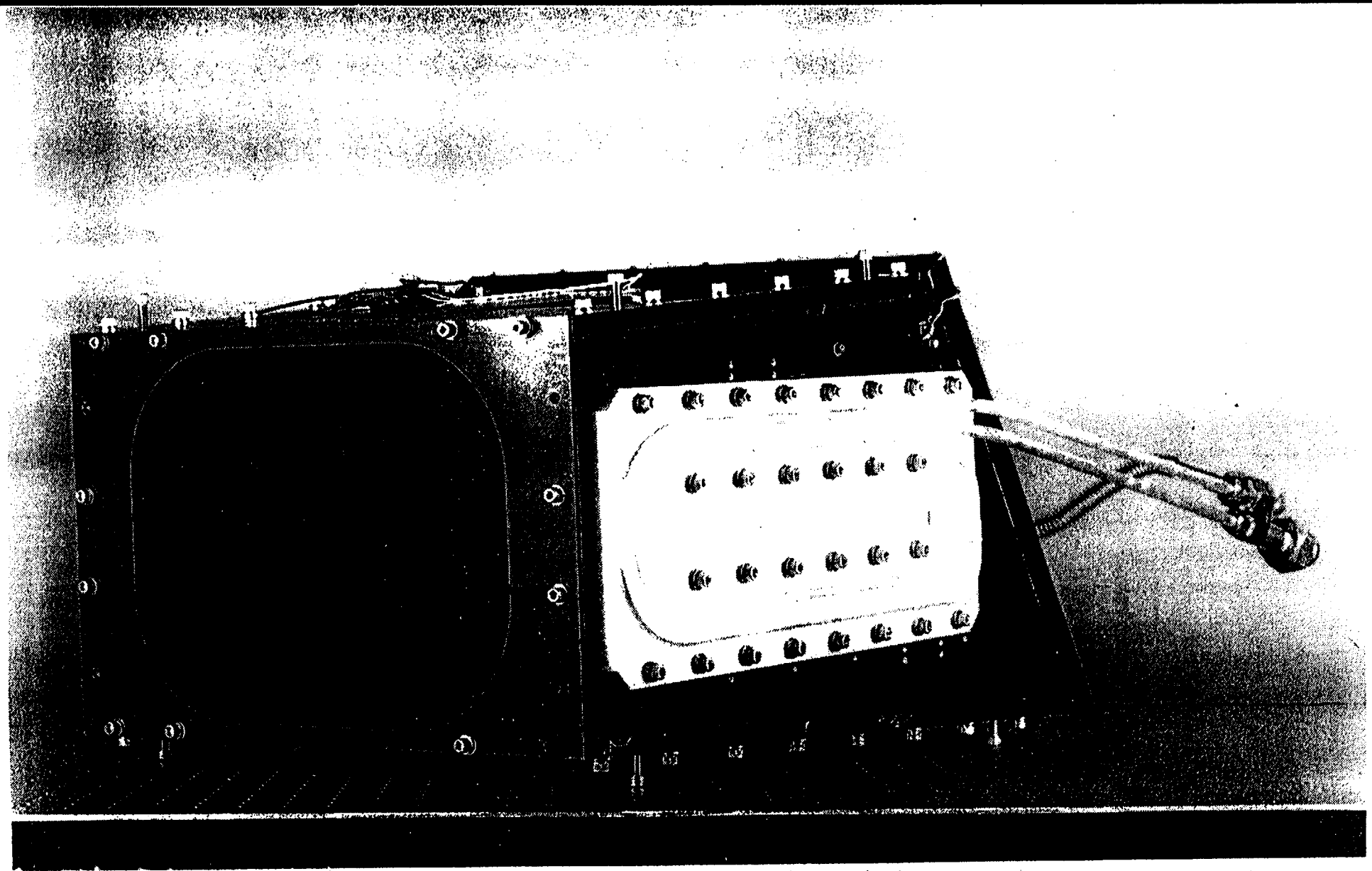

SPACE VIEW SOURCE REQUIREMENTS & PERFORMANCE

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PARAMETER	REQUIREMENT	PERFORMANCE
• Temperature Range (Ambient)	Floats at ambient	Floats at Ambient
• Temperature Accuracy (Vacuum)	Remain below 85K	82K
• Temperature Accuracy (Ambient)	±0.040K	±0.04K
• Effective Cavity Emittance	>0.999	0.999845±E-6
• Temperature Uniformity (Ambient)	<±0.1K	<±0.04K

SVS FUNCTIONAL BLOCK DIAGRAM

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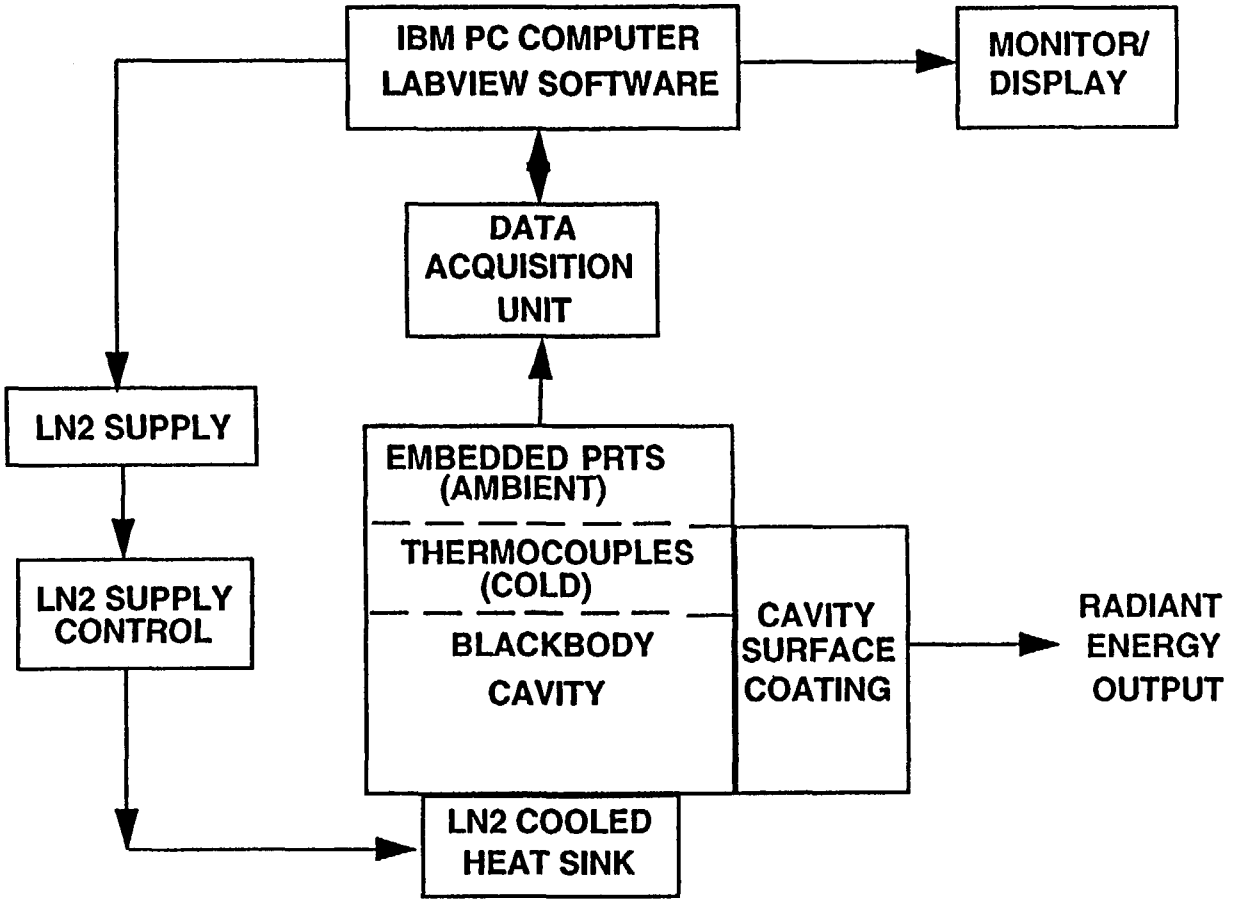

BCS & SVS PERFORMANCE EVALUATION & PROPOSED SYSTEM MODIFICATONS

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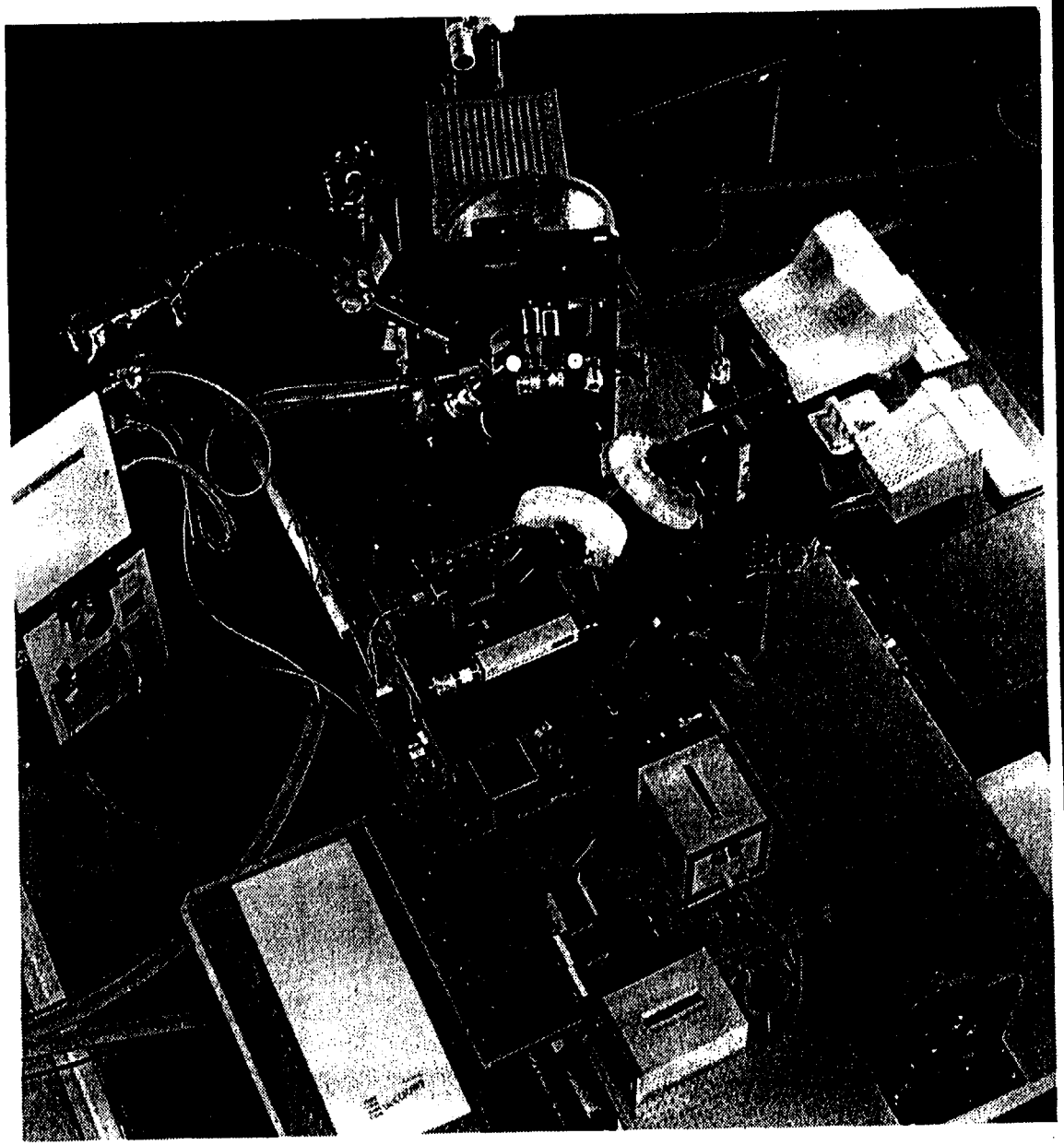
- **Performance Evaluation**
- BCS & SVS performed as per specifications with no problems.
- BCS transitions were accurate and predictable.

- **Proposed System Modifications**
- IBM PC Controller will be driven via an IEEE bus by the Stimulus Controller Workstation running OASIS.



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INTEGRATION AND ALIGNMENT COLLIMATOR

MODIS
GSFC SBRC

073

INTEGRATION & ALIGNMENT COLLIMATOR REQUIREMENTS AND PERFORMANCE

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TESTS	PRIME ITEM REQUIREMENTS	DERIVED IAC REQUIREMENTS*	IAC PERFORMANCE
• Wavelength Range	0.43μm to 14.3μm	0.43μm to 14.3μm	0.43μm to 14.3μm
• MODIS SBR / MTF	SBR: ±0.2 IFOV	Pointing : ±1.2° Scan ±0.4° Track Blur Diameter: ≤90 μrad SBR Test SNR: ≥ 200 Angle Uncertainty: ±10μrad Beam Nonuniformity: ≤3%	±1.7° Scan ±0.5° Track 70 μrad 900 Minimum <±10μrad
• IFOV	Scan IFOV: ±6% Track IFOV: +0, -6%	FOV: 0.2 x 16 TO 11 x 11 IFOV	0.2 x 16 IFOV to 11x11 IFOV
• IFOV Uniformity	IFOV Unif: ±20%	Pointing: ±1.2° Scan at 100 inch ±0.4° Track at 100 inch	±5.7° Scan @ 25inch ±2.0° Track @ 25inch
MTF Along Track	MTF: 0.3 @ $F_{Nyquist}$	IFOV/MTF Tests SNR: ≥ 500 Angle Uncertainty: ±10 μrad	503 Minimum <±10μrad

* Ref Doc :SBRC Specification Number 151872

MEASUREMENT OF KEY IAC PARAMETERS

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- **Pointing Accuracy**

  The IAC track and scan mirrors were driven from a boresight position to the extreme field position, and that angular position was checked with a theodolite having a 1 arc-second accuracy. Uncertainty was better than 2 arc-seconds.

- **Pointing Resolution**

  The IAC track and scan mirror motions are controlled by interferometers with an angular least count of 1/5 arc-second.

- **Pointing Repeatability**

  The position of a pinhole source was monitored by a 1 arc-second theodolite coaxial with the IAC boresight axis. Multiple scans were initiated with the track and scan mirrors driving the IAC optical axis to the extreme field position and back to boresight.

- **Wavefront Quality**

  Interferograms taken over the IAC full aperture showed better than 1/4 wave flatness at 632.8 nanometers.

IAC FUNCTIONAL BLOCK DIAGRAM

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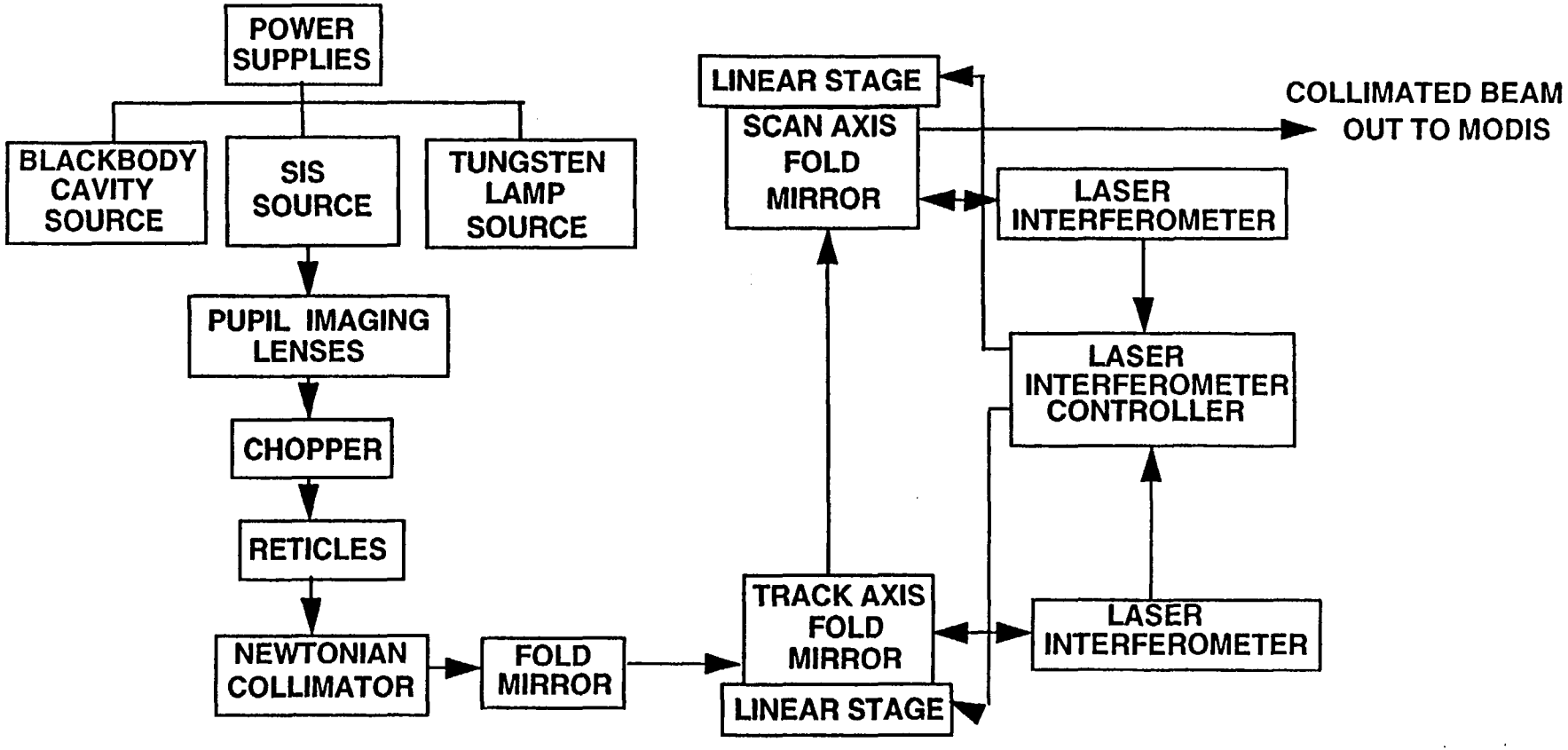

IAC PERFORMANCE EVALUATION & PROPOSED SYSTEM MODIFICATIONS

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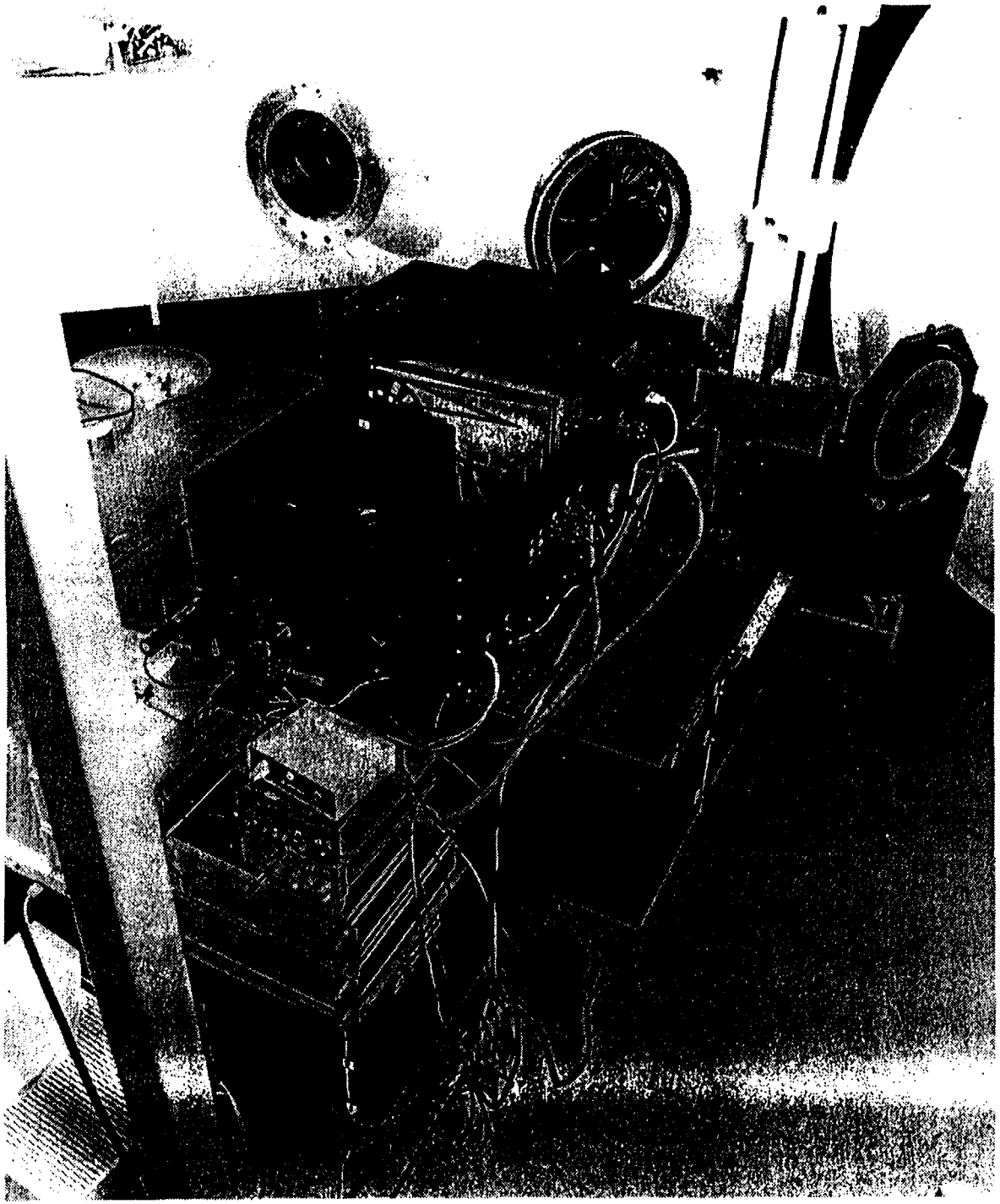
- **Performance Evaluation**
  - The Integration & Alignment Collimator performed as per specifications with no functional problems during testing.

- **Proposed System Modifications**
  - The IBM PC and software now controlling the IAC will come under OASIS control via the STE Stimulus Controller Workstation.



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SPECTRAL MEASUREMENT ASSEMBLY

078

SPECTRAL MEASUREMENT ASSEMBLY REQUIREMENTS AND PERFORMANCE

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PARAMETERS	REQUIREMENTS	PERFORMANCE
• Wavelength Coverage	0.40μm to 14500μm	0.38μm to >14500μm
• Spectral Slit Widths	1 nm to 50 nm	0.40 nm to 40 nm
• Wavelength Accuracy	±0.33 nm, 1 sigma up to 1μm, then scales linearly to 14.3 μm	<±0.10 nm, 1 sigma up to 1μm,* then scales linearly to 14.3 μm
• Wavelength Repeatability	±0.23 nm, 1 sigma up to 1μm, then scales linearly to 14.3 μm	±0.10 nm, 1 sigma up to 1μm, then scales linearly to 14.3 μm
• Signal - to - Noise Ratios	> 100 at all bands	>130 LWIR, >190 VIS-MWIR
• Slit Image Position Control	Step size 25 μrad over ± 1° field	Step size 10 μrad over ± 1° field
• Automated System Control	All functions remote controllable and outputs digitized	Automated controls, Digitized outputs

* Some visible bands did not meet requirement, possibly because of grating misalignments. This will be corrected for protoflight.

MEASUREMENT OF KEY SPMA PARAMETERS

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- **Wavelength Accuracy**

  Hg and Krypton atomic line standard lamps provided 10 calibration wavelengths covering 0.435μm to 13.1μm. Repeated scans of these lines and at multiples of the wavelengths of some lines established an accuracy rating.

- **Wavelength Repeatability**

  Repeat scans of atomic lines at 0.435μm and 0.546μm over a two month period were used to establish repeatability of better than ±0.2nm.

- **Wavelength Coverage**

  Four pairs of diffraction gratings blazed at 0.4μm, 1.5μm, 4.0μm, and 12.0μm were used to cover a wavelength range from 0.38μm to 15.0μm.

SPECTRAL MEASUREMENTS ASSEMBLY

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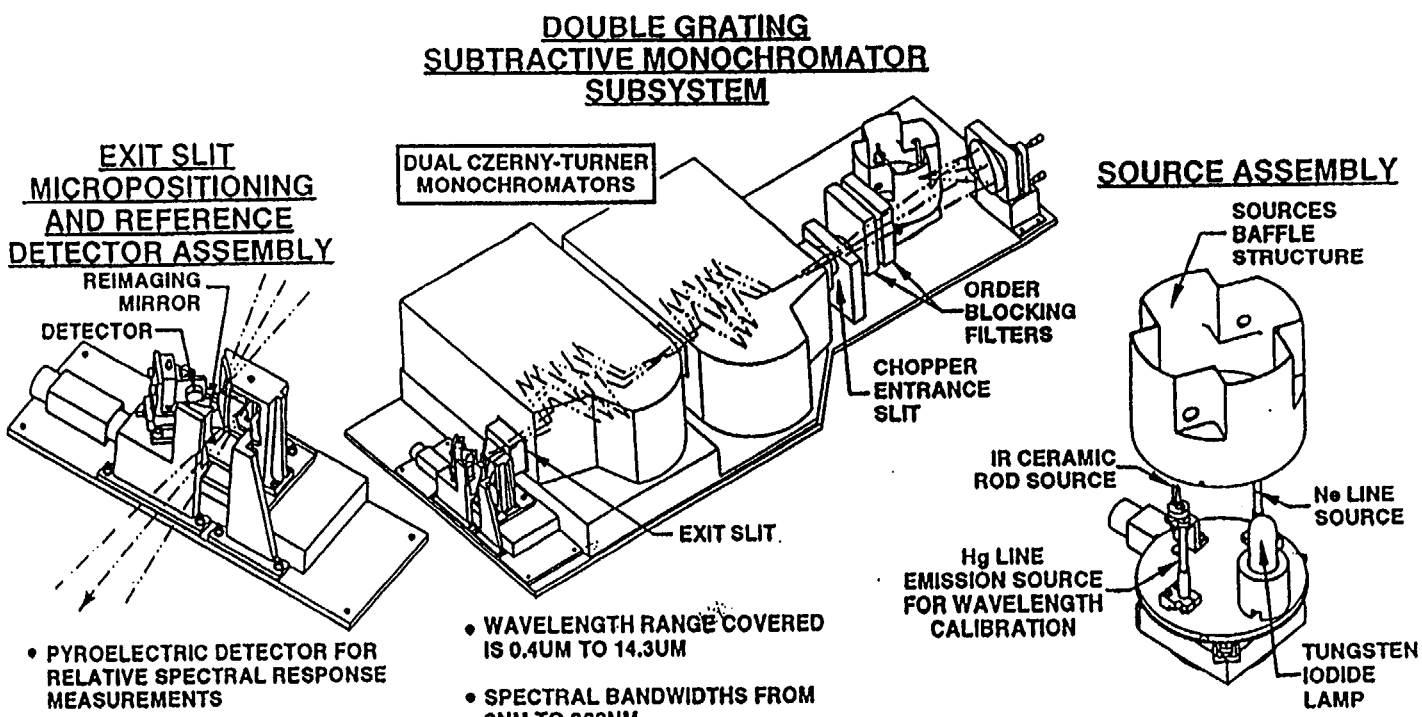

- PYROELECTRIC DETECTOR FOR RELATIVE SPECTRAL RESPONSE MEASUREMENTS
- EXIT SLIT CAN BE POSITIONED ON MODIS FOCAL PLANE WITH VERNIER POSITIONING

- WAVELENGTH RANGE COVERED IS 0.4UM TO 14.3UM
- SPECTRAL BANDWIDTHS FROM 2NM TO 300NM
- AUTOMATIC SLIT WIDTH CONTROL (3 SLIT MECHANISMS) FOR MAXIMIZING THROUGHPUT

- LINE SOURCES PROVIDE WAVELENGTH CALIBRATION OVER ENTIRE RANGE
- TUNGSTEN SOURCE COVERS VIS/NIR/SWIR
- CERAMIC ROD SOURCE COVERS MWIR/LWIR

SPMA FUNCTIONAL BLOCK DIAGRAM

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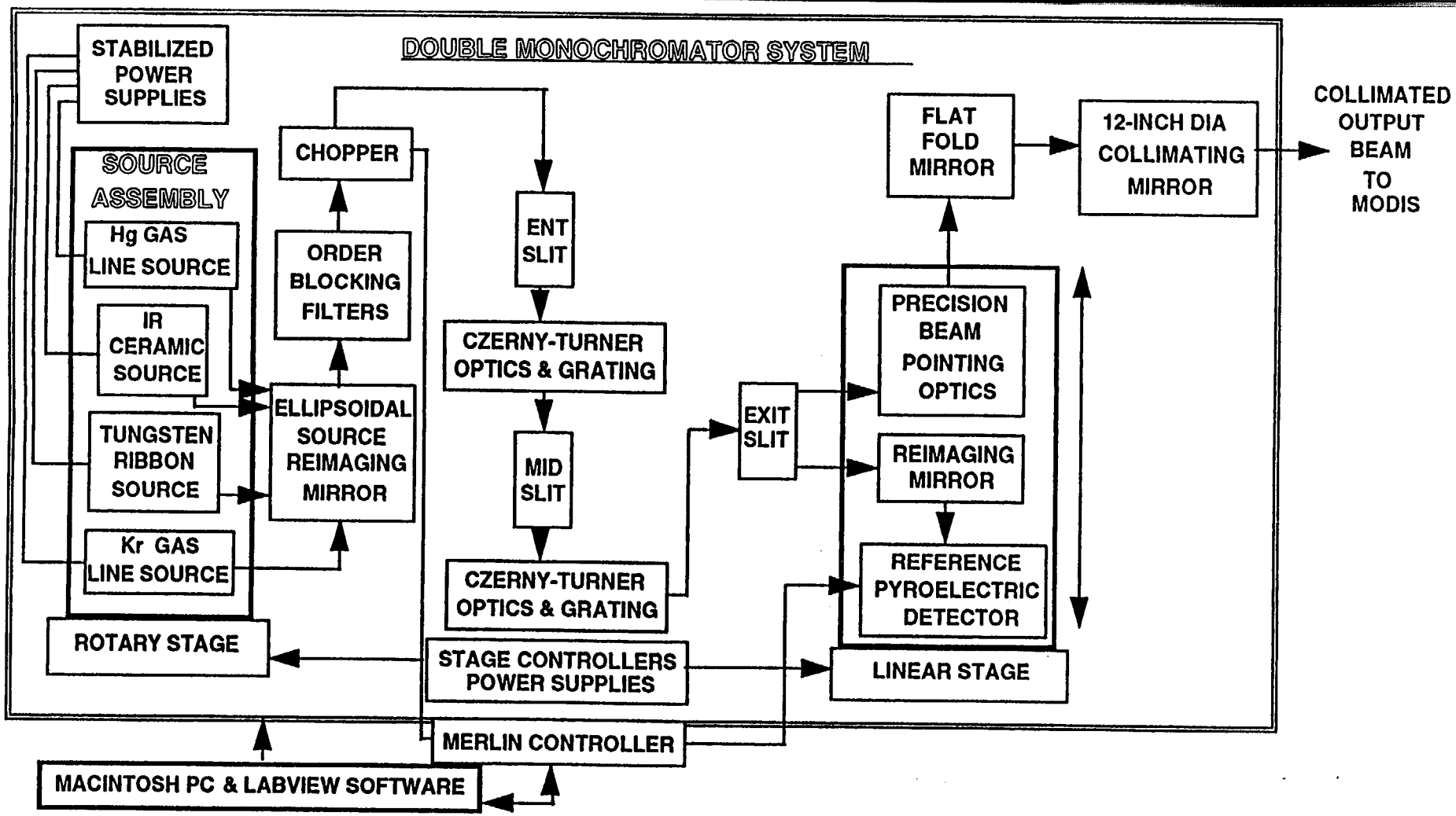

SPMA PERFORMANCE EVALUATION & PROPOSED SYSTEM MODIFICATIONS

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- **Performance Evaluation**
  - SPMA functioned well during testing and its performance equaled or exceeded nearly all specifications.
  - Dual gratings were not synchronized and slightly out of step during data collects for relative spectral response.
  - Low signal-to-noise ratio was experienced for LWIR Bands 27 through 29 due to water absorption at Band 27 and low grating efficiency for Bands 28 and 29.
  - Slit image position control mechanism did not operate under remote control. Manual control was possible but awkward to implement.

- **Proposed System Modifications**
  - Implement an improved alignment procedure for dual grating sets to assure coincidence of grating rotation.
  - The Macintosh PC and Labview software will be replaced by OASIS control on the STE Stimulus Controller Workstation.
  - Tent monochromator and path to vacuum chamber window and purge with N2 to avoid water absorption losses.
  - For safety improvement, a lifting fixture will be fabricated for the monochromator unit that is removed and replaced for grating-mirror swaps during testing.

MODIS CALIBRATION CHAMBER

95-5-165

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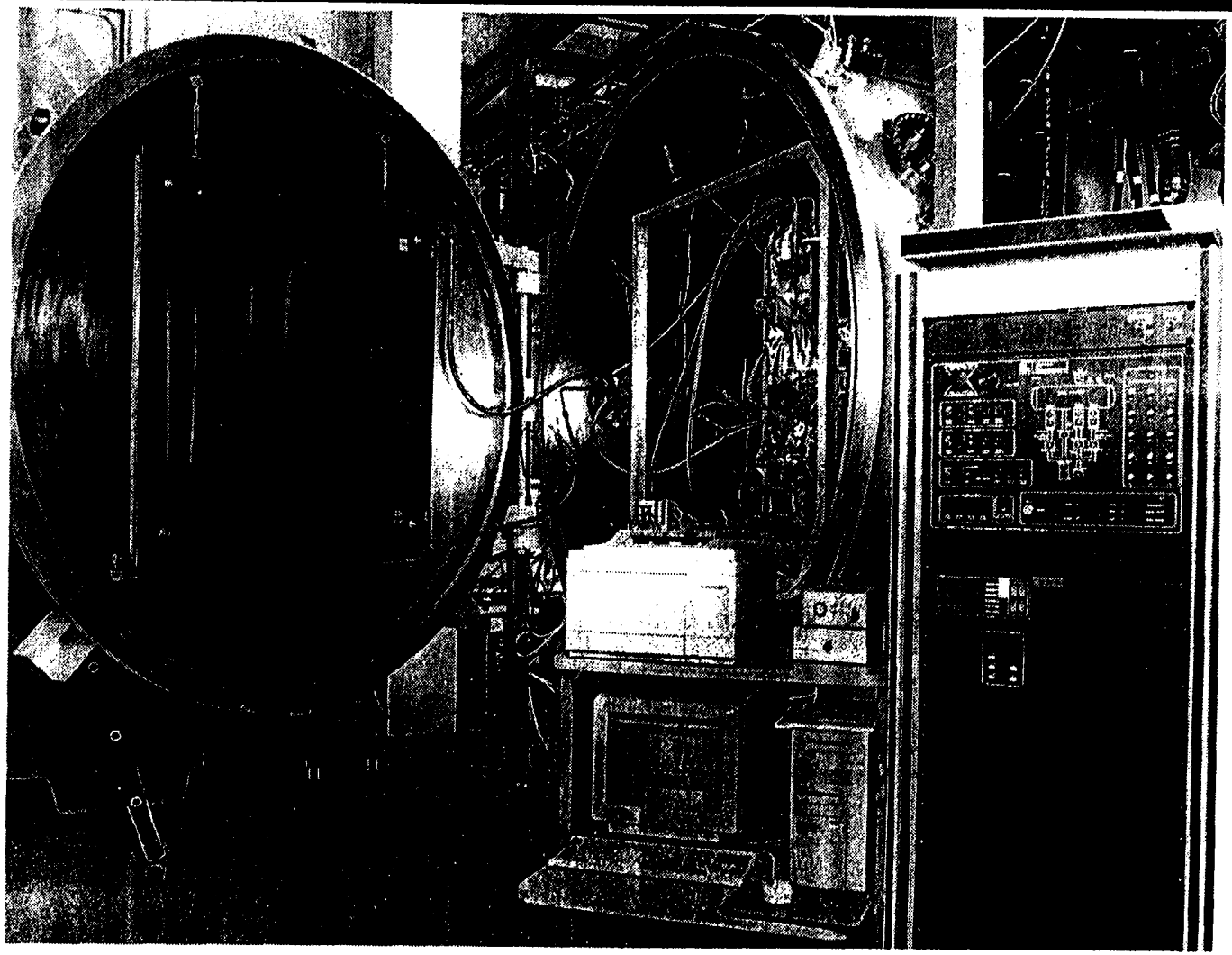

MODIS CALIBRATION CHAMBER (MCC) FEATURES

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- Vacuum Vessel Dimensions 13.5 Ft. long by 8 Ft. ID
- Vacuum Wall Material - 304 Stainless Steel
- Vacuum Pumping System:

(1) Mechanical Pump Specs

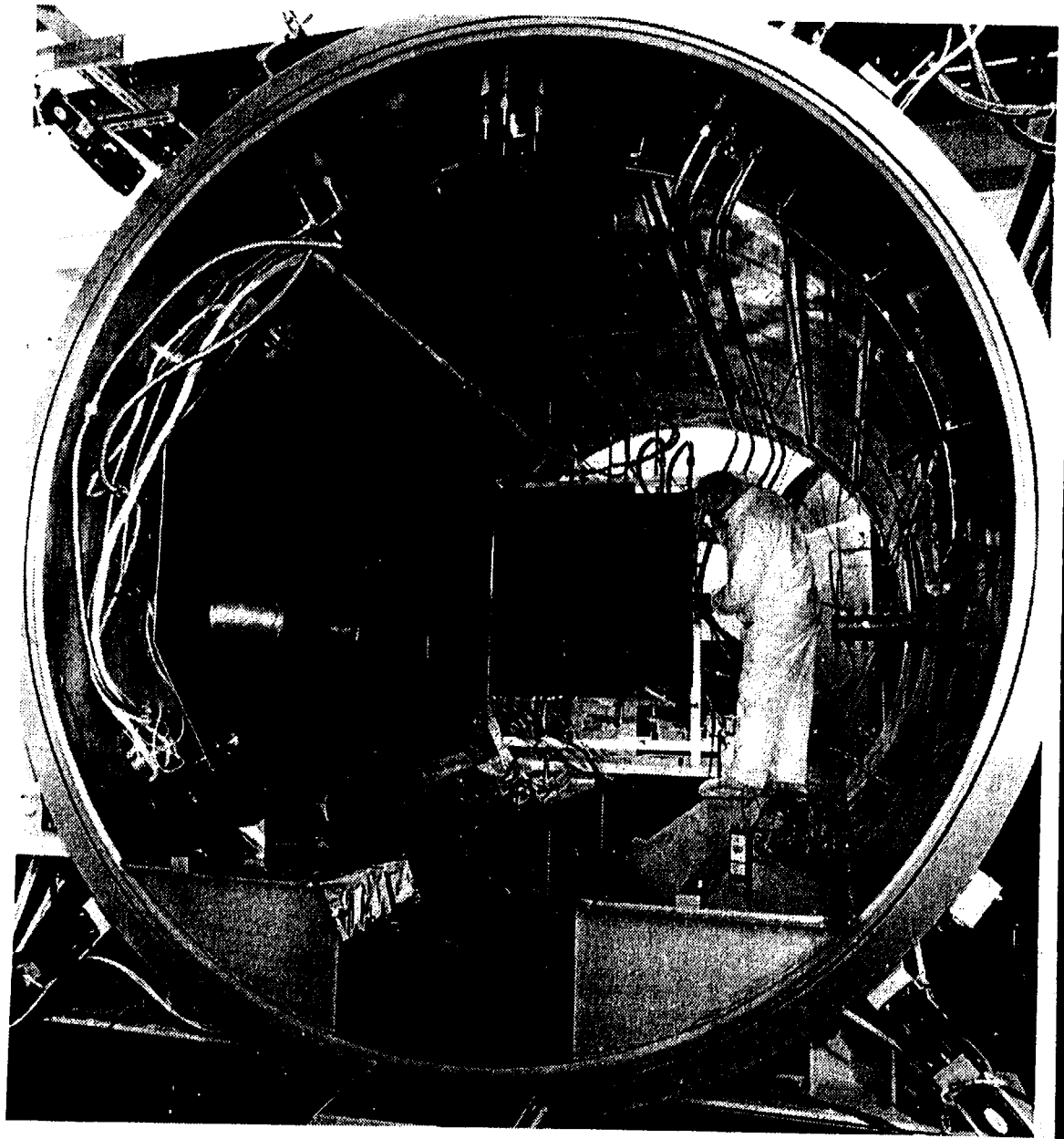
Chamber Roughing
Dry Pumping (Hook and Claw)
Leybold Dryvac 100B=59CFM
Ultimate Pressure 8 x 10^{-3} Torr

(2) Cryopump Specs

- 2 each Leybold RPK10,000
- Ultimate Pressure 5.5 x 10^{-8} Torr
- Pumping Speed
  - Air 9500 Ltrs./Sec.
  - Water 31000 Ltrs./Sec.
  - Argon 8000 Ltrs. /Sec.
  - Helium 6000 Ltrs./Sec.

(3) Turbomolecular Pump Specs

- 1 each Leybold 1000 MC
- Ultimate Pressure 5.5 x 10^{-8} Torr
- Pumping Speed
  - Nitrogen 1000 Ltrs./Sec.
  - Helium 950 Ltrs/Sec.
  - Hydrogen 950 Ltrs./Sec.



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SBS UNITS IN MCC

MODIS
GSFC SBRC

086

MCC VACUUM PERFORMANCE WAS EXCELLENT

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PRESSURE	REQUIREMENT	PERFORMANCE
• 760 Torr to 1×10^{-2} Torr	≤ 4 Hours	1.4 Hours
• 0.5×10^{-2} Torr to 1×10^{-5} Torr	≤ 16 Hours	6.0 Hours
• 1×10^{-5} Torr to 1×10^{-6} Torr	≤ 28 hours	8.0 Hours
• 1.83×10^{-7} Torr (Ultimate)	≤ 72 Hours	60.0 Hours

EM MODIS Tests were performed at 1.0×10^{-6} Torr

PERFORMANCE PREDICTIONS FOR PROTOFLIGHT

PERFORMANCE PREDICTIONS
TOPICS

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- Radiometric sensitivity (Pagano and Bauer)
- Radiometric accuracy (Pagano and Bauer)
- Radiometric stability (Pagano and Bauer)
- Polarization (Young and Pellicori)
- Near field response (Young and Pagano)
- Spatial (Therrien and Lommen)
- Spectral (Young and Pellicori)
- Stray light (Young)
- In-flight calibration (Johnson *et al*)

Radiometric Sensitivity

Tom Pagano

RADIOMETRIC SENSITIVITY (SNR,NEΔT) WELL UNDERSTOOD

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- Budgets established and described in detail in CDRL 101, "RMM"
- EM SNRs/NEΔTs meet specs in most bands; out-of-spec bands identified
- Transmissions as predicted except LWIR which are much lower
- Noise as predicted for most bands
- Reduced performance in VIS and NIR may be related to source drift
- Dynamic Range accommodates Lmax and OBC signal ranges
- Limited EM Dynamic Range due to premature saturation on detectors and inadequate background shielding
- Predict PFM will meet requirements for all but 35, 36

SENSITIVITY AND ACCURACY BUDGETS IN RADIOMETRIC MATH MODEL

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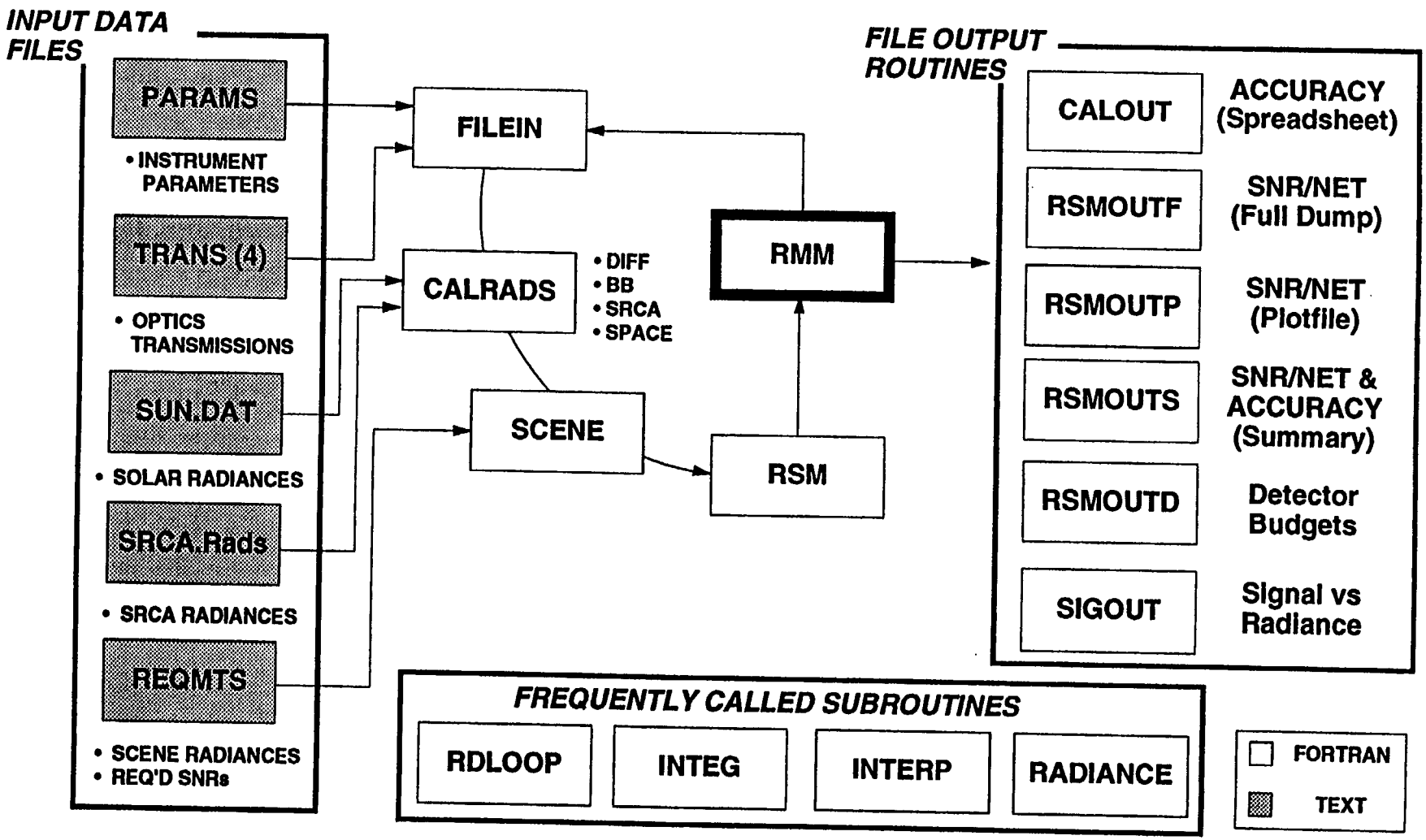

SIGNAL TO NOISE
MOST VIS/NIR/SWIR BANDS MEET SPEC

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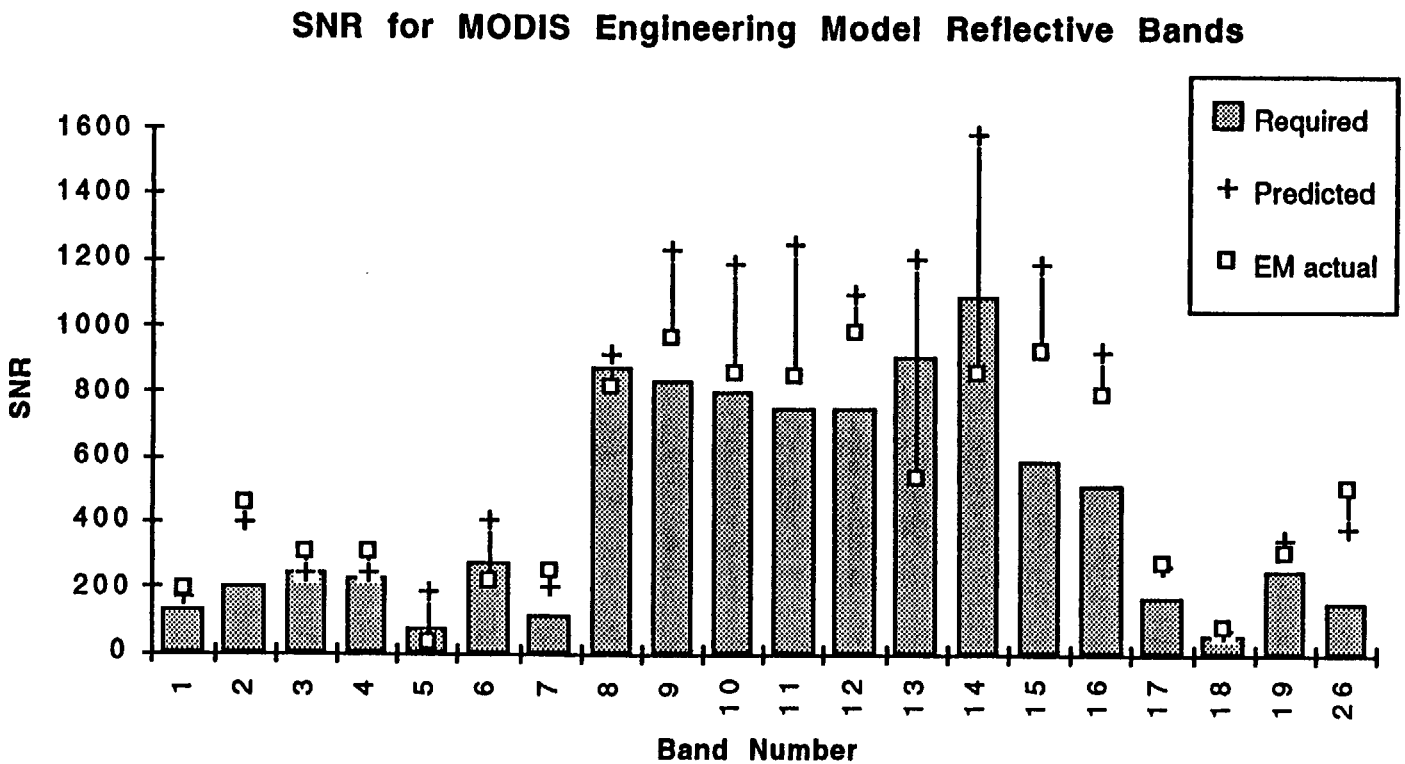

NEΔT
NOT SENSITIVE TO CHARGE SUBTRACTION

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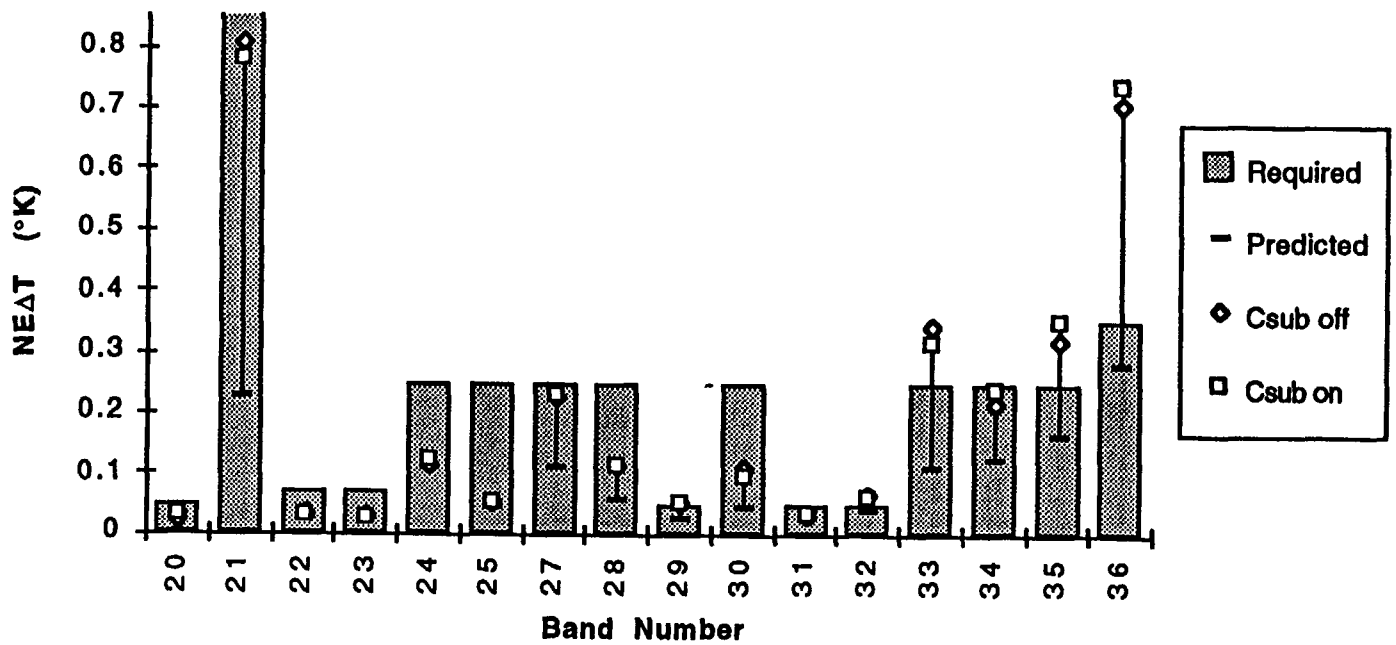
NEΔT for MODIS Engineering Model Emissive Bands



LIMITING FACTORS FOR NON-COMPLIANT BANDS

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Band	SNR spec	Measured	Reason
SWIR			
6	275	244	Bad filter
VIS			
8	880	838	Marginal
NIR			
13	910	537	Higher electronics noise than expected
14	1087	898	
PC			
29	1066	945	Lower transmission values than expected
33	247	195	
35	220	185	
36	135	62	

THROUGHPUT AS PREDICTED FOR MOST BANDS

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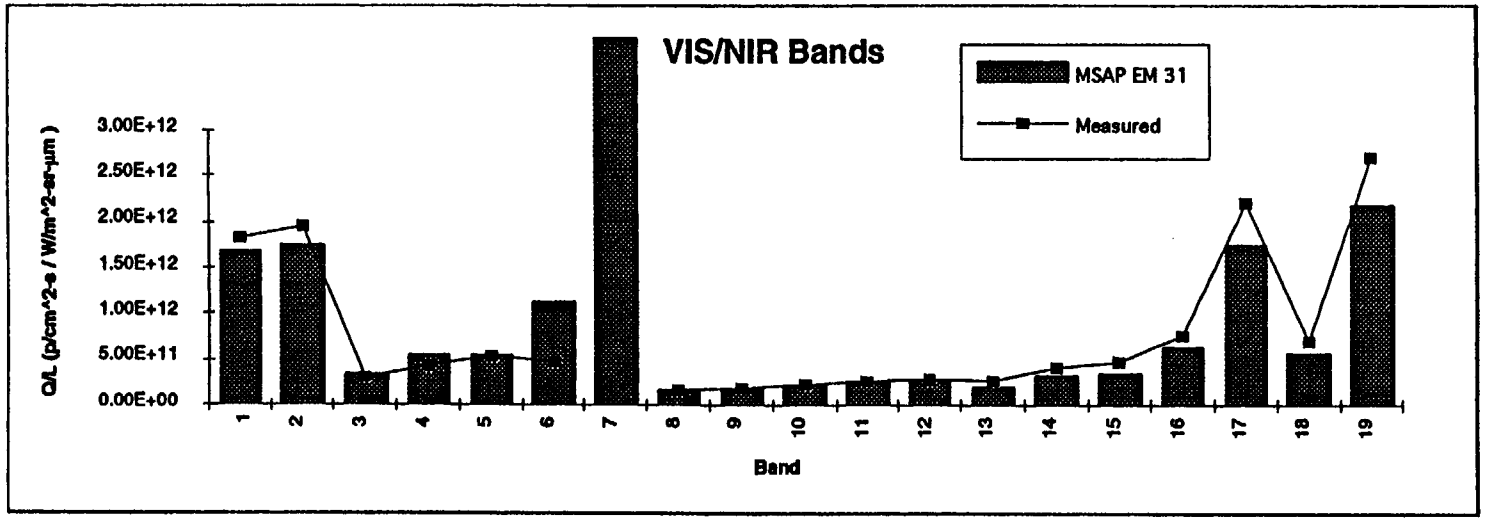

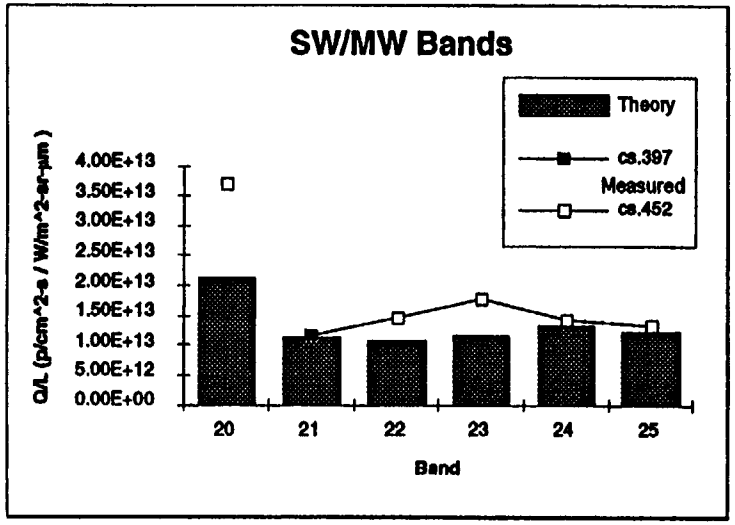

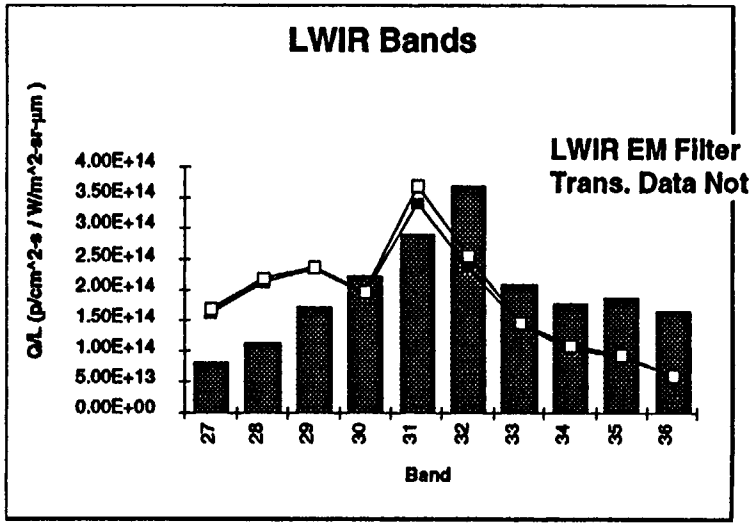

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NOISE LEVELS WERE CLOSE TO PREDICTIONS ON EM

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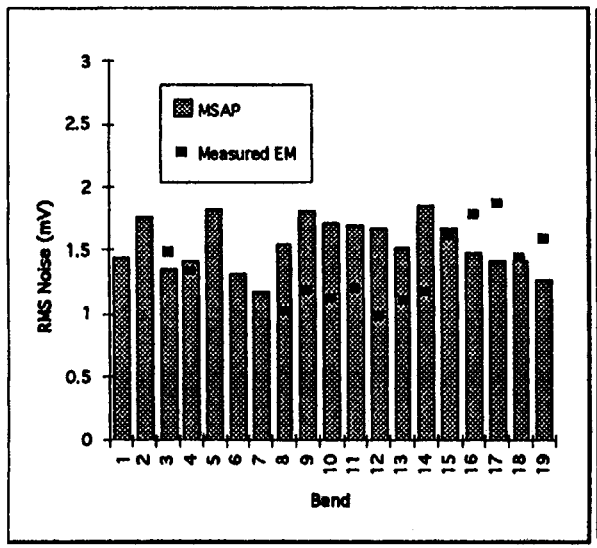
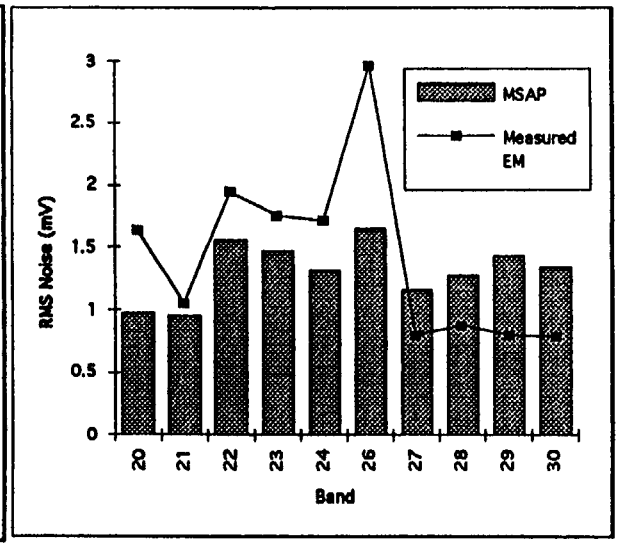
- MSAP used with component data to predict noise for EM
- Measured noise determined by analysis of spaceport data
- Noncompliances not caused by noise levels except B33

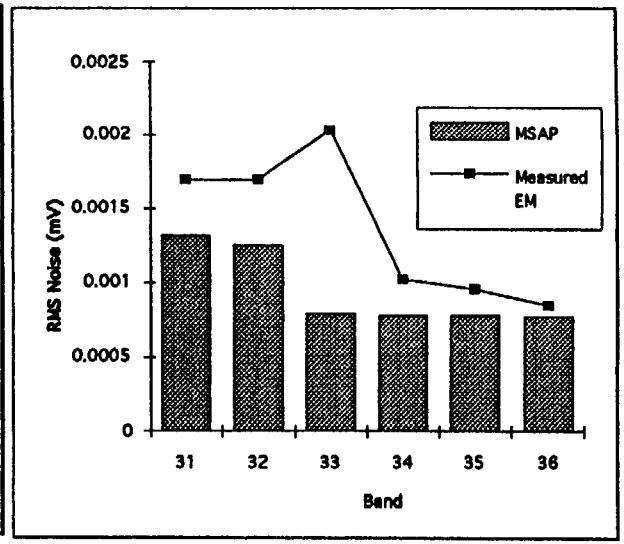
VIS, NIR, SWIR



MWIR, LWIR PV



LWIR PC



- Bands 1, 2, 5, 6, 7 had excessive ringing on EM

SIGNAL TO NOISE
THREE WAYS TO SKIN A CAT

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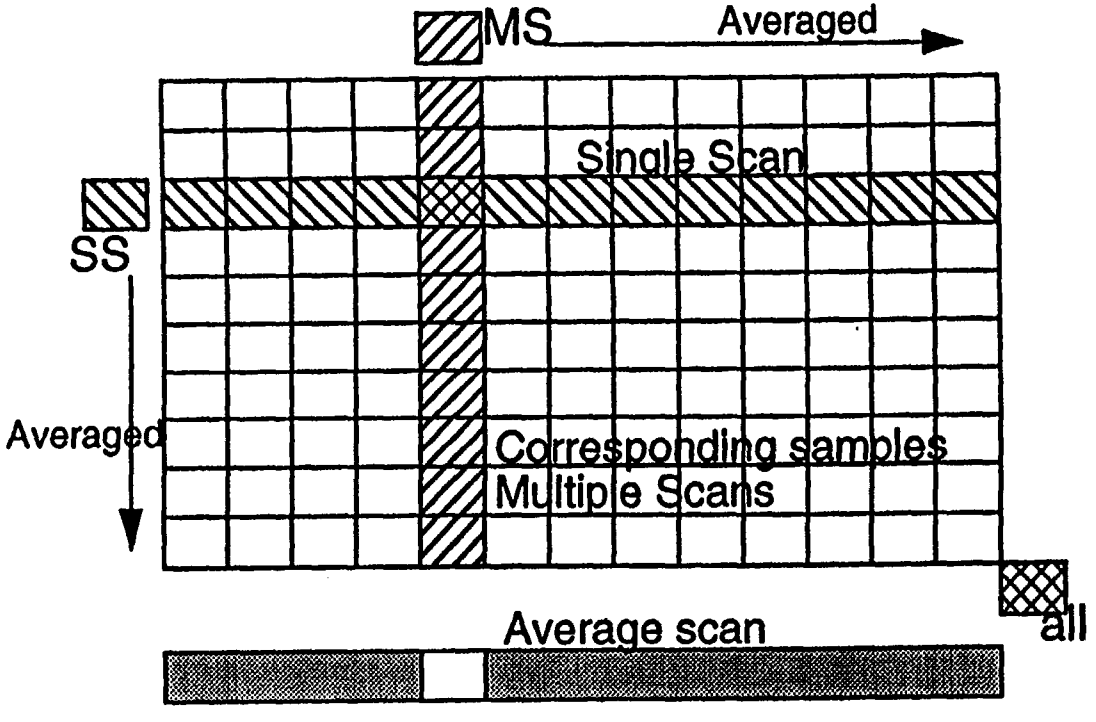

Band 1

SNR_SS	SNR_MS	SNR_all	Radiance-SV
222.3	228.2	221.0	26.1
295.1	303.8	294.4	34.5
386.9	397.7	384.9	46.5
379.0	397.7	373.1	53.4
479.2	485.2	473.4	63.9
558.3	576.1	556.8	75.3
519.7	522.7	498.9	80.9
631.2	638.6	621.6	91.3
631.2	627.0	612.6	94.8
620.0	592.5	561.9	109.1
676.9	656.7	639.8	117.3
810.9	802.3	780.6	130.7
912.0	850.0	833.7	164.8
1121.3	1001.3	990.4	221.7
1373.2	1291.2	1270.1	277.8
1316.3	1156.8	1126.5	335.8
1844.3	1630.8	1606.6	394.4
1896.2	1937.9	1885.7	452.3
1689.3	1728.9	1680.9	510.5
1868.0	1906.7	1864.4	567.8
1841.3	1864.2	1833.3	620.9

•Stable sources lead to consistent results

NONCOMPLIANT SNRs IN VIS/NIR BELIEVED TO BE SOURCE RELATED

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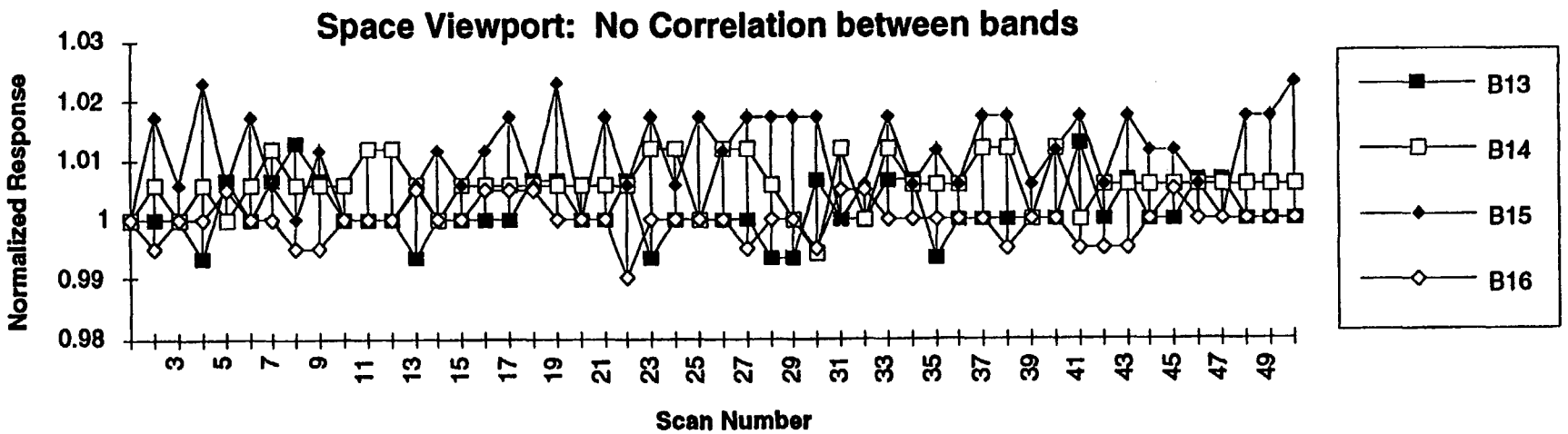
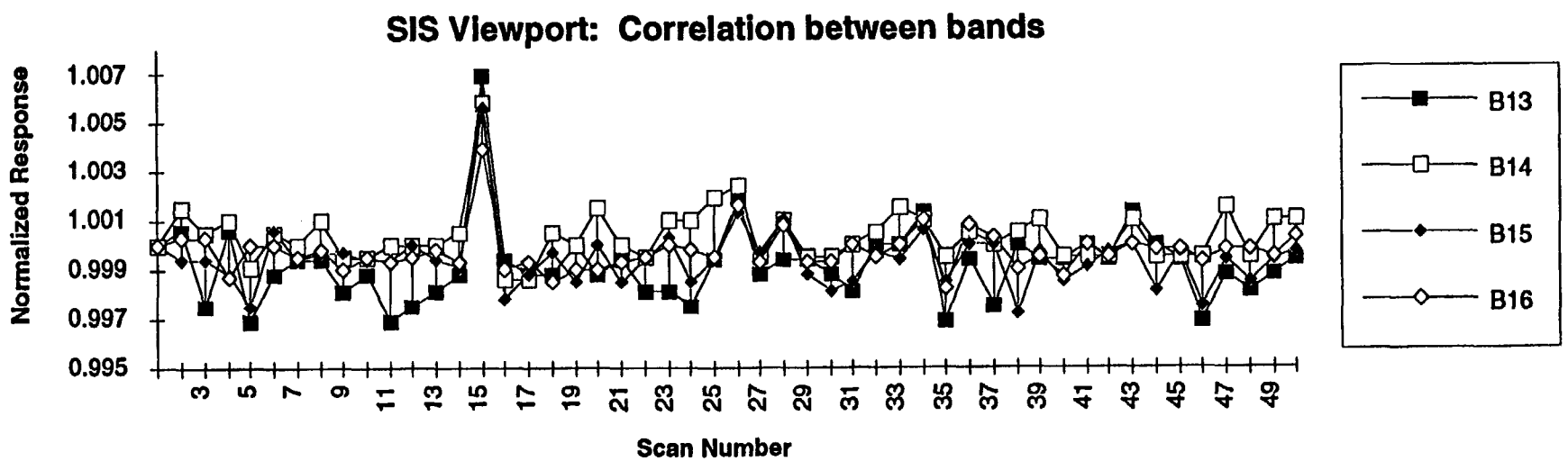
- **SNR calculated on SIS port inconsistent with noise levels in space port**





DYNAMIC RANGE SIZED FOR Lmax and Tbb=320K

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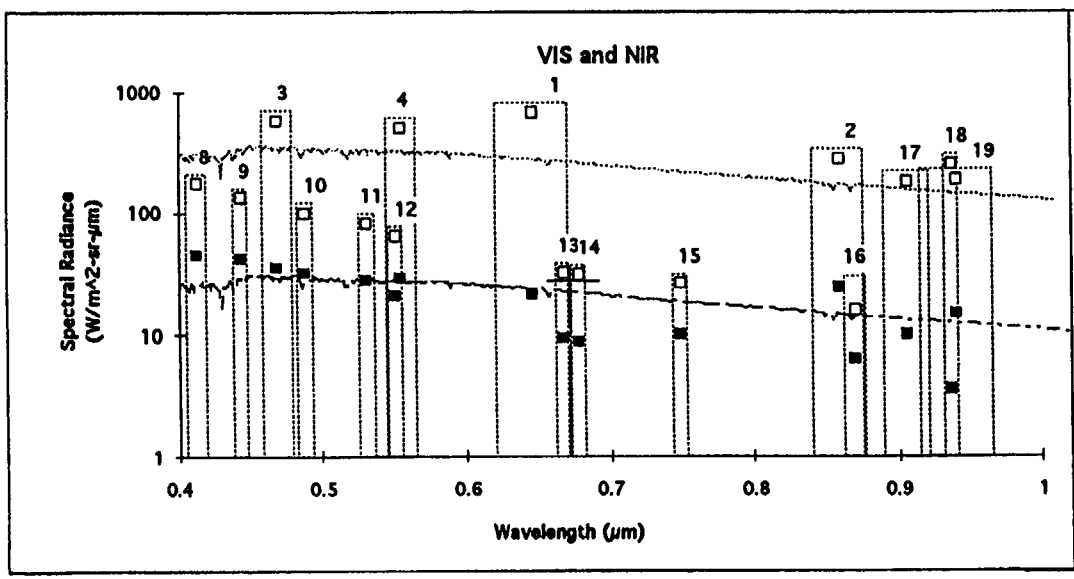

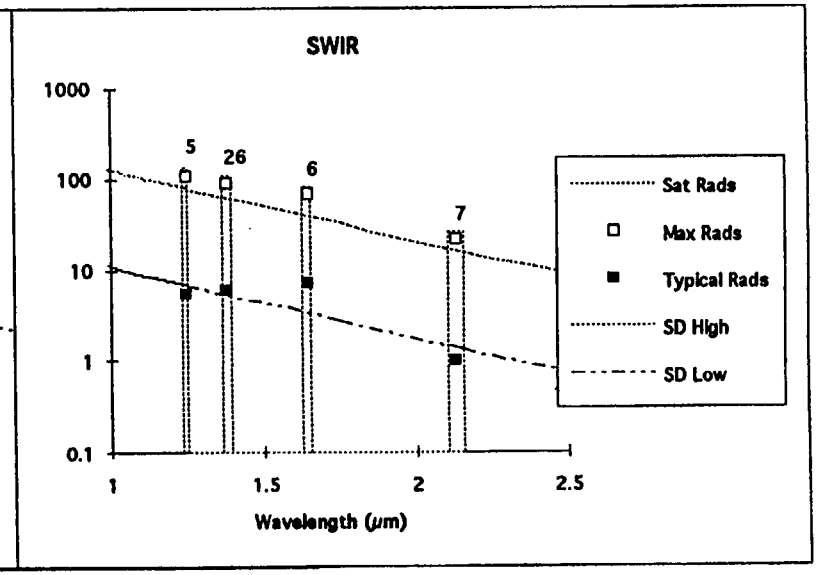

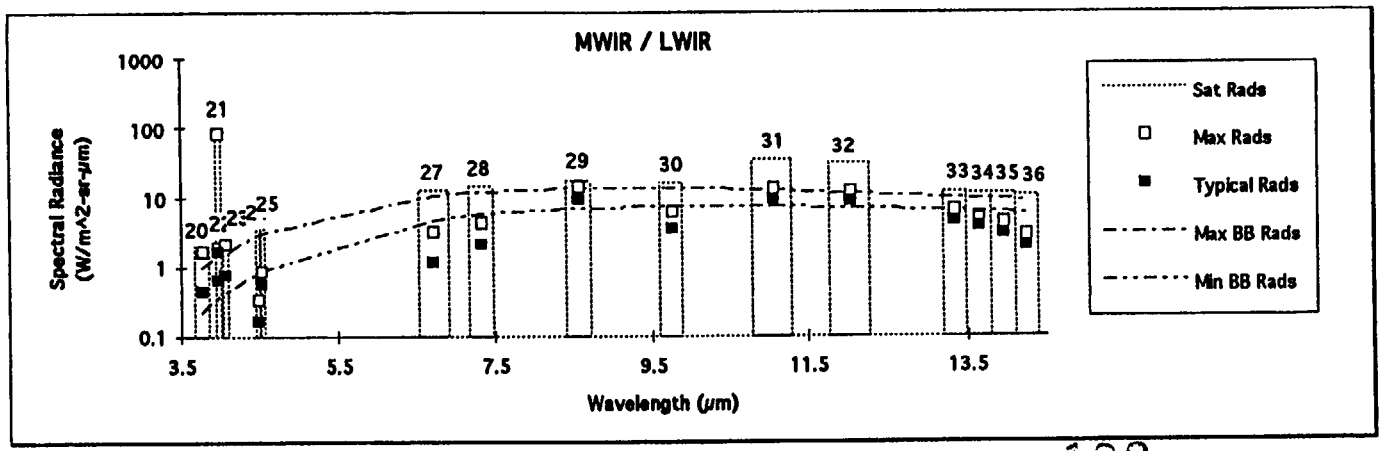

EM SUFFERED PREMATURE SATURATION

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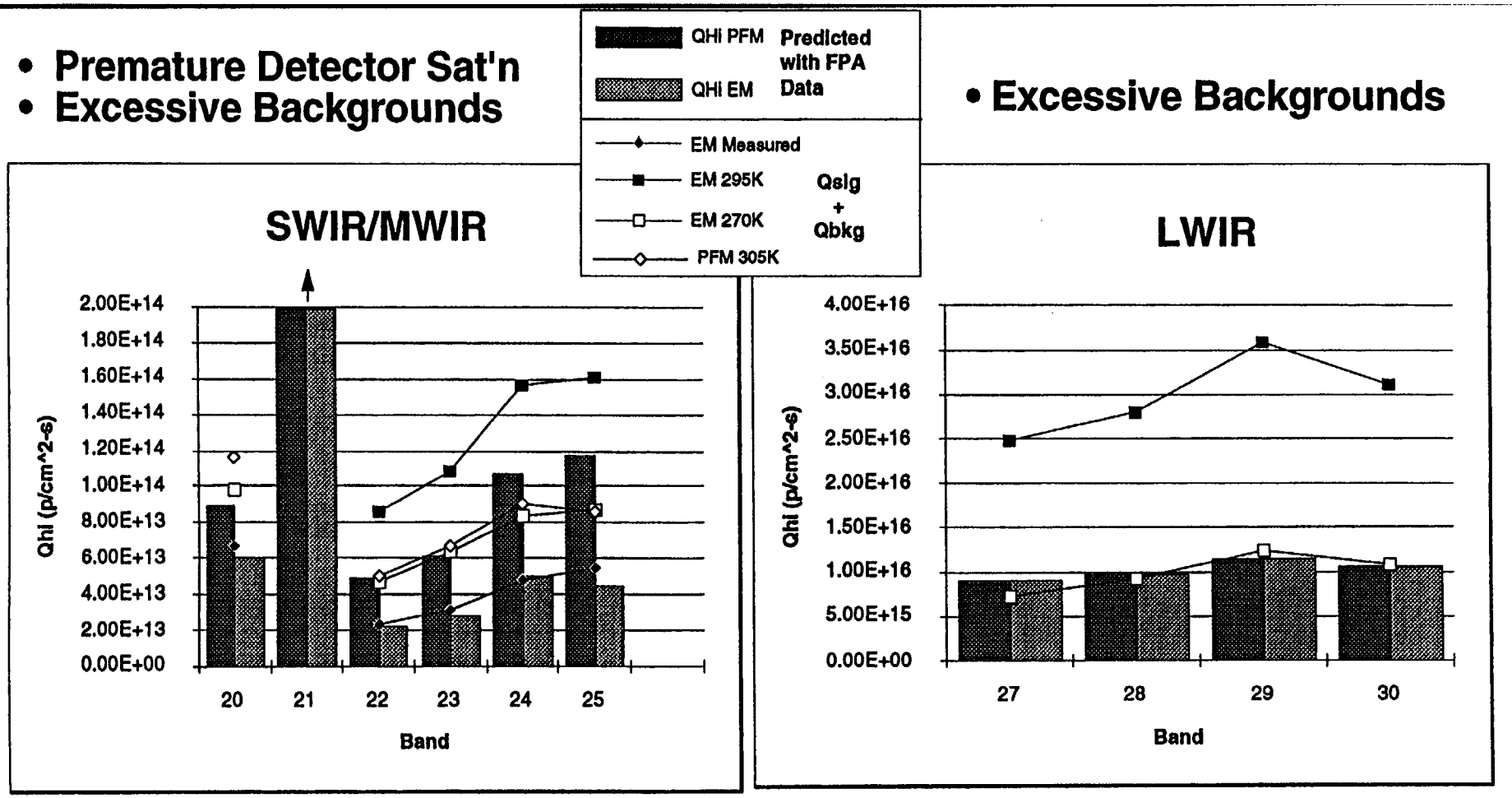
- Premature Detector Sat'n
- Excessive Backgrounds



- Excessive Backgrounds

- PFM redesigned background shields and lowered aft optics temp.

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PLANS IN PLACE TO CORRECT FOR PREMATURE SATURATION

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1) Detectors fabricated to flight specifications without premature sat

2) Cold/warm shields redesigned and implemented to correct specifications

- 1 and 2 should be enough to meet specifications!

3) Background test will be performed. It will be combined with radiative cooler unit level test. Aft optics and scene temp's will be cycled.

4) Results from background test will determine background sensitivity to instrument temperature

5) Main electronics radiating area increased. Reduces instrument temperature by 8°C

6) Option exist to blanket aft optics if necessary, achieving an additional significant temperature margin. Option will be exercised if needed pending results from background test

Radiometric Accuracy

Tom Pagano

MANY SOURCES CONTRIBUTE TO RADIOMETRIC ERROR

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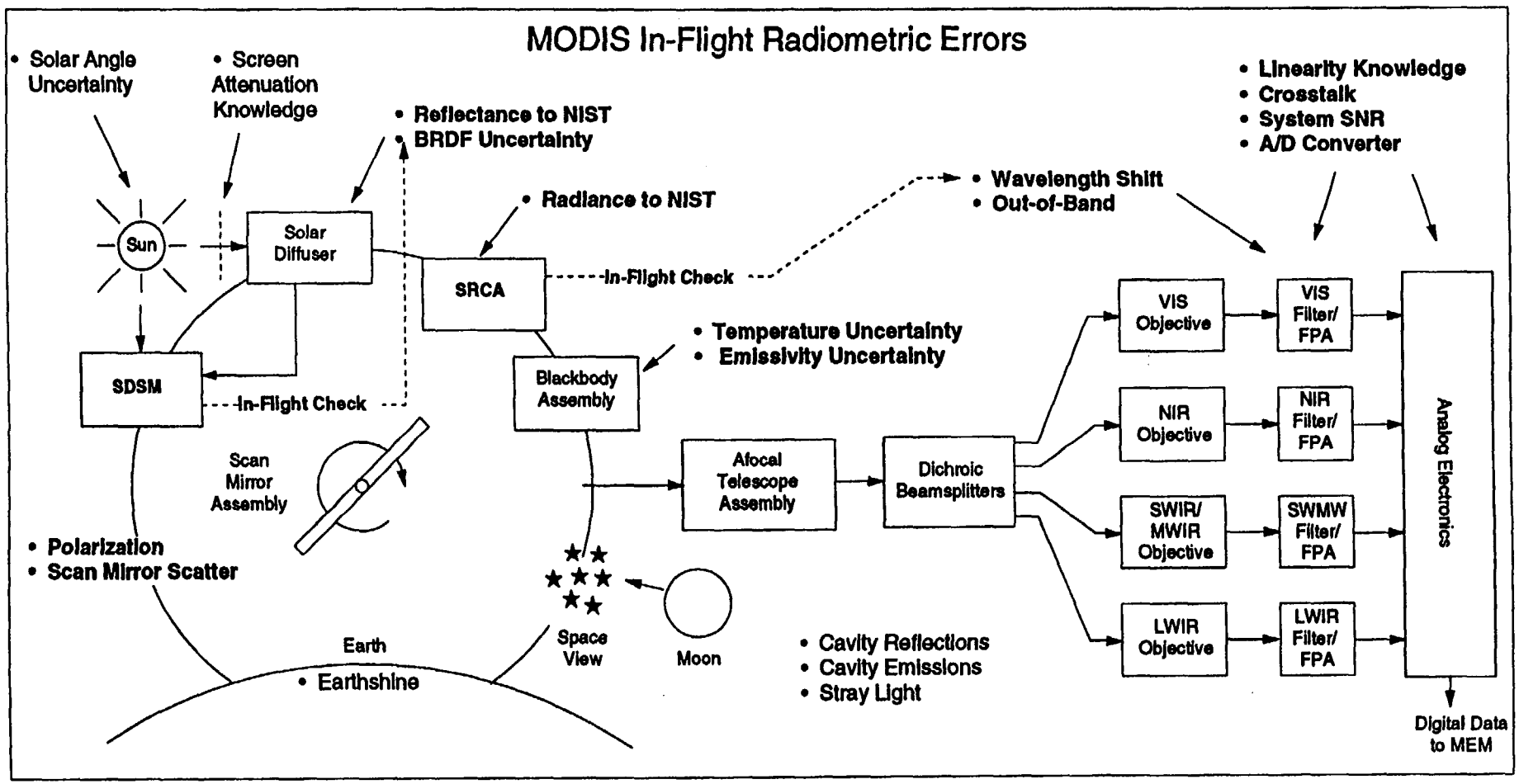

• Bold Items are Characterized Pre-Flight

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RADIOMETRIC ACCURACY BUDGET ESTABLISHED

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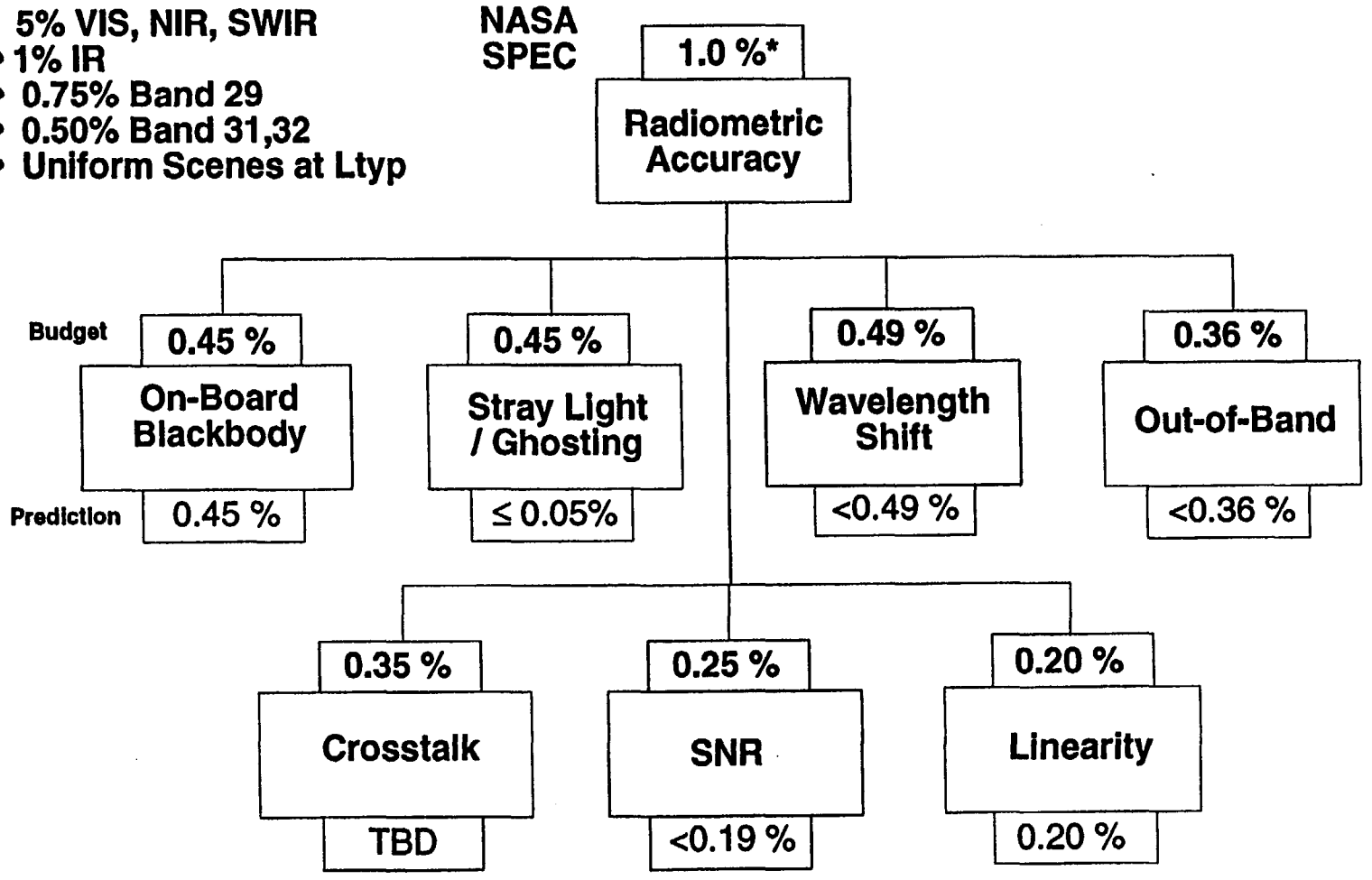
* • 5% VIS, NIR, SWIR
• 1% IR
• 0.75% Band 29
• 0.50% Band 31,32
• Uniform Scenes at Ltyp



PFM EXPECTED TO MEET RADIOMETRIC ACCY BUDGETS

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Accuracy Budget	In-Flight Solar Radiance (%)	In-Flight Solar Reflectance (%)
Transfer to NIST	3.00	0.89
Source	2.28	1.25
BRDF*	1.00	1.00
Attenuation	0.50	0.50
Angle of Inc.	0.47	0.47
Cavity Refl	0.13	0.13
Earthshine	0.28	0.28
WL Shift	1.68	0.00
OOB	0.89	0.00
MODIS	2.30	1.23
SNR	0.50	0.30
Linearity	0.50	0.50
Crosstalk	0.35	0.35
WL Shift	1.68	0.00
OOB	0.89	0.00
Polarization	0.00	0.00
SM Scatter	0.25	0.25
Ghost/Stray	1.00	1.00
RSS Total	4.41	1.97
Requirement	5.00	2.00
Margin	0.59	0.03

*1.5% Band 7

Accuracy Budget	In-Flight Infrared Radiance (%)	Band 20 In-Flight Infrared Radiance (%)	Bands 31,32 In-Flight Infrared Radiance (%)
Transfer to NIST	0	0	0
Source	0.45	0.45	0.16
BB Temp	0.44	0.44	0.16
BB Emiss*	0.40	0.40	0.40
Inst. Emiss*	0.36	0.34	0.36
Direct Solar	0.00	0.00	0.00
Indir Solar	0.00	0.00	0.00
Earthshine	0.05	0.07	0.00
*Correlated			
MODIS	0.89	0.59	0.47
SNR	0.25	0.05	0.02
Linearity	0.20	0.20	0.20
Crosstalk	0.35	0.20	0.30
WL Shift	0.49	0.08	0.02
OOB	0.36	0.31	0.02
Polarization	0.00	0.00	0.00
SM Scatter	0.01	0.01	0.02
Ghost/Stray	0.45	0.40	0.30
RSS Total	1.00	0.74	0.50
Requirement	1.00	0.75	0.50
Margin	0.00	0.01	0.00

*Correlated

SCAN MIRROR TEMPERATURE KNOWLEDGE REQUIREMENT: ≤ 1K

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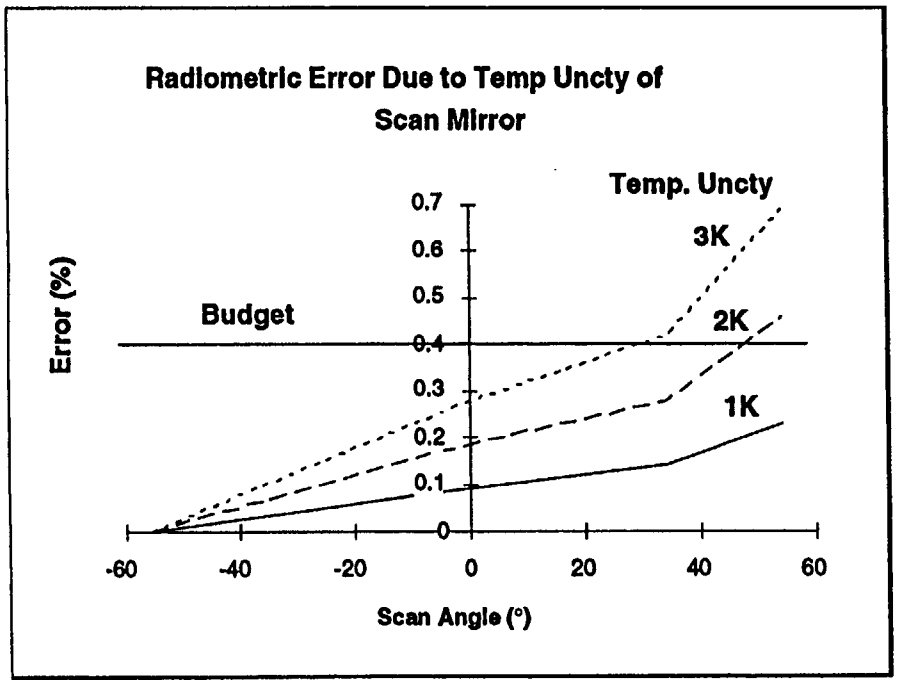
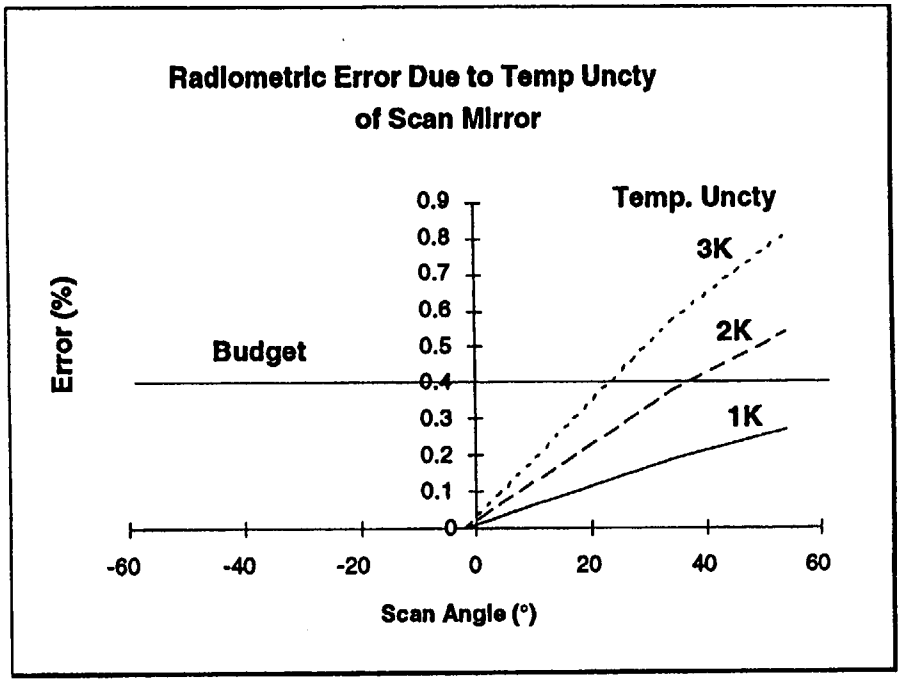
- Dip in mirror reflectance at 8.55 0 9.7 μm
- Radiometric error due to emission depends on temperature knowledge

Band 29



Band 30



- Scan mirror temperature contributions to all other bands are negligible

PFM SCAN MIRROR TEMPERATURE SENSOR DESIGN COMPLETE

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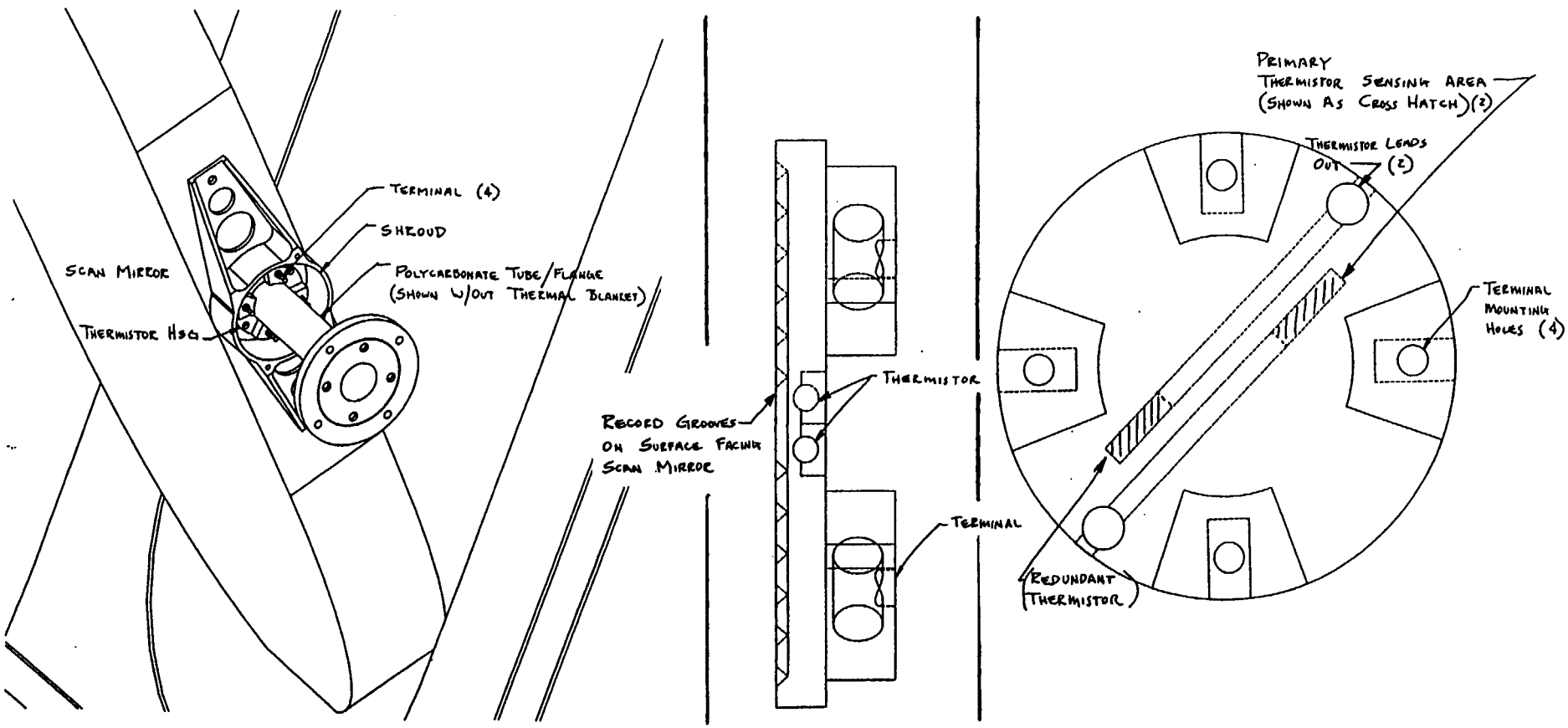
- Approach uses radiative coupling to scan mirror edge
- Thermal and structural analyses have determined that design will meet requirements



REFLECTIVE BANDS MEET REFLECTANCE ACCURACY REQUIREMENTS

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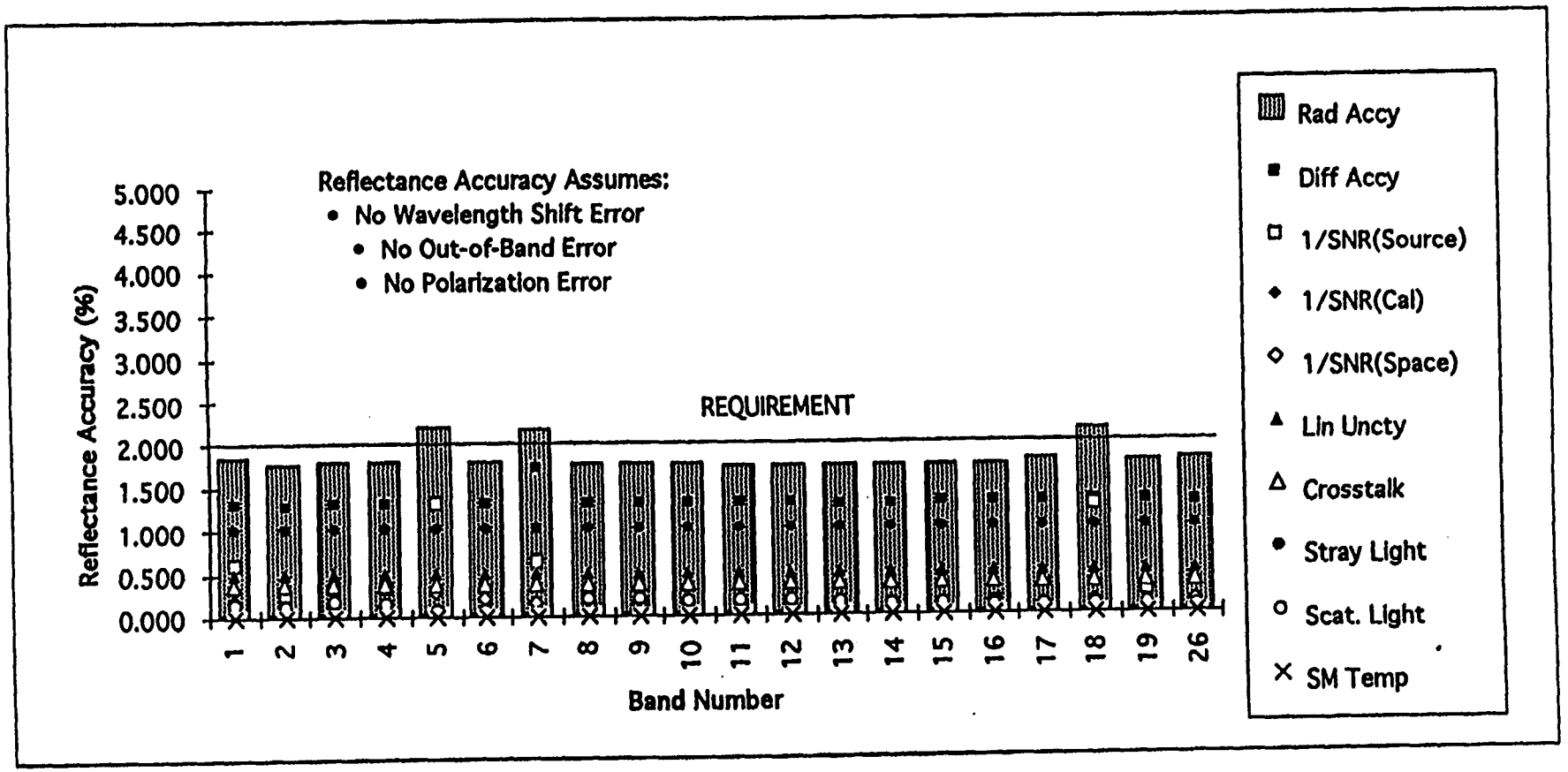

- SINGLE SAMPLE SHOWN TO DEMONSTRATE HIGH PERFORMANCE
- BANDS 5,7, AND 18 MEET SPEC FOR MULTIPLE SAMPLES (SNR ERROR GOES TO ZERO)

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93-0868-140

EMISSIVE BANDS MEET RADIOMETRIC ACCURACY REQUIREMENTS

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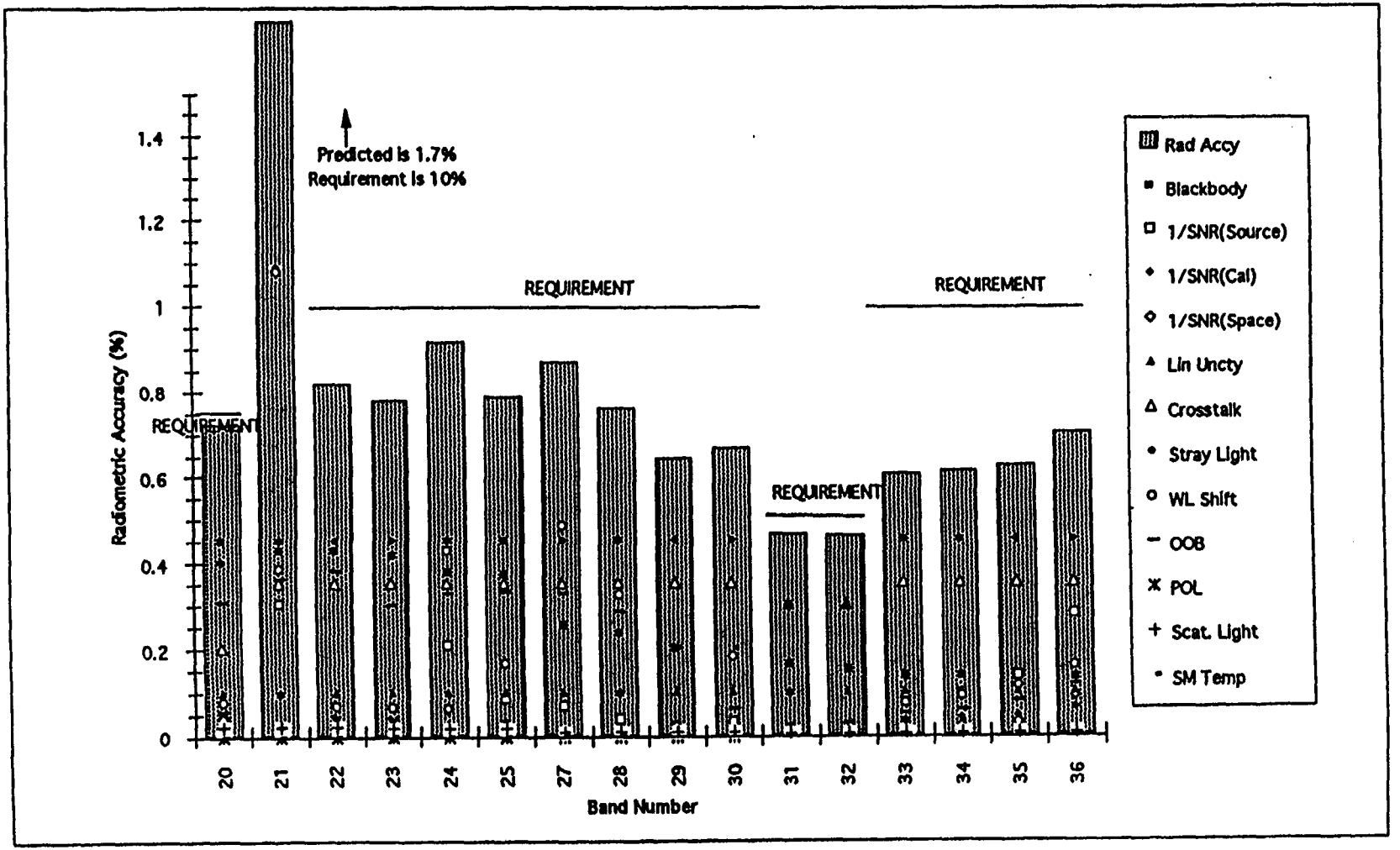

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PRE-FLIGHT RADIOMETRIC AND REFLECTANCE ACCURACY BUDGETS

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REFLECTIVE BANDS	Pre-Flight 1-19,26 Radiance	Pre-Flight 1-19,26 Reflectance
Accuracy Budget	(%)	(%)
SIS (100)		
Irrad/Rad Standard	0.50	0.50
Transfer to Working Std	1.00	0.50
Standard Lamp Usage	1.69	0.00
Orientation	0.30	0.00
Diffuser to Lamp	0.50	0.00
Current	0.50	0.00
Linearity	1.50	0.00
Halon Diffuser	0.50	0.50
Monochromator	1.76	1.26
Scattered Light	1.00	1.00
WL Calibration	0.30	0.30
Nonuniformity	1.00	0.50
Geometric Error	1.00	0.50
SIS	0.71	0.00
Current Control	0.50	0.00
Nonuniformity	0.50	0.00
MODIS	2.28	1.22
SNR	0.50	0.30
Linearity	0.50	0.50
Crosstalk	0.50	0.50
WL Shift	1.00	0.00
OOB	1.24	0.00
Polarization	1.00	0.00
SM Scatter	0.80	0.80
Stray Light	0.50	0.50
RSS Total	3.62	1.95
Requirement	5.00	2.00
Margin	1.38	0.05

EMISSIVE BANDS	Pre-Flight Infrared Radiance	Pre-Flight Band 20 Radiance	Pre-Flight Bands 31,32 Radiance
Accuracy Budget	(%)	(%)	(%)
BCS			
BB Temp	0.42	0.42	0.15
BB Emiss	0.10	0.10	0.10
MODIS	0.55	0.27	0.18
SNR	0.25	0.05	0.02
Linearity	0.10	0.10	0.10
Crosstalk	0.10	0.10	0.10
WL Shift	0.40	0.08	0.02
OOB	0.15	0.05	0.01
Polarization	0.00	0.00	0.00
SM Scatter	0.01	0.01	0.02
Stray Light	0.20	0.20	0.10
RSS Total	0.70	0.51	0.25
Requirement	1.00	0.75	0.50
Margin	0.08	-0.03	0.00

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RAW RADIOMETRIC DATA SHOWS WIDE VARIABILITY WITH TEMP

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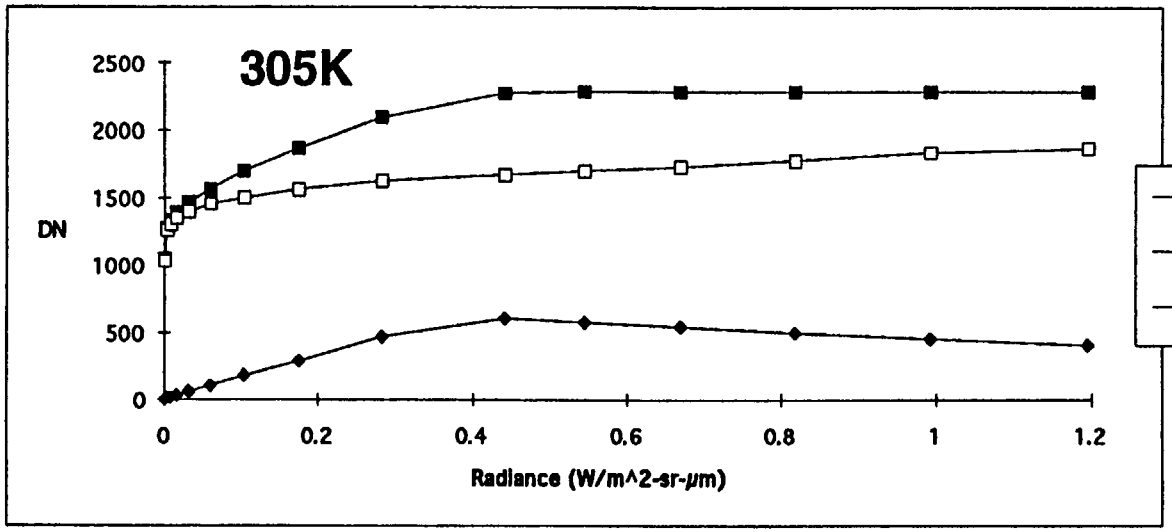

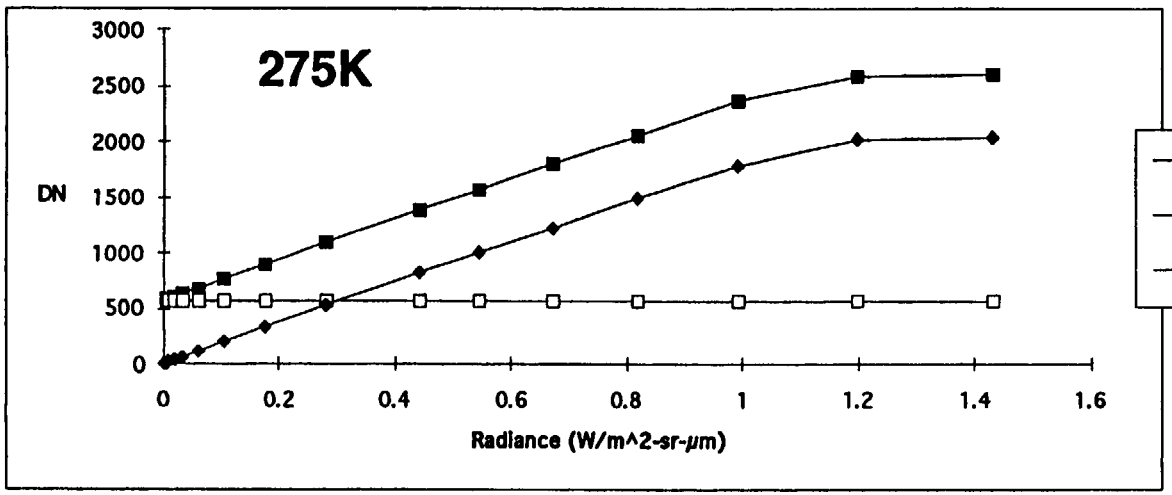

Band 22, Worst Case

- **305K Calibration data affected by baseline drift**
- **275K data OK**

REFERRING BACK TO FPA OUTPUT REVEALS MASTER CURVE

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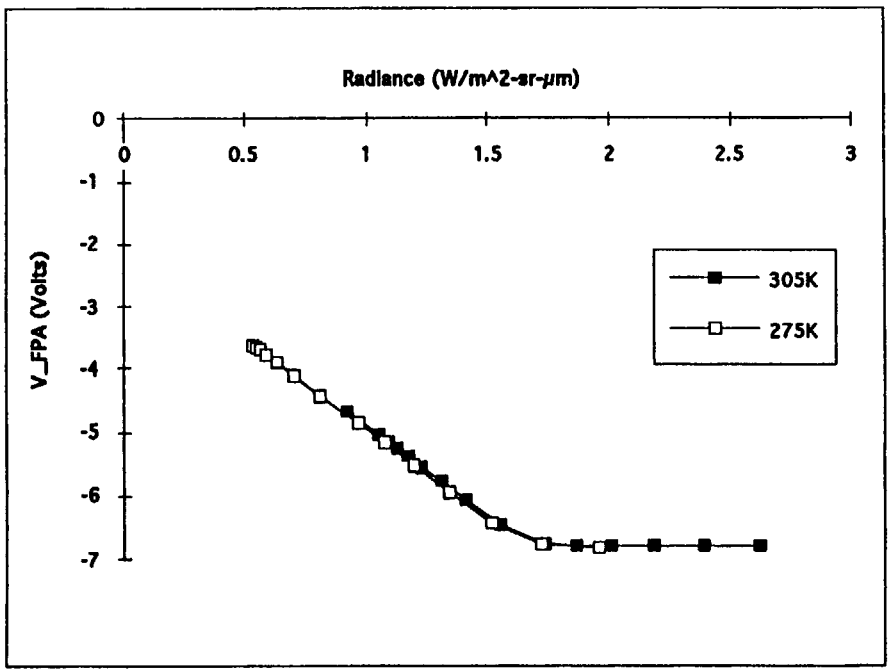
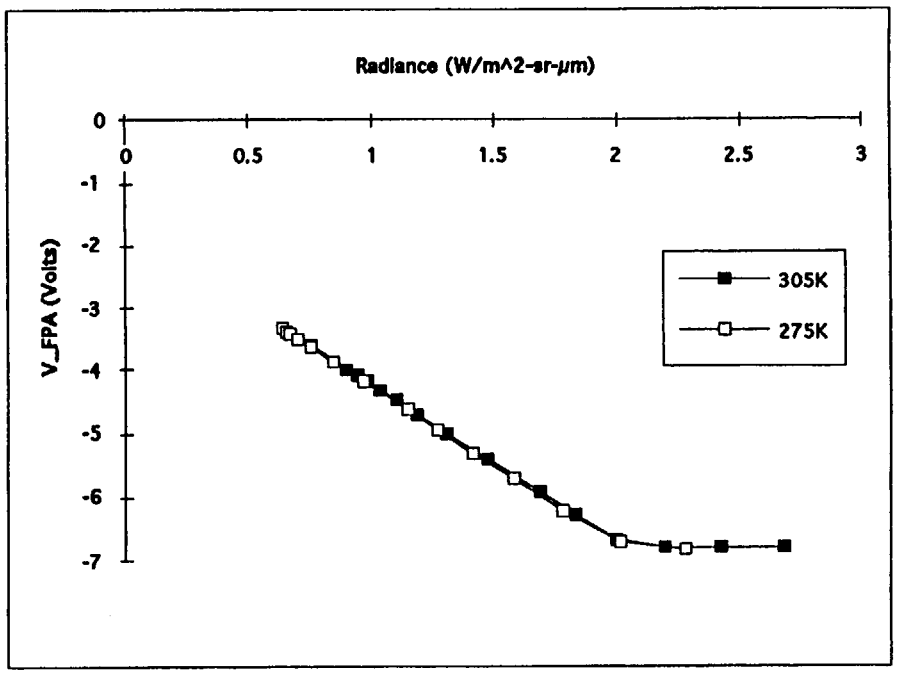
Band 22



Band 23



- Method reveals master curve invariant with temperature
- Curves generally linear to saturation; small second order terms
- Method accurately predicts point of saturation

LINEARITY
SAMPLE BANDS, ONE ACQUISITION

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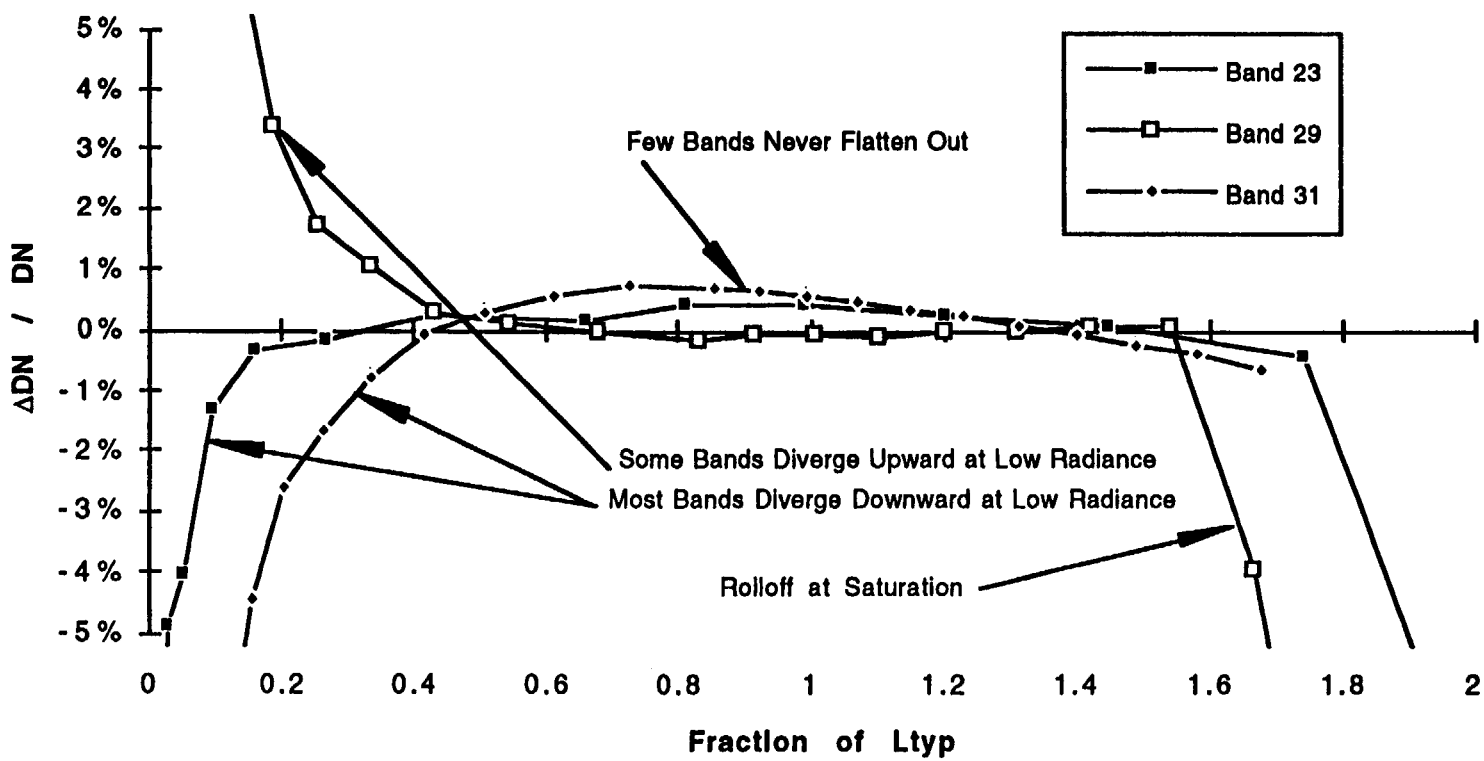
Linearity on Sample Bands, UAID 452 (TV @ 275°K), Channel 6



LINEARITY
ONE CHANNEL, SEVERAL ACQUISITIONS

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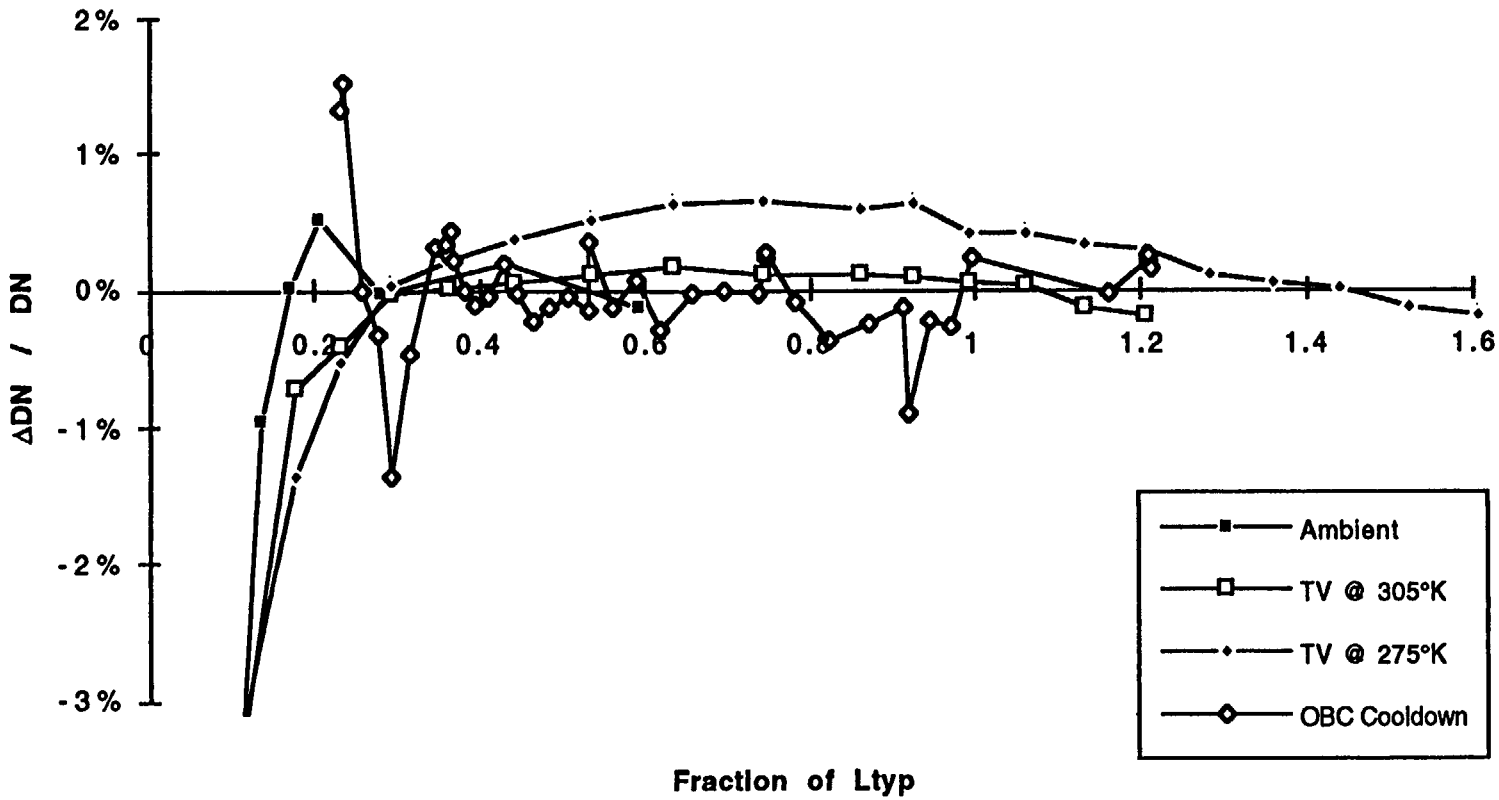
Band 32, Channel 6



MTF AND MISREGISTRATION PRODUCE RADIOMETRIC ERROR

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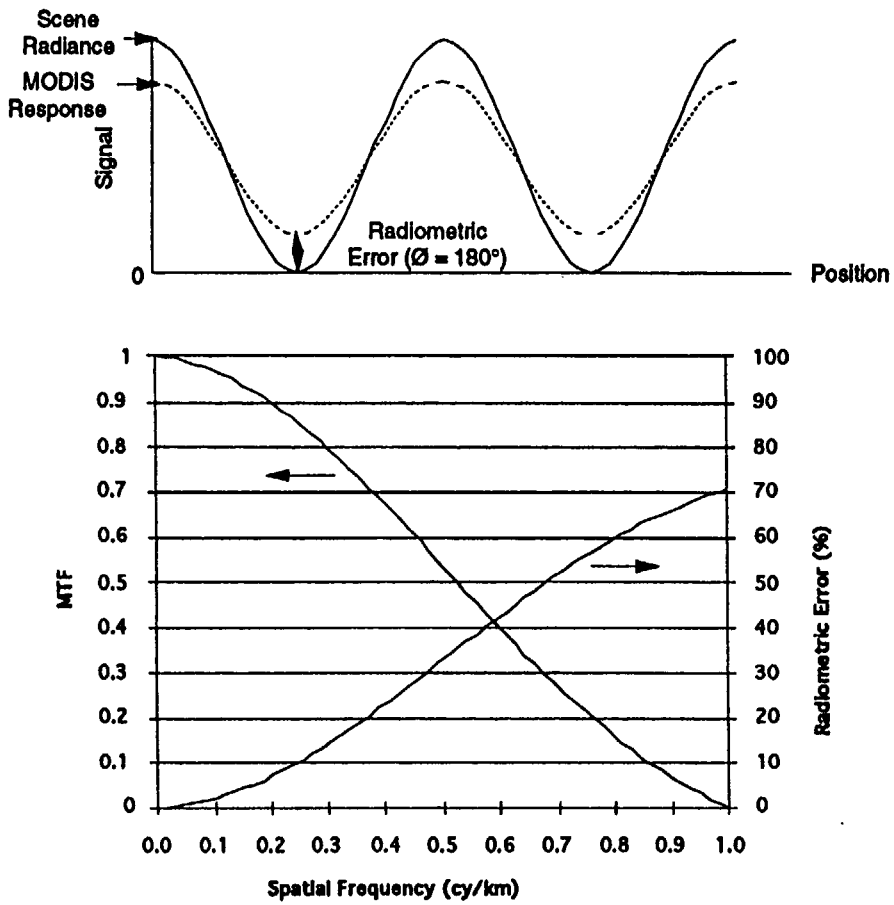
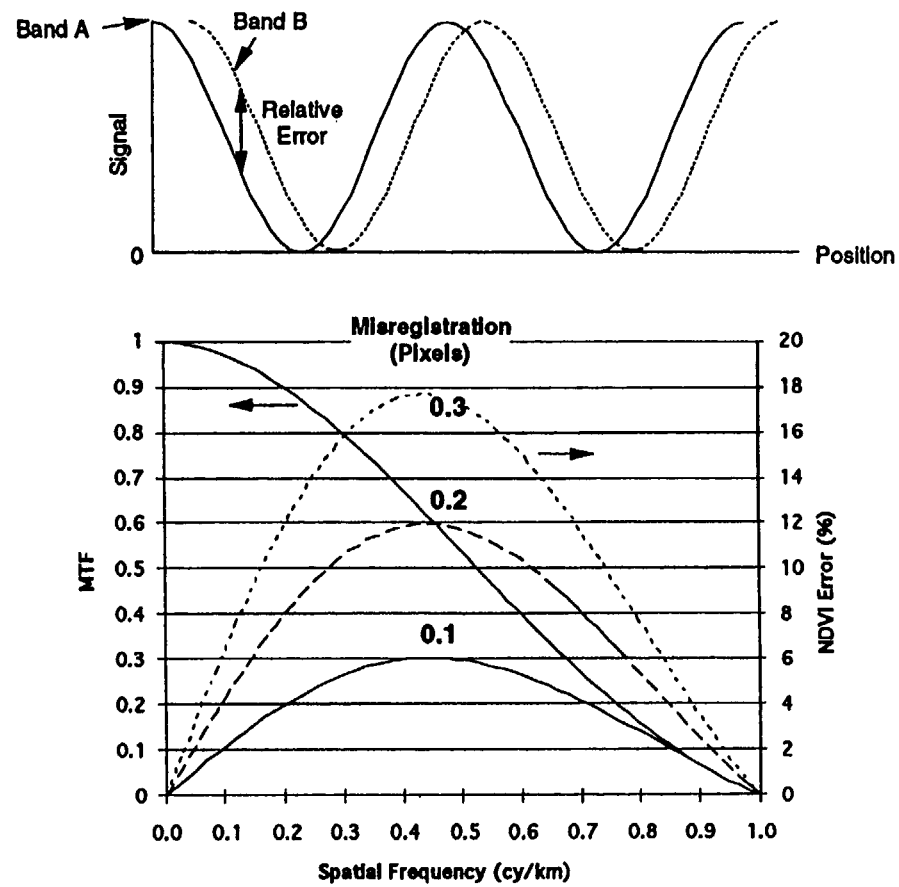
- SENSOR RESPONSE (MTF) RESULTS IN RADIOMETRIC ERROR



- MISREGISTRATION RESULTS IN NDVI TYPE ERROR



- MTF Registration and Radiometric Accuracy: PL3095-N01370

Radiometric Stability

Tom Pagano

STEPS TAKEN TO ENSURE RADIOMETRIC STABILITY MAINTAINED

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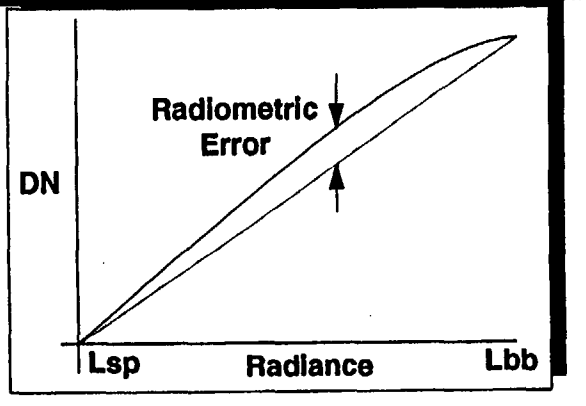
- Uncertainty in Transfer Curve Shape Leads to Radiometric Error



- Source Stability: 0.05%: 151868
- Measurement SNR: ≥ 1000: 151868
- Number of Samples > 5: 151868
- Nonlinearity ≤ 5%: 151771
  Transfer Curve Calibration: PL3095-M03082

0.2 %*
Curve Shape Knowledge

*0.5% VIS, NIR, SWIR

0.18 %	0.05 %	0.05 %	0.05 %
Pre-Flight Measurement	Detector Stability	Electronics Stability	Margin

(See Next Viewgraph)

DETECTOR THROUGH ELECTRONICS STABILITY ADDRESSED

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- **Detector Stability Through Temperature Control**
- **Electronics Stability Through Calibration & Telemetry**

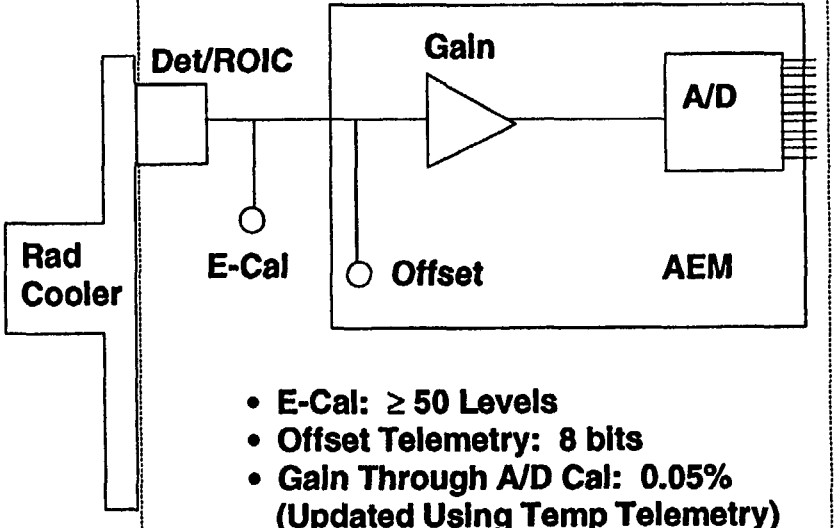
PC TEMP SENSITIVITY DATA DETERMINES COOLER REQUIREMENTS

Wafe	Temp 80 R (kv/W)	Temp 85 R (kv/W)	Temp 88 R (kv/W)	dR/dT	(dR/dT) / Rav	ΔR/ΔT ±0.2K
P4-443-1 A5		14.4	10.4	-1.333	-10.75%	-4.30%
P6-668-1 A11		36.5	24.3	-4.067	-13.38%	-5.35%
[illegible]969-1 A11		48.7	37.8	-3.633	-8.40%	-3.36%
[illegible]65-1-C10	74.8		46.1	-3.588	-5.93%	-2.37%
			Mean	-3.156	-9.62%	-3.85%
			StDev	1.234	3.19%	1.27%

FOR 0.05% RADIOMETRIC ERROR

- **COLD FPA TEMP STABILITY REQUIREMENTS:**
  ± 3.7 mk / 1.477 s FOR WORST CASE DETECTOR

- **ORBITAL FLUCTUATIONS PREDICTED**
  ±0.68 mK / 1.477 s



- E-Cal: ≥ 50 Levels
- Offset Telemetry: 8 bits
- Gain Through A/D Cal: 0.05% (Updated Using Temp Telemetry)

Temperature Stability Requirements for Cold FPA: Spec 151779 & PL3095-M02173
Cal Ramp Requirements: Spec 151780 & PL3095-M02262
Electronics Gain & Offset Requirements: Spec 151783, 151784, & PL3095-M03082

STABILITY OF RADIOMETRIC RESPONSE

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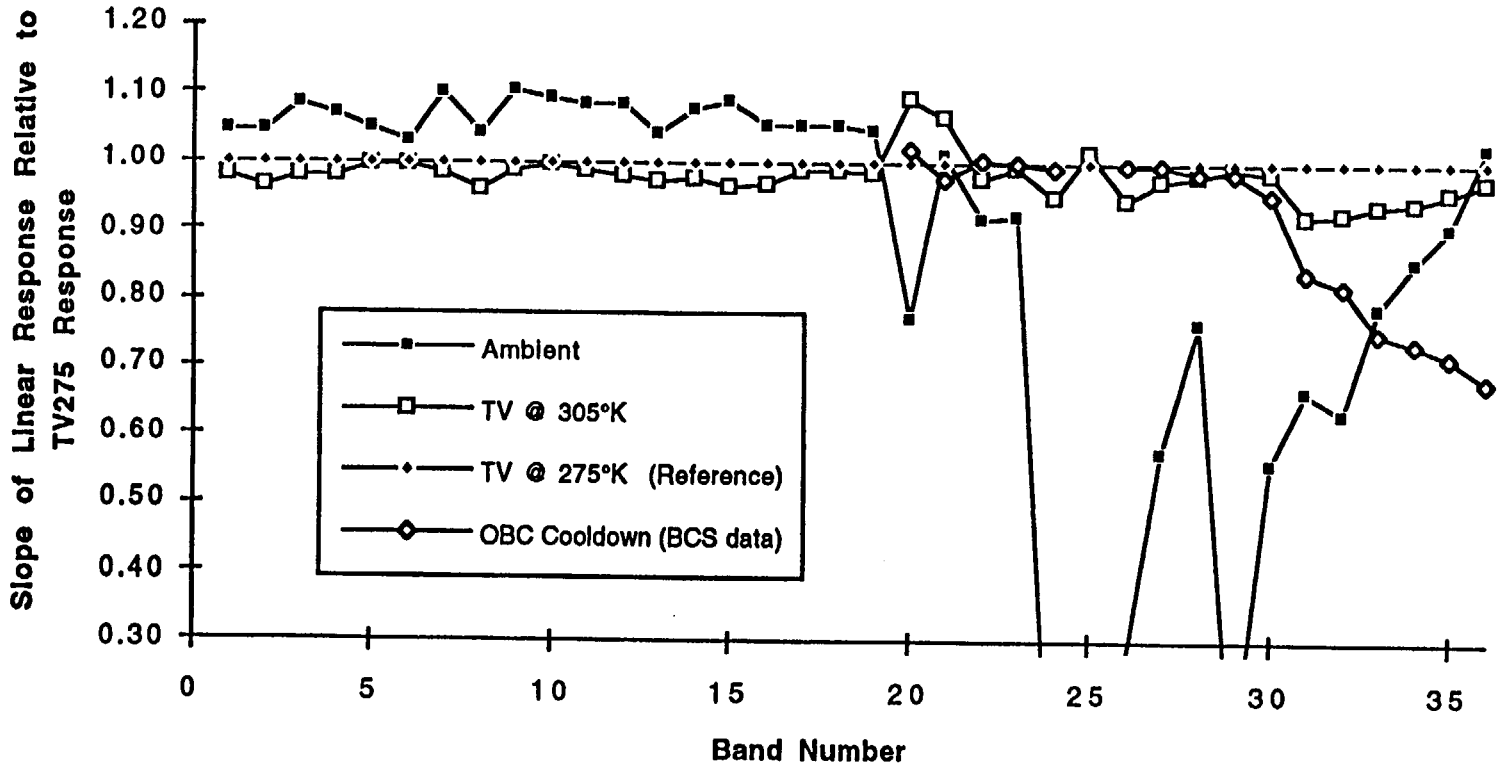

Polarization Insensitivity

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TOPICS

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- PSA functional diagram
- PSA measurement methodology- PFM
- Polarization measurements
  - PSA characterization
  - Polarization modeling
  - EM raw data curves
- Observed polarization measurement anomalies - EM
- Linear drift anomaly
  - Vignetting model
  - Vignetting model output
  - Experimental verification methodology

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PSA FUNCTIONAL BLOCK DIAGRAM

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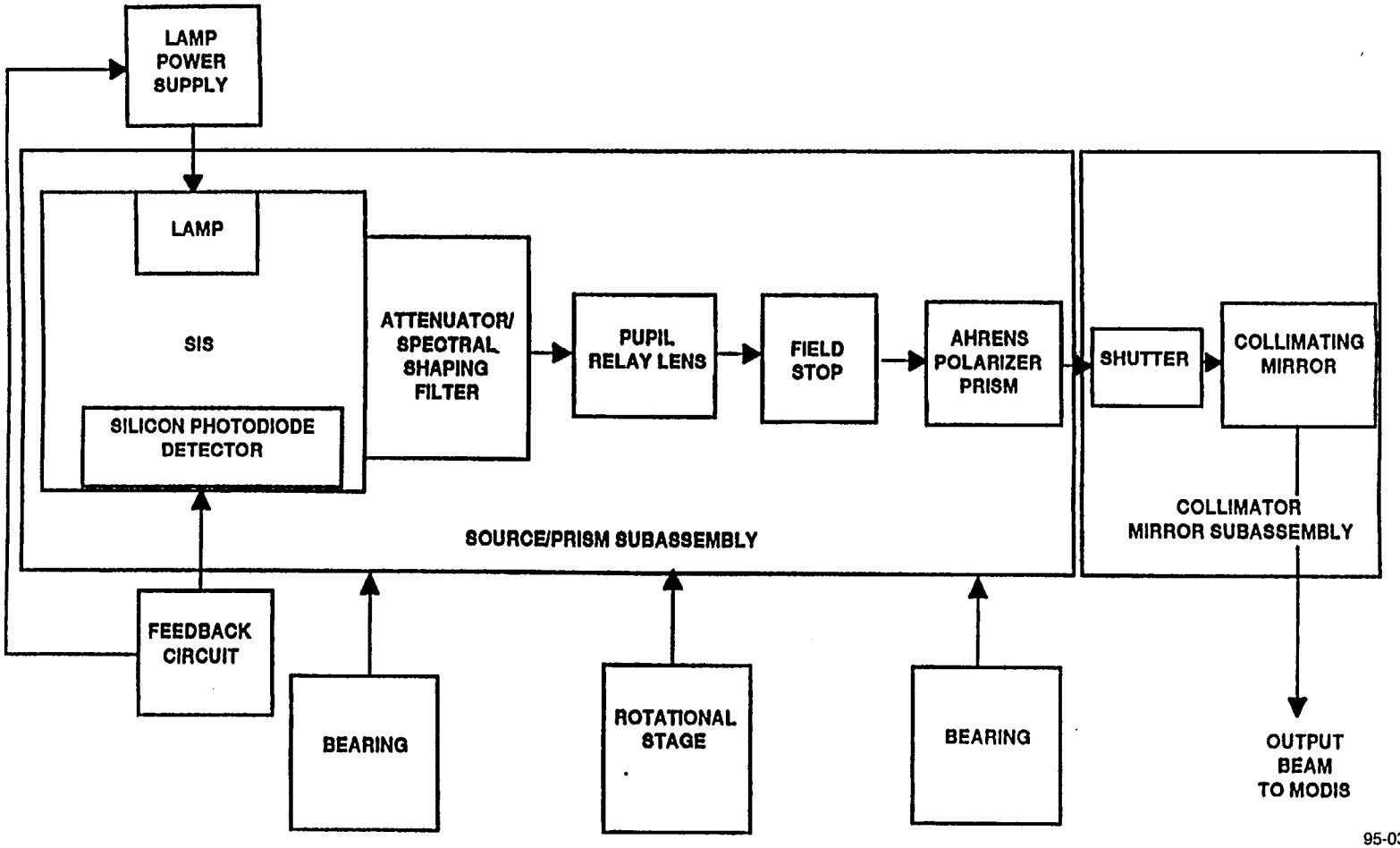

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MODIS - PSA ALIGNMENT CONFIGURATIONS

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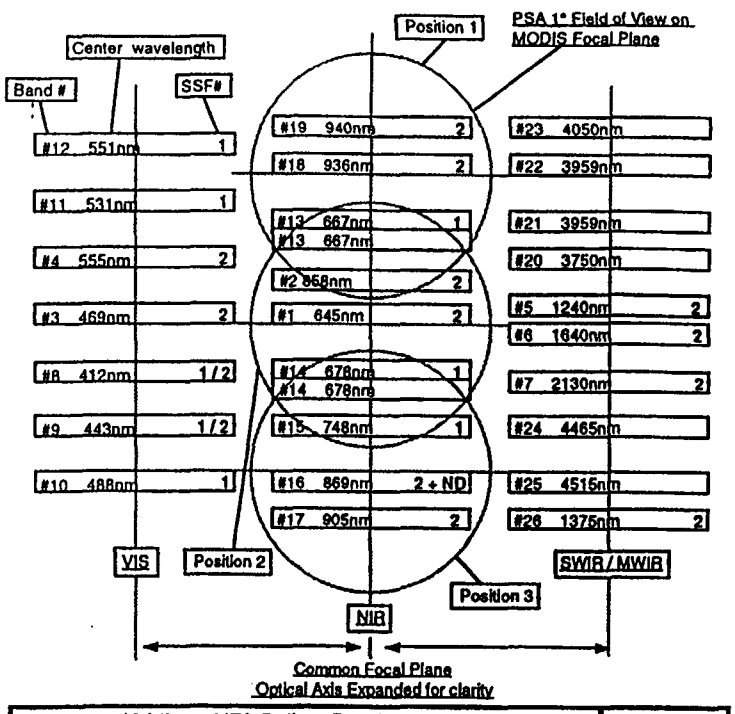
PSA 3 Position Option



Position 1 (SSF 1 + ND) Collect Bands 11, 12, 13 Position 1 (SSF 2 + ND) Collect bands 4, 18, 19,	Acquision Group 1
Position 2 (SSF 1 + ND) Collect Bands 8, 14 Position 2 (SSF 2 + ND) Collect bands 1, 2, 3, 4, 5, 6, 7, 8	Acquision Group 1
Position 3 (SSF 1 + ND) Collect Bands 9, 10, 15 Position 3 (SSF 2 + ND) Collect bands 9, 16, 17, 26	Acquision Group 5

Figure 3.3

PSA 1° field fully illuminates all reflectance bands and channels

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POLARIZATION CHARACTERIZATION OF THE PSA

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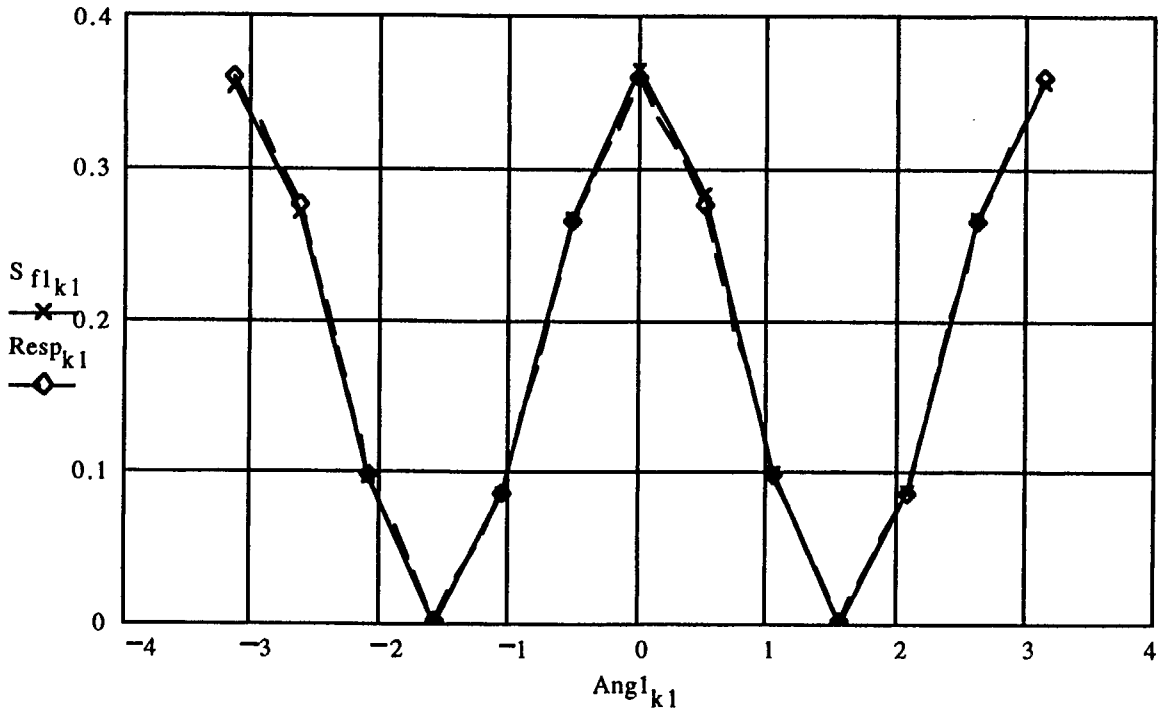
- The SBRC polarimeter ≈ 0.35 inch diameter and a large acceptance field angle (>1°)
- The polarization performance was uniform across its aperture within ± 0.99
- The entire PSA illumination field was accepted by the polarimeter
- Polarization performance measured at: 420, 500, 800, 1300, and 2100 nm
- Note symmetry of measurement 0° to 180° is almost identical to 180° to 360°



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SIMULATION OF POLARIZATION MEASUREMENT WITH NOISE

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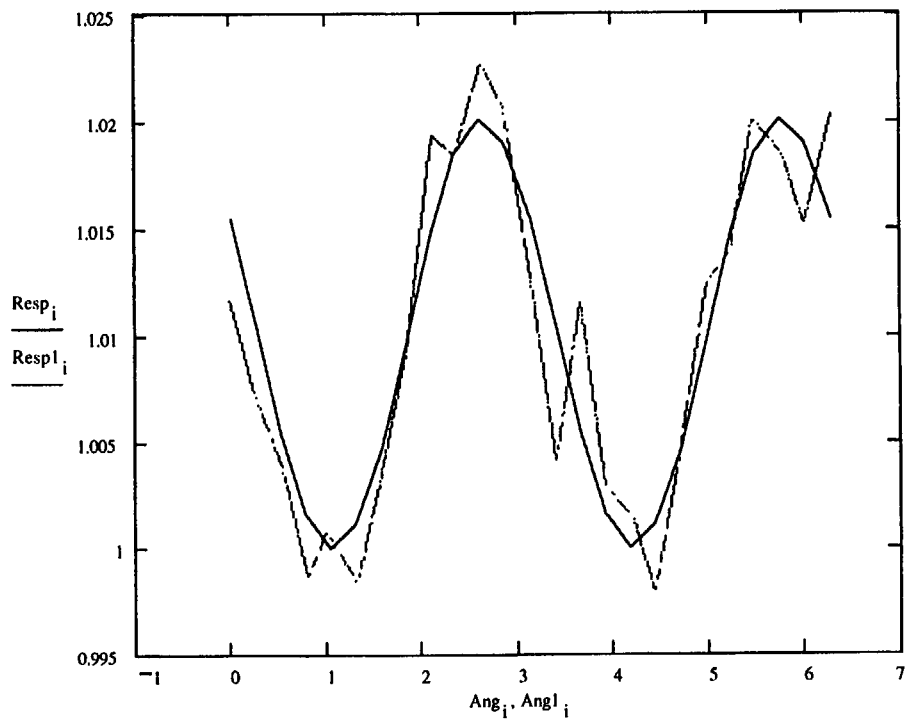
- Illustration of the simulated MODIS data sets (noisy data) and the function using the fitted parameters: K1, Ampl1, and Ph1.



- Retrieved polarization factor retrieval uncertainty. $\Delta P := \frac{\sqrt{2}}{\sqrt{N_{ang} \cdot SNR}}$

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TYPICAL POLARIZATION RESPONSE: RAW DATA AVERAGED OVER 5 SCANS: -45°

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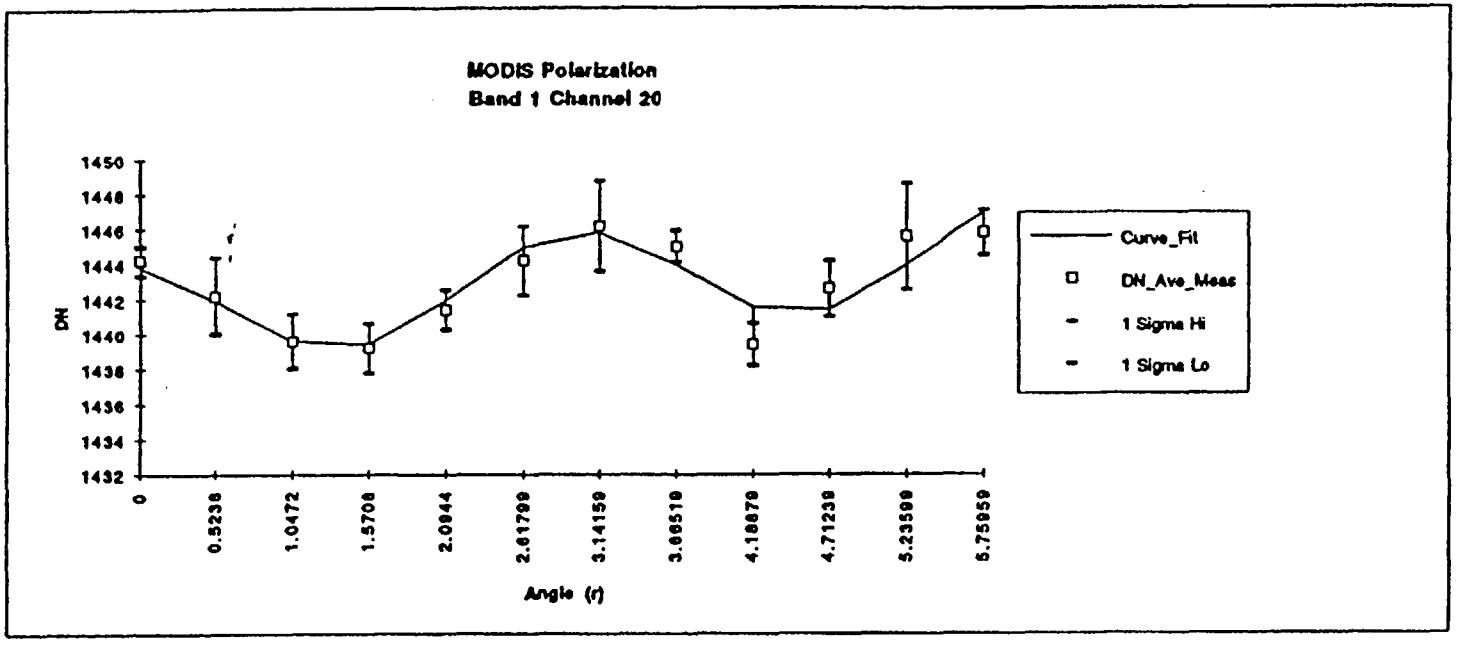

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TYPICAL POLARIZATION RESPONSE: RAW DATA AVERAGED OVER 5 SCANS: -45° (CONT'D)

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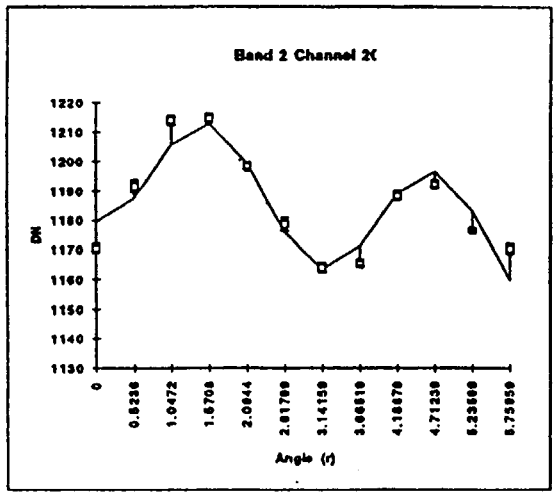

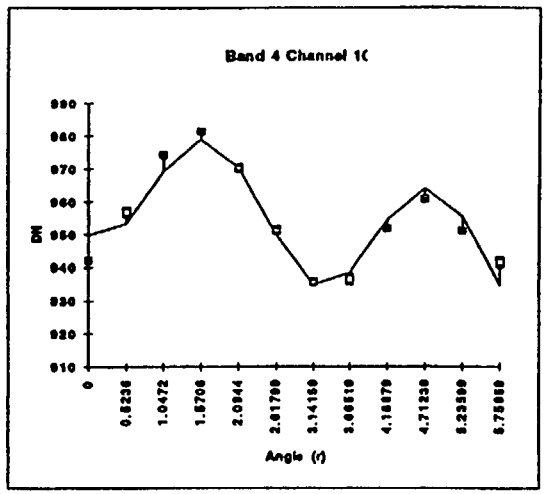

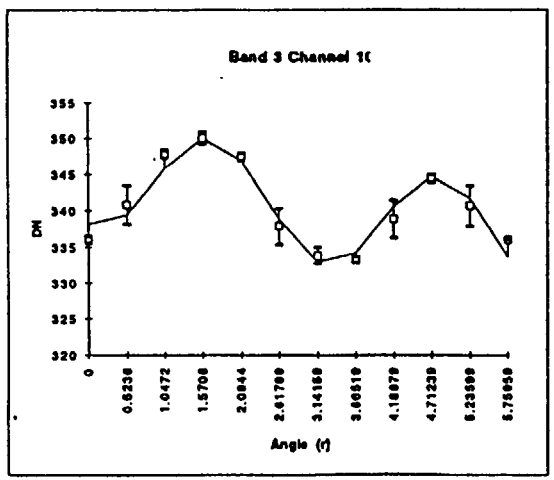

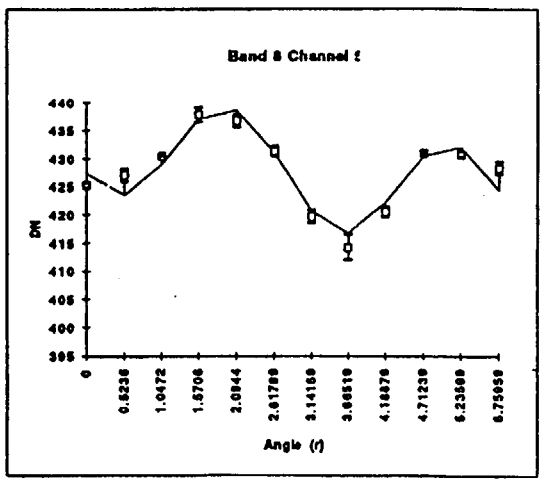

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POLARIZATION MEASUREMENT ANOMALIES

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- Observed phenomena
  - Irregular cosine squared fit
  - High noise
  - Linear drift with polarization angle
- Potential sources of anomalies
  - 260 Hz noise
  - Frame jitter (minimal effect)
  - PSA field nonuniformity
  - PSA/MODIS vignetting
  - PSA lamp output variation
- Potential causes of anomalies
  - Electronics
  - PSA field nonuniformity
  - PSA/MODIS optical misalignment
  - PSA optical feedback not operating properly

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SIMULATION OF PSA/MODIS LINEAR DRIFT ANOMALY

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First Order Aperture Vignetting Model

- Define PSA axis via field stop and aperature stop centers
- Define PSA rotational axis relative to PSA axis
- PSA rotational axis offset relative to field stop center
- Project PSA aperture via collimating mirror onto MODIS entrance aperture
- Calculate common area of projected PSA aperture and MODIS entrance aperture as a function of PSA rotation -180° to +180°

Results from Vignetting Model Usage

- Model usage demonstrated feasibility of obtaining a linear drift as a function of rotational angle
- Linear drift required an angle between PSA and rotational axes
- When axes were parallel the variation was "sinusoidal"
- One set of EM polarization measurements had a linear drift and the second set with a different optical alignment was sinusoidal

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EXPERIMENTAL VERIFICATION OF VIGNETTING MODEL

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Measurement Configuration I

- View of PSA with alignment telescope (AT)
- Align AT axis to be coincident with PSA
- Rotate PSA polarizer assembly through -180° to +180°
- Track center of the SIS aperture
- Offset PSA field repeat polarizer assembly rotation
- Input data set into Mathcad first order vignetting model

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EXPERIMENTAL VERIFICATION OF VIGNETTING MODEL (CONT'D)

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Measurement Configuration II

- View PSA with IAC
- PSA is the radiant energy source and IAC the receiving radiometer
- Locate 1.4 mr field stop at IAC focal plane
- Use SiPD or PMT behind the field stop
- Ideal distance between PSA and IAC the same as PSA to MODIS
- Mask IAC collimating mirror to 7.00 diameter
- Align PSA and IAC apertures and IAC central obscuration
- Record detector signals as a function of PSA rotational angle, -180° to +180°
- The relative alignment of apertures can be translated laterally thru use of IAC pointing mirrors
- This is a vignetting test, not a polarization measurement although the two will be folded together

Measurements from Configuration II may not be needed if Configuration I results are conclusive

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Near Field Response

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NEAR FIELD RESPONSE (NFR)

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- Documentation
- Modeling methodology
- EM fit - degree
- EM NFR performance
- Parametric modeling (VIS / NIR / MWIR / LWIR)
  - Harvey Shack coefficients
  - Aft optics vs cloud edge distance
  - Fore optics vs cloud size and edge distance
- AOA measurement results

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SUMMARY OF NEAR FIELD RESPONSE DOCUMENTATION - PL3095

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- N04855 - EM Performance characterization
  Reqt review, algorithm description, data acquisition, files and reduction
- N04856 - Near Field Response (NFR) Modeling: Part 1
  Overview of data analysis goals / integration methodology
- N04857 - Near Field Response (NFR) Modeling: Part 2
  NFR model description
- N04858 - Near Field Response (NFR) Modeling: Part 3
  Detailed comparison EM VIS / NIR data to modeled and extrapolation to P
- N04859 - Near Field Response (NFR) Modeling: Part 4
  MWIR / LWIR background and gain analysis
- N04860 - Near Field Response (NFR) Modeling: Part 5
  Parametric model variable cloud size and location (in progress)
- N04894 - Near Field Response (NFR) Modeling: Part 6
  Recommended add'l EM MWIR / LWIR thermal vacuum test
- N04945 - Near Field Response (NFR) Modeling: Part 7
  Normalization factors for VIS / NIR regions
- N04998 - Near Field Response (NFR) Modeling: Part 8
  STR 020 SCMA Mirror Bevel Scatter
- N05000 - Near Field Response (NFR) Modeling: Part 9
  STR 034 NFR (T/V) using IAC MWIR/LWIR
- T04825 Description of the SCMA instrumentation

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NFR DATA REDUCTION AND MODELING EQUATIONS

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Equation used in the normalization of the NFR signal data

$$k2 := 1 .. 150 \qquad DDN2_{i,k} := DN2_{(\Delta_i + k)} \qquad DN1p_{i,k2} := \frac{\left(DN1_{\Delta_i + k2} - DN5_{\Delta_i + k2}\right) \cdot \tau_{ndf}}{DDN2_{i,78} + DDN2_{i,79} + DDN2_{i,80}}$$

Scattering source angles: k1 along track and k along scan

(1) $$\theta 2_{k,k1} := \left[\left[k1 - \left(\frac{k1_{max}}{2} + 0.5\right)\right]^2 + (\phi_k)^2\right]^{0.5} \cdot 0.001418 \cdot mag2$$

(2) $$\theta 1_{k,k1} := \left[\left[k1 - \left(\frac{k1_{max}}{2} + 0.5\right)\right]^2 + (\phi_k)^2\right]^{0.5} \cdot 0.001418 \cdot mag1$$

Two component Harvey Shack model: aft optics eqn (3), fore optics eqn (4)

(3) $$\rho 2_{i,k} := \sum_{k1} A2 \cdot \left(\frac{\lambda_{brdf}}{\lambda_{c_i}}\right)^{4 + M2a} \cdot \left(\left|\frac{\sin(-\theta 2_{k,k1} + \phi 2_0) - \sin(\phi 2_0)}{0.01}\right|\right)^{M2} \cdot (0.001418 \cdot mag2)^2$$

(4) $$\rho 1_{i,k} := \sum_{k1} A1 \cdot \left(\frac{\lambda_{brdf}}{\lambda_{c_i}}\right)^{4 + M1a} \cdot \left(\left|\frac{\sin(-\theta 1_{k,k1} + \phi 1_0) - \sin(\phi 1_0)}{0.01}\right|\right)^{M1} \cdot (0.001418 \cdot mag1)^2$$

Combining the aft and fore optics components consistent with field baffle

(5) $$\rho_{i,k} := if((\phi_k - offset_i > \phi_{fb1}) \cdot (\phi_k - offset_i < \phi_{fb2}), \rho 1_{i,k} + \rho 2_{i,k}, \rho 1_{i,k})$$

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EM NFR EXPERIMENTAL TO MODELED COMPARISON

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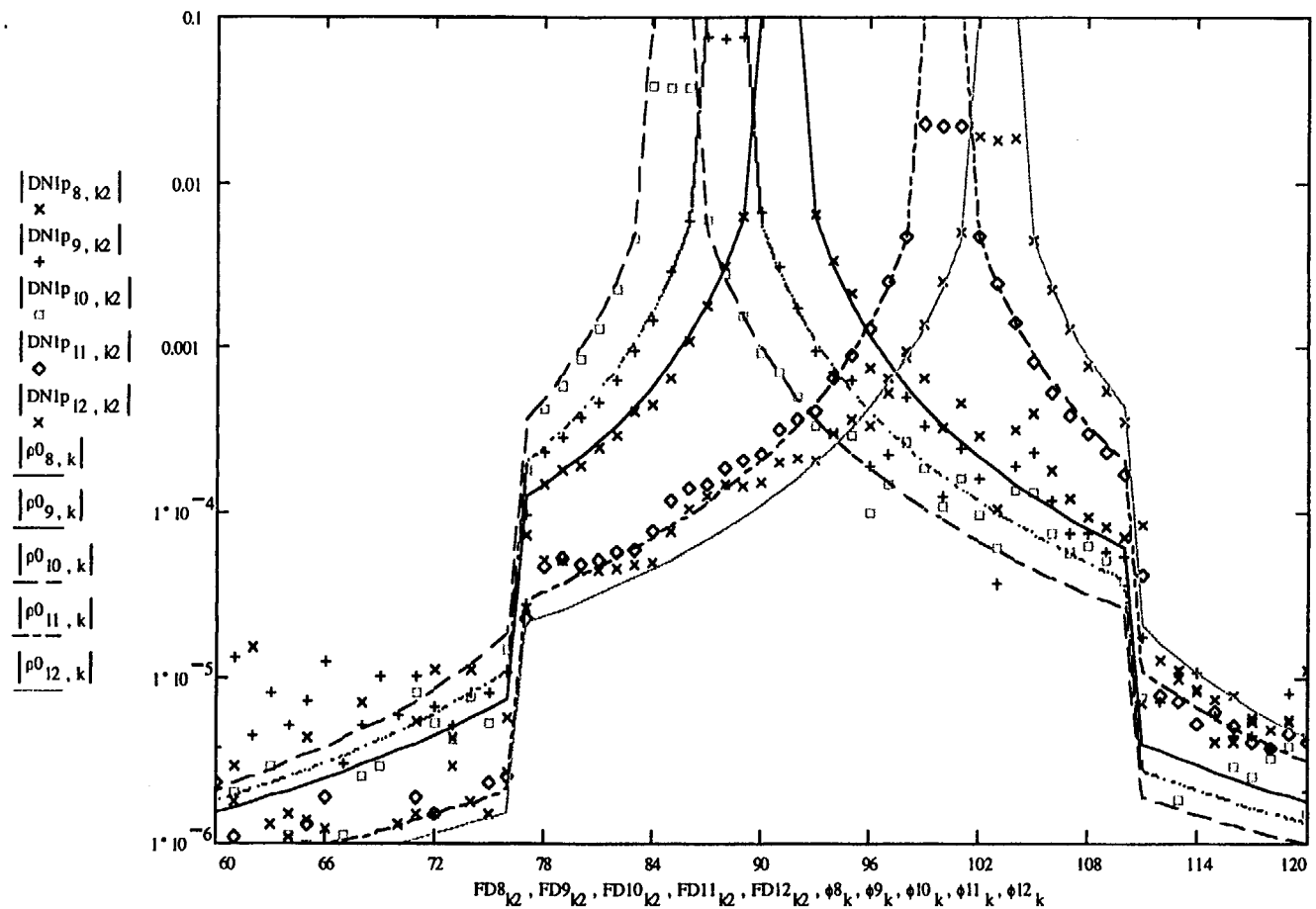

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INTEGRATED NFR 2 KM FROM A 10 × 20 KM CLOUD

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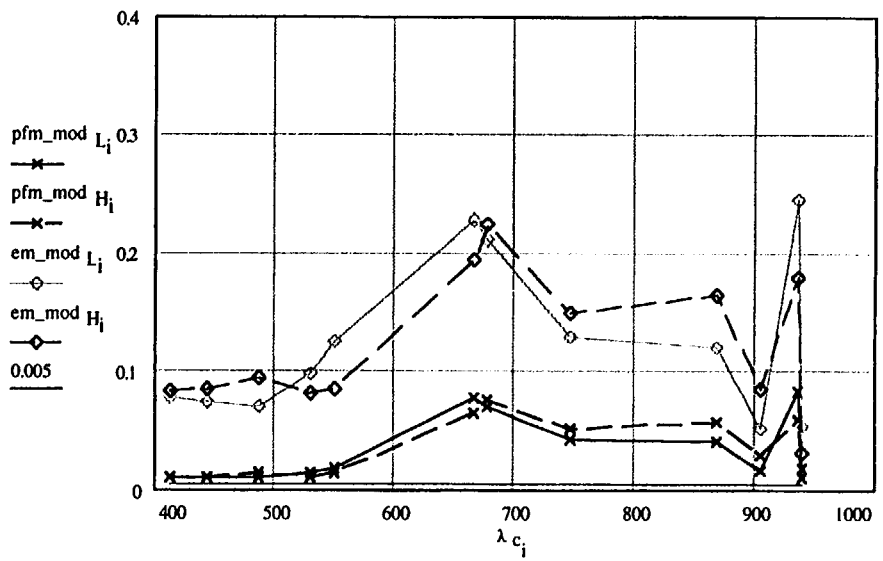
band	EM meas.		EM simulation		PFM simulation	
	low FD	high FD	low FD	high FD	low FD	high FD
8	0.070	0.096	0.078	0.083	0.011	0.012
9	0.064	0.092	0.074	0.086	0.011	0.012
10	0.056	0.104	0.070	0.095	0.011	0.014
11	0.103	0.076	0.099	0.082	0.014	0.012
12	0.135	0.078	0.125	0.085	0.018	0.014
13	0.275	0.243	0.227	0.195	0.078	0.065
14	0.265	0.316	0.211	0.224	0.071	0.076
15	0.142	0.221	0.129	0.150	0.043	0.051
16	0.110	0.181	0.121	0.164	0.040	0.057
17	0.049	0.102	0.051	0.086	0.017	0.030
18	0.064	0.186	0.245	0.180	0.084	0.059
19	0.018	0.037	0.054	0.032	0.018	0.011



- Values normalized to Ltypical
- Spec - 0.005 Ltypical
- PFM values based upon replacement of dichroic 1 only

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PARAMETER STUDY OF MODIS PROTOFLIGHT NFR

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Two Harvey Shack models based upon fitting EM data and extrapolating to PFM

All VIS and NIR 1 km bands used in study.

Aft optics configurations:

- Bands 8 through 19
- Three channels used: 1, 5.5 and 10
- Five cloud edge distances: 3, 5, 7, 9, and 11 km
- Four illumination configurations: cloud source west, north, east, and south of the receiving pixel
- Cloud size fills field baffle consistent with edge distance and location
- NIR element # 2 cases: ZnSe used and replaced

Cases with ZnSe element covered in PL3095-N04860:

- Total individual cases is 1440.

Fore optics configurations:

- Bands 8 through 19
- Three channels used: 1, 5.5 and 10
- Five cloud edge distances: 3, 5, 7, 9, and 11 km
- Cloud size: 20 km through 120 km in steps of 20 km

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MODIFIED HARVEY SHACK MODEL PARAMETERS USED TO EXTRAPOLATE THE EM MODEL TO PFM NFR PERFORMANCE

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Region	Fore optics			Aft optics			
	Parameter	EM	PFM-1/2	Parameter	EM	PFM-1	PFM-2
VIS	A1	0.8	0.8	A2	30.0	1.5	1.5
	M1	-2.2	-2.2	M2	-2.4	-2.0	-2.0
	M1a	-3.0	-3.0	M2a	-3.0	-3.0	-3.0
NIR	A1	0.8	0.8	A2	34.0	6.0	2.4
	M1	-2.2	-2.2	M2	-2.4	-2.0	-2.0
	M1a	-3.0	-3.0	M2a	-3.0	-3.0	-3.0
MWIR LWIR	A1	2.0	2.0	A2	10	10	
	M1	-2.2	-2.2	M2	-2.4	-2.4	
	M1a			M2a			

Harvey Shack parameters for contamination:
Level 300 : A = 0.2; M = -2.24
Level 450 : A = 1.0; M = -1.87

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AFT OPTICS NFR DEPENDENCY UPON ZnSe ELEMENT

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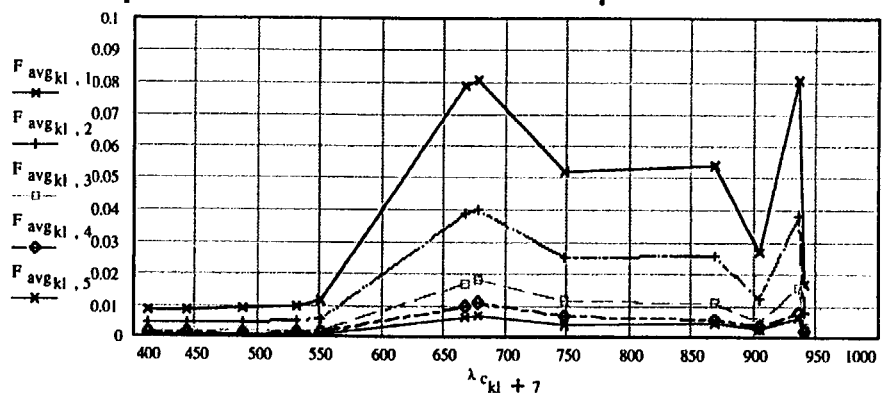
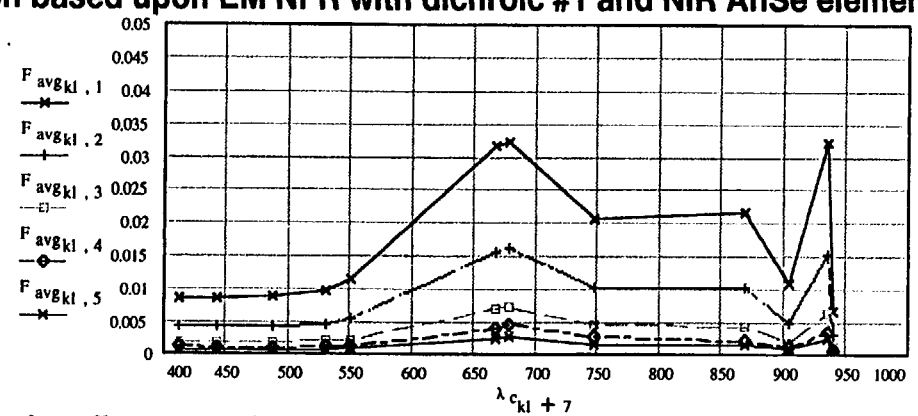
Prediction based upon EM NFR with dichroic #1 replaced



Prediction based upon EM NFR with dichroic #1 and NIR AnSe element replaced



- **Cloud edge distances: 3 km to 11 km in steps of 2 km**
- **Configurations: west, north, east, and south averaged; channel 5.5 used**

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FORE OPTICS NFR 120 KM AND 20 KM ILLUMINATING CLOUD

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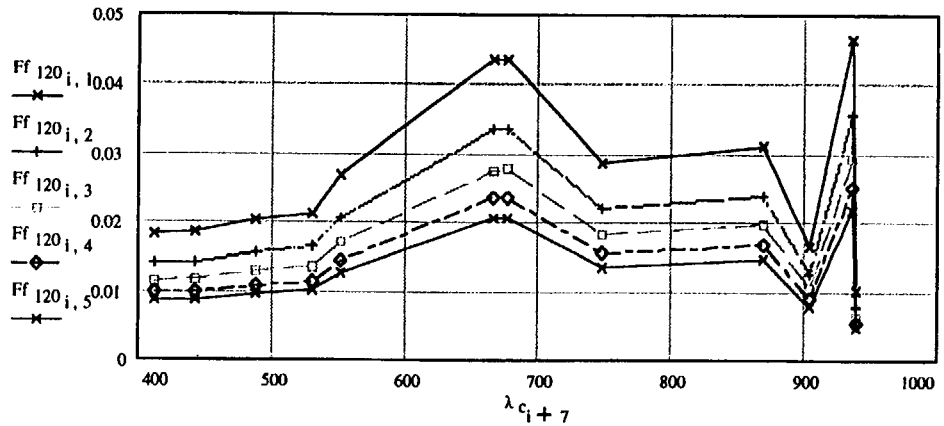

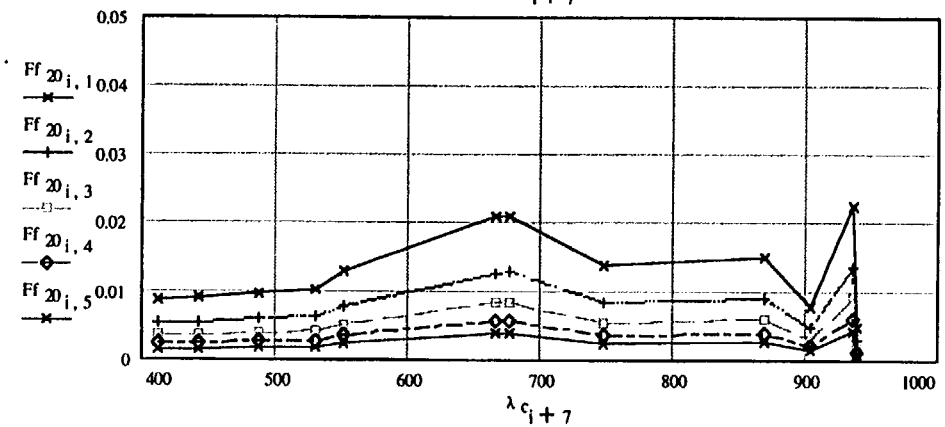

- Illuminating cloud: 120 km × 120 km and 20 km × 20 km
- Cloud edge distances: 3 km to 11 km in steps of 2 km

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RELATIONSHIPS BETWEEN NEΔL, L_{Cloud}, and L_{TYP}

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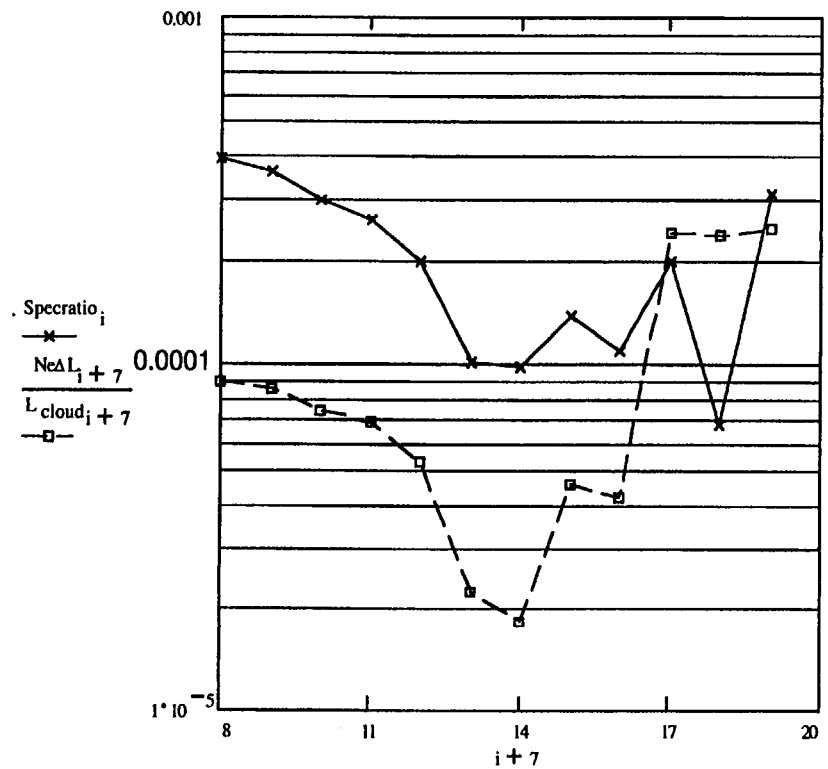
$i := 1 .. 12$ $\qquad$ $Specratio_i := \dfrac{0.005 \cdot L_{typ_{i+7}}}{L_{cloud_{i+7}}}$



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FORE OPTICS NFR LESS THAN 0.01 L_{TYP}

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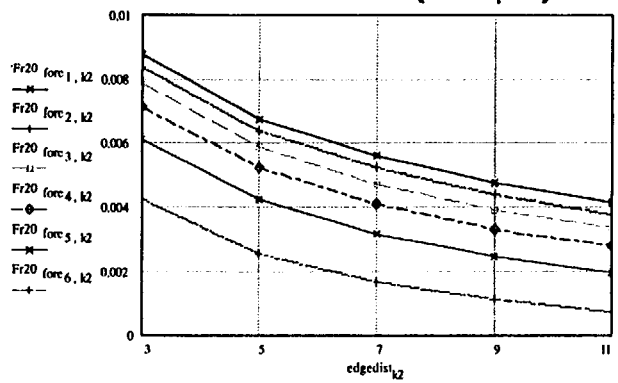
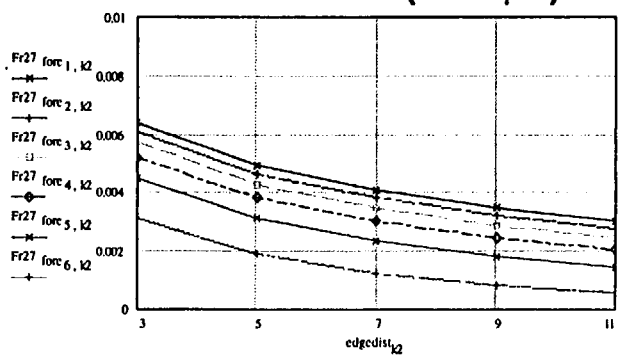
MWIR Band 20 (3.75 μm)



LWIR Band 27 (6.715 μm)



- Edge distance: 3 km to 11 km in steps of 2 km
- Lmax scene size: 120 km to 20 km in steps of 20 km
- EM NFR data used to generate Harvey Shack parameters

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AFT OPTICS NFR LESS THAN 0.01 L_{TYP}

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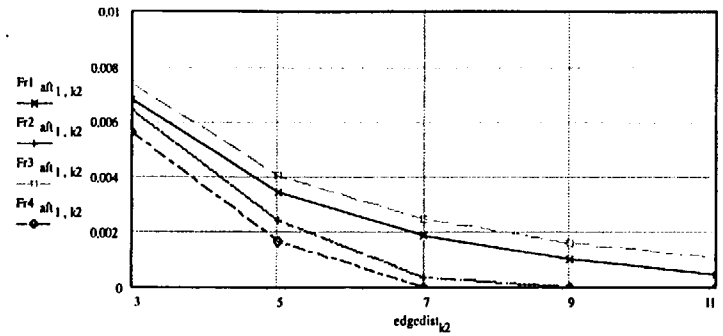
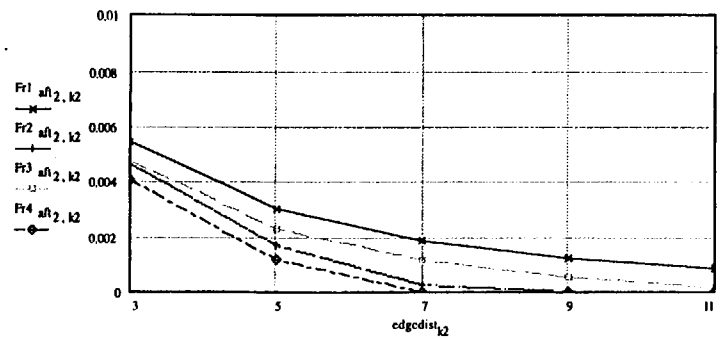
MWIR Band 20 (3.75 μm



LWIR Band 27 (6.715 μm)



- Edge distance: 3 km to 11 km
- Four positions of Lmax illumination – west, north, east, south
- EM NFR data used to generate Harvey Shack parameters

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NORMALIZED NFR AS A FUNCTION OF CLOUD SIZE AND CLOUD EDGE DISTANCE

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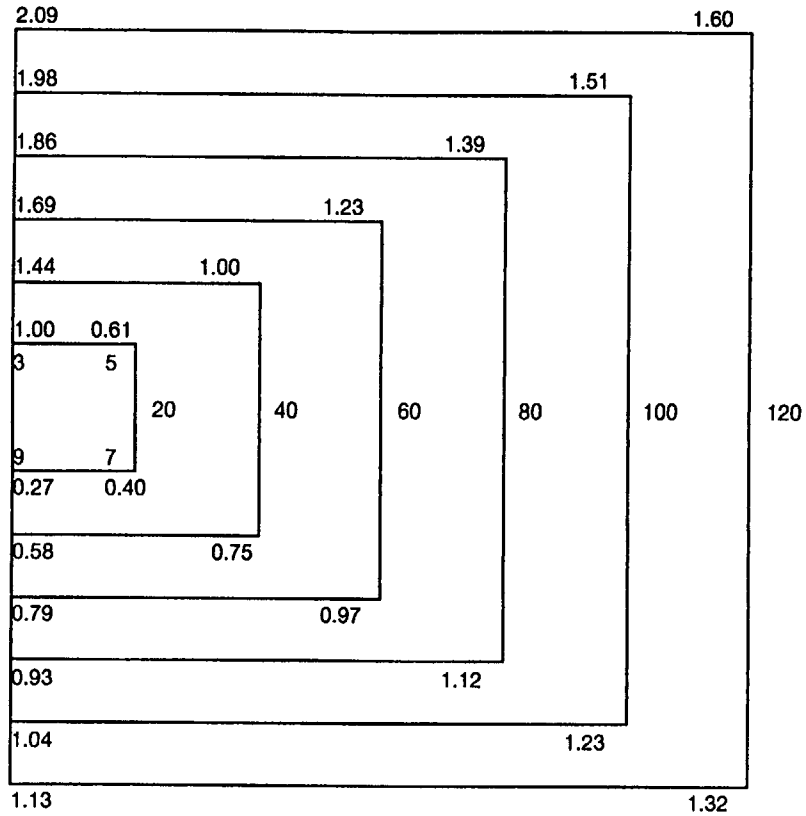

Normalization uses 20 km by 20 km cloud with a cloud edge distance of 3 km. Cloud size varies 20 km square to 120 km square. Cloud edge distance varies between 3 km and 9 km. This NFR is associated with fore optics scatter.

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PFM AOA MEASURED NFR IS COMPARED TO MODELED DATA

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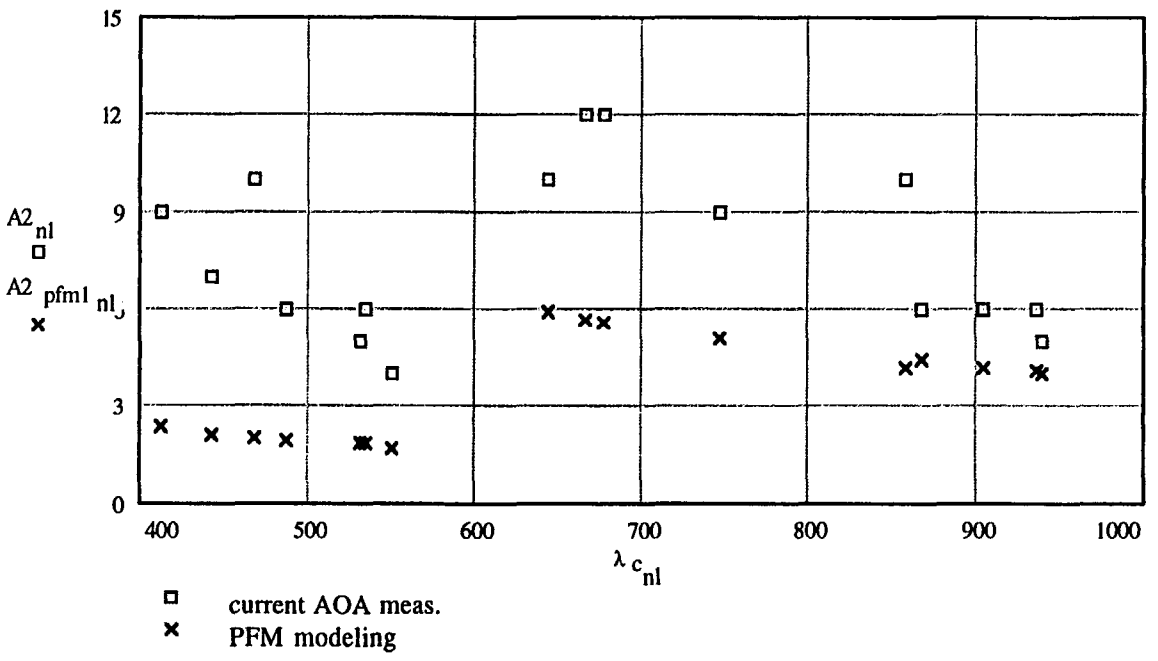
- AOA NFR measured using the IAC with SIS
- Noise floor is ≈ 10^-4, desirable to have 10^-5
- Increased SNR is attainable with use of ribbon filament source
- IAC is a significant, but unknown, portion of measured NFR
- Measured data fit to Harvey Shack model is good (most bands)
- Each band was fitted individually



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COMMENTS RE AOA MEASUREMENTS - VERSION I

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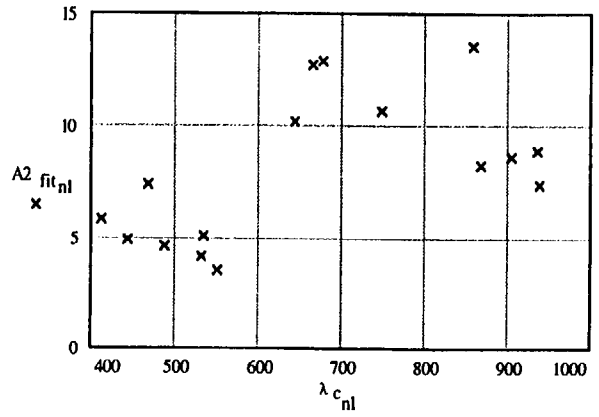
- If inverse wavelength scaling is assumed

$nl := 1 .. 16$

$$A2_{fit_{nl}} := \frac{A2_{nl}}{\left(\frac{633}{\lambda_{c_{nl}}}\right)}$$



nl	$\lambda_{c_{nl}}$	$A2_{nl}$	$M2_{nl}$	$A2_{fit_{nl}}$
1	645	10	-1.9	10.2
2	858	10	-1.9	13.6
3	469	10	-1.9	7.4
4	535	6	-1.9	5.1
5	412	9	-1.9	5.9
6	443	7	-1.9	4.9
7	488	6	-1.9	4.6
8	531	5	-1.9	4.2
9	551	4	-1.9	3.5
10	667	12	-1.8	12.6
11	678	12	-1.8	12.9
12	748	9	-1.6	10.6
13	869	6	-1.4	8.2
14	905	6	-1.4	8.6
15	936	6	-1.6	8.9
16	940	5	-1.6	7.4

- Average values of A2 are 5.1 and 10.3 for VIS and NIR, respectively.
- If AOA VIS is equivalent to EM then IAC, A = 3.6 and TIS = 0.0028
- Resultant AOA (without IAC) has A2 = 1.5 and 6.7 for VIS and NIR
- This is a close match to PFM modeling
- EM data fit inverse wavelength scaling

8/95
95-0392/9-16

COMMENTS RE AOA MEASUREMENTS - VERSION II

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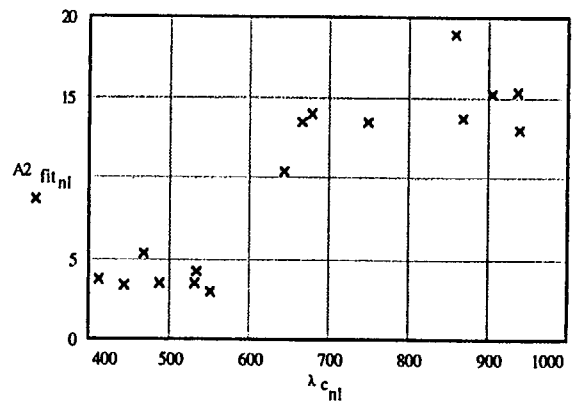
- If Harvey Shack model wavelength scaling is assumed

$nl := 1..16$

$$A2_{fit_{nl}} := \frac{A2_{nl}}{\left(\frac{633}{\lambda_{c_{nl}}}\right)^{4+M2_{nl}}}$$



nl	$\lambda_{c_{nl}}$	$A2_{nl}$	$M2_{nl}$	$A2_{fit_{nl}}$
1	645	10	-1.9	10.4
2	858	10	-1.9	18.9
3	469	10	-1.9	5.3
4	535	6	-1.9	4.2
5	412	9	-1.9	3.7
6	443	7	-1.9	3.3
7	488	6	-1.9	3.5
8	531	5	-1.9	3.5
9	551	4	-1.9	3
10	667	12	-1.8	13.5
11	678	12	-1.8	14
12	748	9	-1.6	13.4
13	869	6	-1.4	13.7
14	905	6	-1.4	15.2
15	936	6	-1.6	15.3
16	940	5	-1.6	12.9

- Average values of A2 are 3.8 and 14.1 for VIS and NIR, respectively.
- If AOA VIS is equivalent to EM then IAC, A = 2.3 and TIS = 0.0018
- Resultant AOA (without IAC) has A2 = 1.5 and 11.8 for VIS and NIR
- This is higher than PFM NIR modeling by a factor of two.
- AOA data appears to fit (4+M) scaling better than inverse linear

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POINT SPREAD FUNCTION (PSF) CHARACTERIZATION OF NFR

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- This characterization is conceptually feasible
- What are the requirements: two dimensional region, SNR, band, channel
- Required resources very dependent upon what is needed
- Expect volume of data will be a major problem
- Source 1 pixel square vs 1 x 10 pixel results in a 3 to 10 x reduction of SNR depending upon angular distance from sensing IFOV
- EM used 1 x 10 slit with 100 scan lines to obtain data across 100 data frames
- If comparable SNR is needed then number of scan lines needs to be increased
- Number of along track traces increases data volume linearly.
- Need the data volume obtained in the EM VIS/NIR test.

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95-0392/9-18

SPATIAL PERFORMANCE

N. Therrien

AGENDA

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- Spatial design parameters
- Field of view, Response vs scan angle
- IFOV, MTF
- Registration
- Pointing, 1g release
- Spurious Signals
- Conclusions

IFOV AND ORBITAL PARAMETERS DETERMINE SCAN RATE

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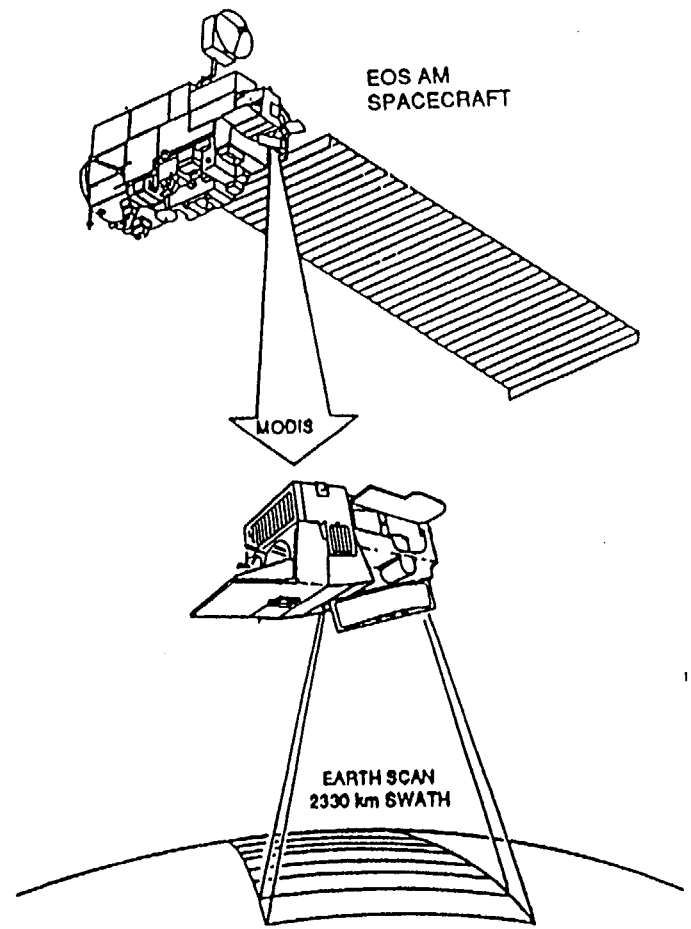
Equatorial Radius = 6378.17 m
Earth Rotation Rate = 0.4651 km/s
Orbit Altitude = 705.295
Orbit Inclination = 98.21°
Ground Velocity = 6.75457 km/s

IFOV = 1 km/705.295 km = 1.41785 mr
IFOV = 0.5 km/705.295 km = 0.708923 mr
IFOV = 0.25 km/705.295 km = 0.354462 mr

Dwell Time = 333.333 µs, (48 MHz Master Osc.)
166.667 µs, 83.3333 µs

Object Space Scan Rate =
1.41785 mr/333.333 µs = 4.25354 r/s
Object Space Scan Period = 1.47717 s

Swath Width = 10 km
Distance Along-Track Per Scan = 9.92426 km
Sampling Gap Along Track = 0.0757 m (Worst Case)



MODIS BANDS DISTRIBUTED AMONG FOUR FPAS/OPTICAL OBJECTIVES

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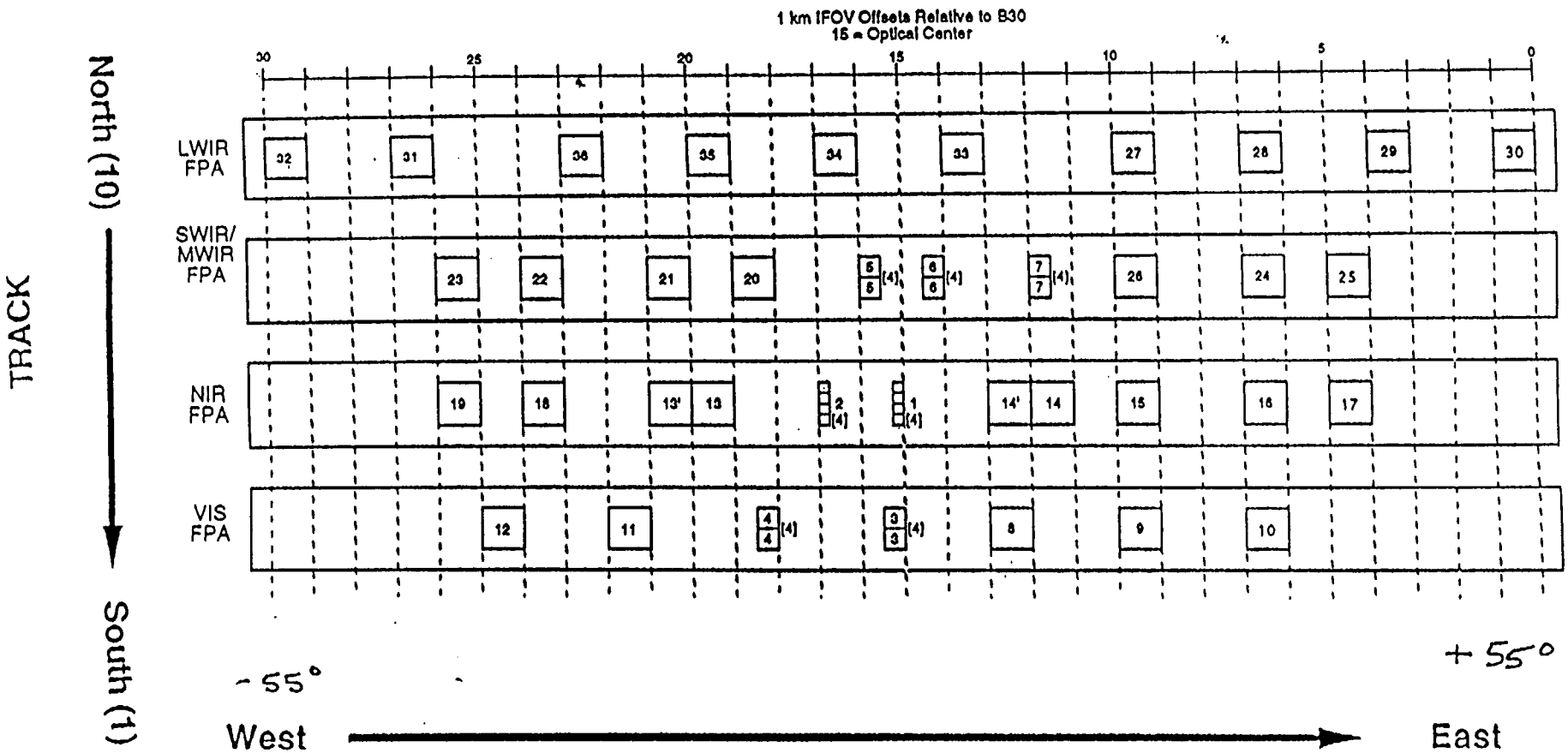

FOV AND RESPONSE VS SCAN ANGLE WILL BE WELL CHARACTERIZED

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- EM test data shows full FOV attained
  - No instrument design changes planned for PF
- MODIS PF test will include
  - All MODIS band/channels sampled at 1 to 2 radiance levels per band
  - 5 to 10 angles of incidence
  - Scan mirror rotating during data collection at each angle
    - Both sides of scan mirror characterized
  - MODIS electronics using DC restore
  - BCS/SIS will be used (EM test used the IAC)

EM BANDS 29 AND 30 SHOW EXPECTED RESPONSE CHANGE WITH SCAN ANGLE

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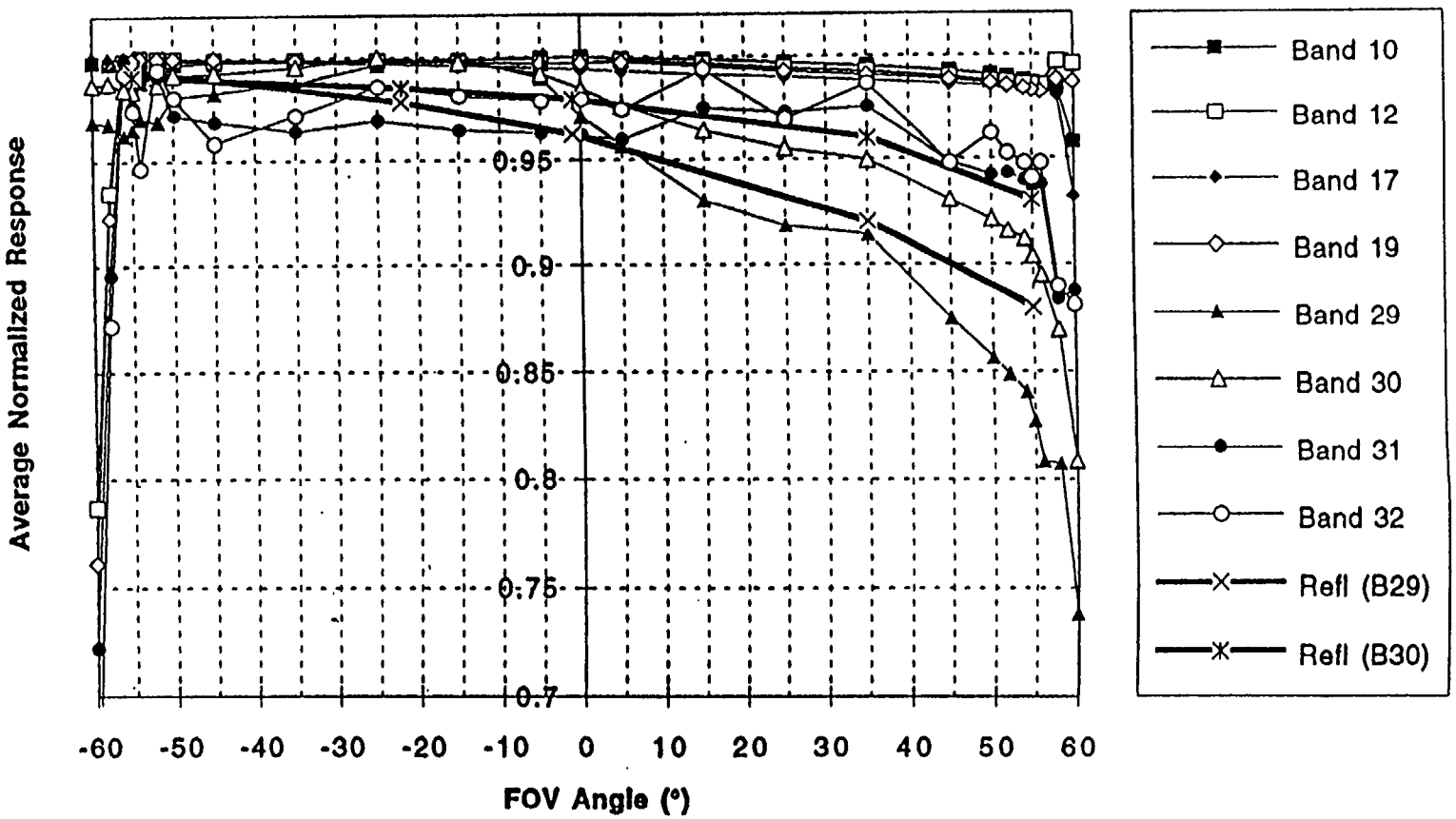

RESPONSE VS SCAN ANGLE TEST WILL USE SIS AND BCS

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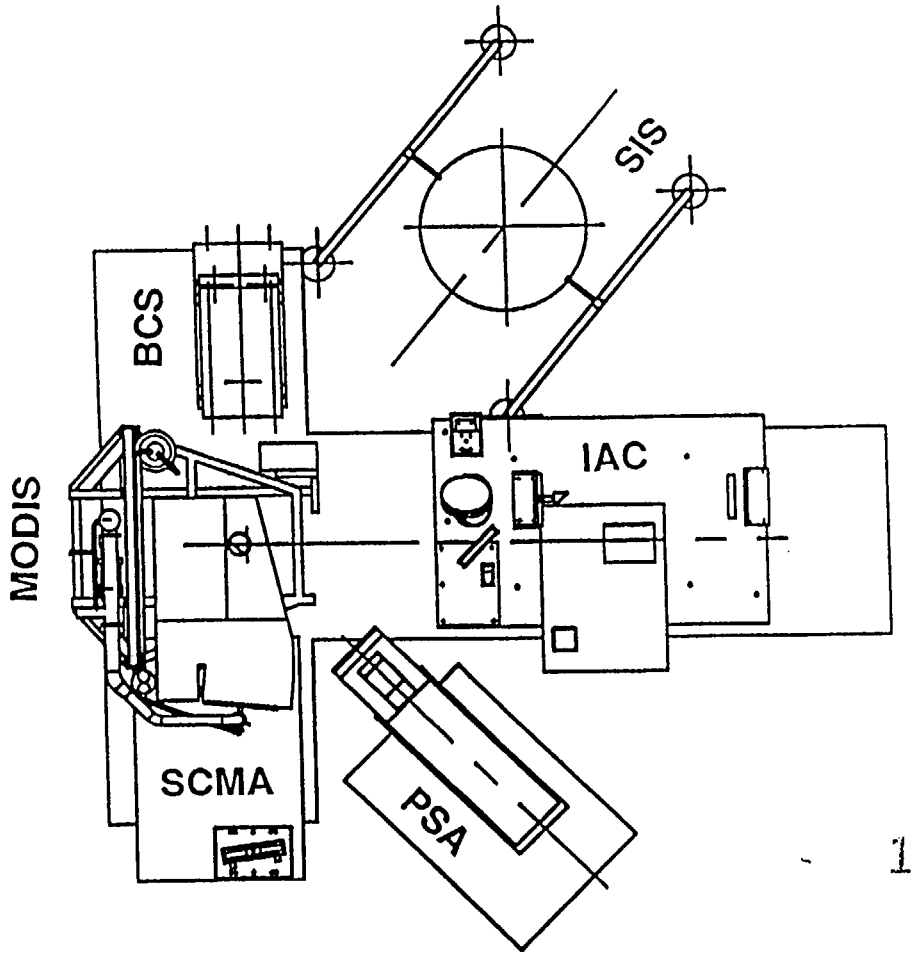
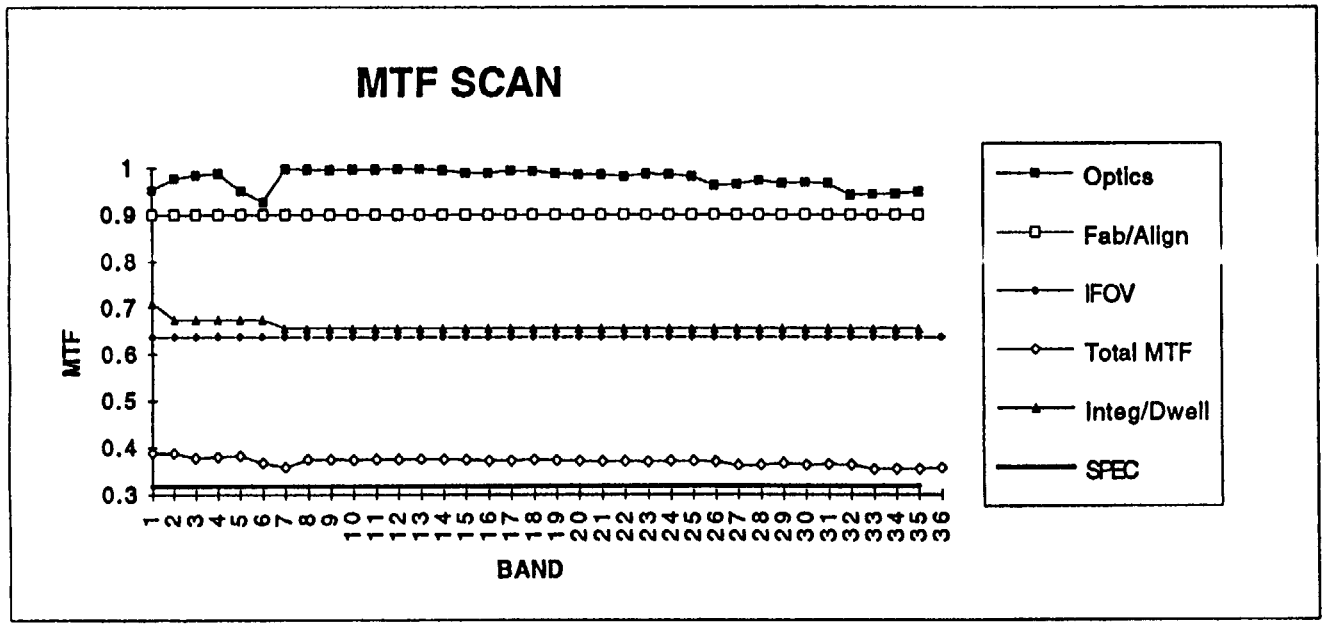
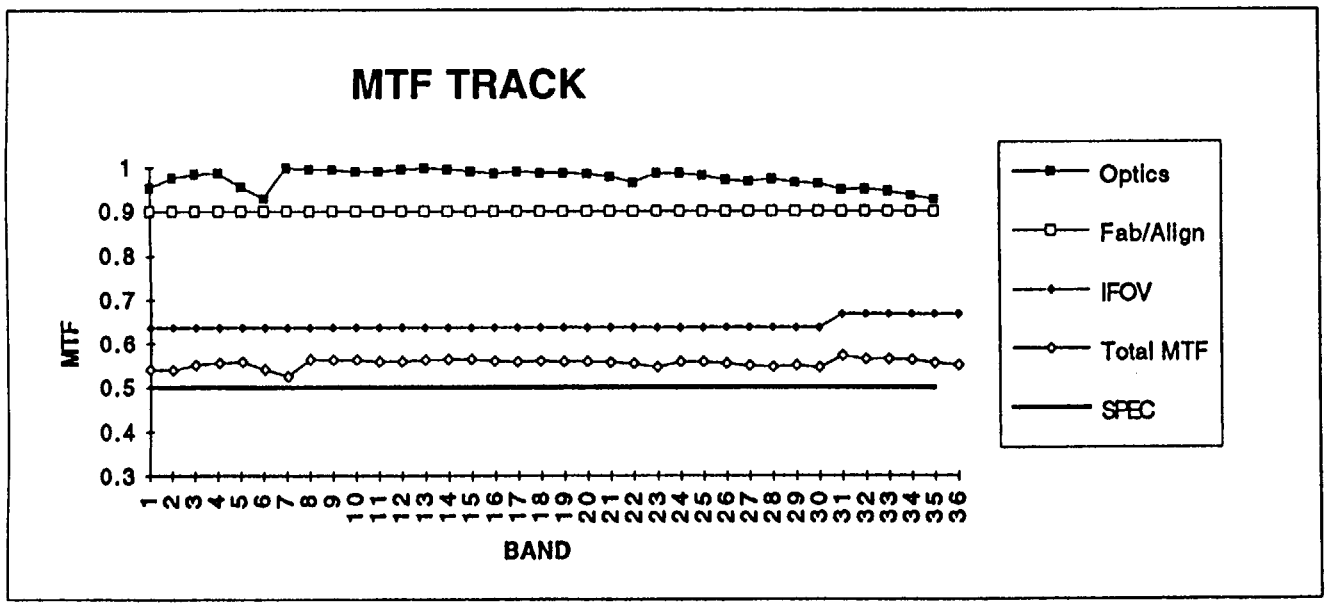
- Full aperture illumination
- Optimized layout minimizes table rotations, test time







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MTF BUDGETS UPDATED FOR PF

MODIS
GSFC SBRC

11/93
93-0858-116

EM IFOV AND MTF RESULTS ARE CORRELATED

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- Nominal LSFs meet 0.5 spec
- Most MTF failures result from obvious anomalies in LSFs (incomplete scans, spurious signals)
- Uncorrelated results (PC bands) suggest a more detailed focus/distortion checkout at PF subassembly level

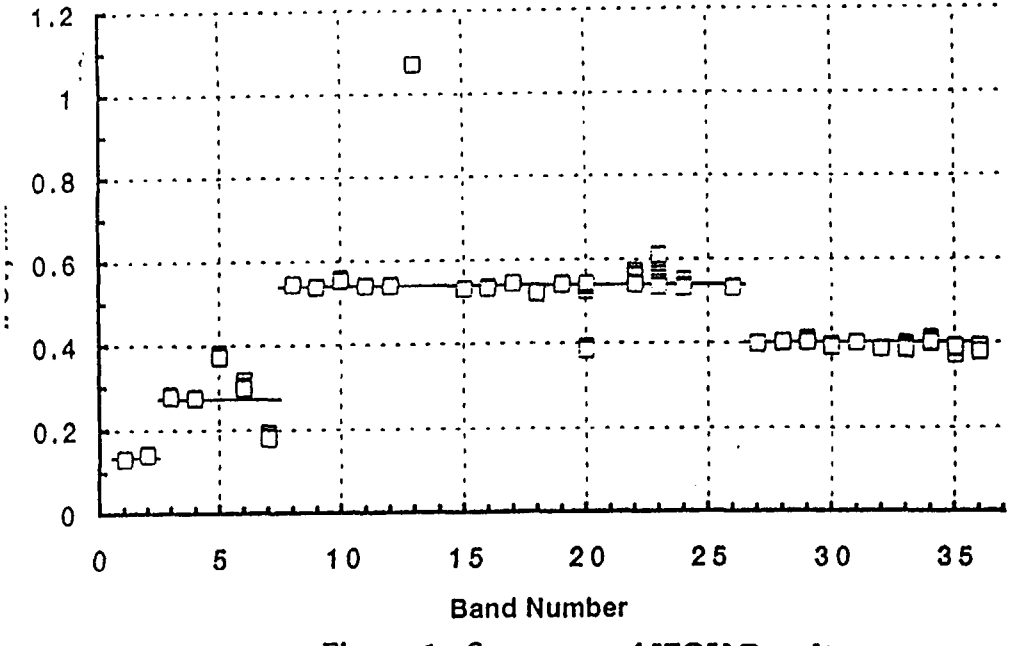

Figure 1 - Summary of IFOV Results

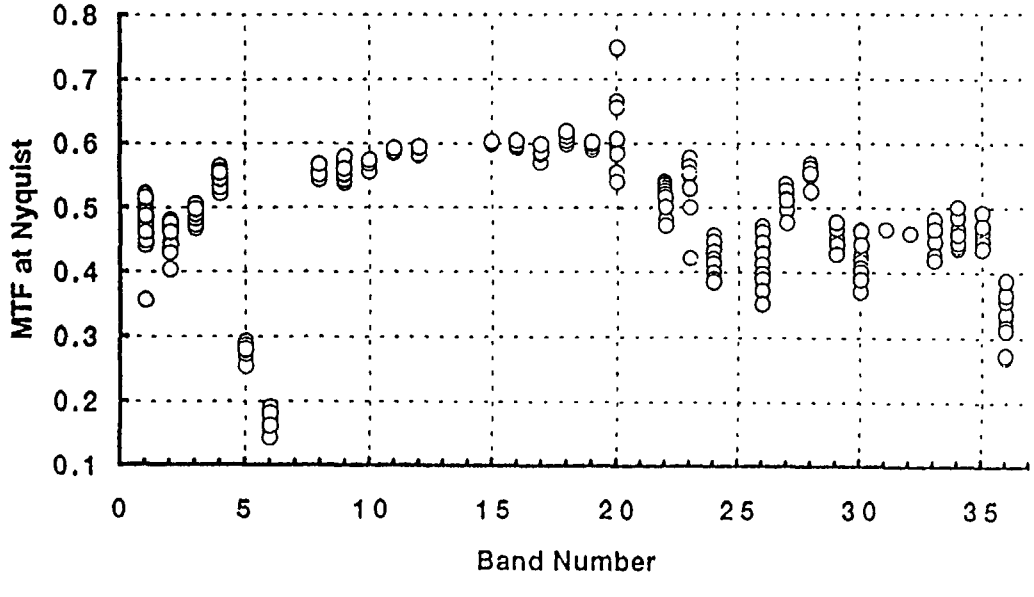

Figure 2 - Summary of MTF Results

PF VIS/NIR AFT OPTICS AND FPAS MEET MTF SPEC

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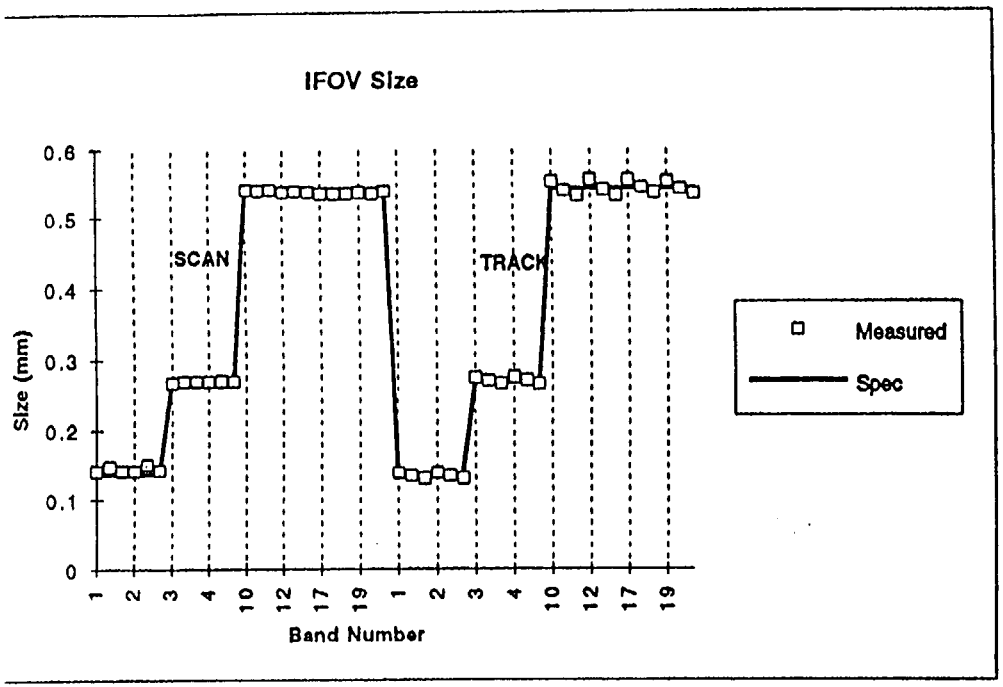
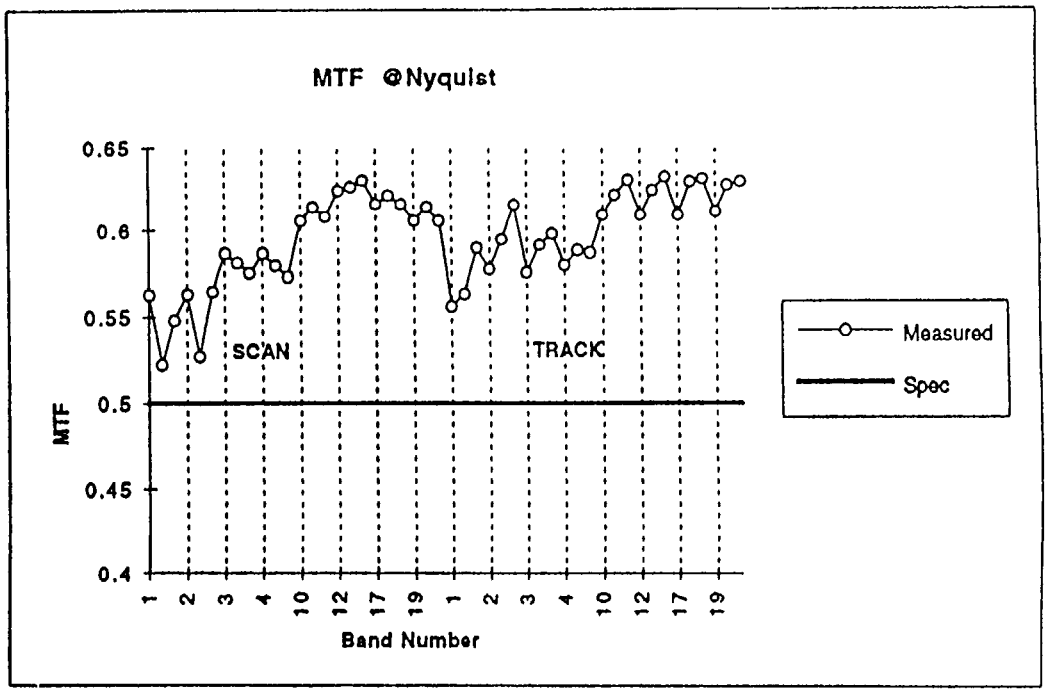
- MTF computed over extreme objective field angles
  - Outer and boresight bands for scan and track
  - Outside and middle channels for each band





REGISTRATION PREDICTIONS SATISFY SPECIFICATION

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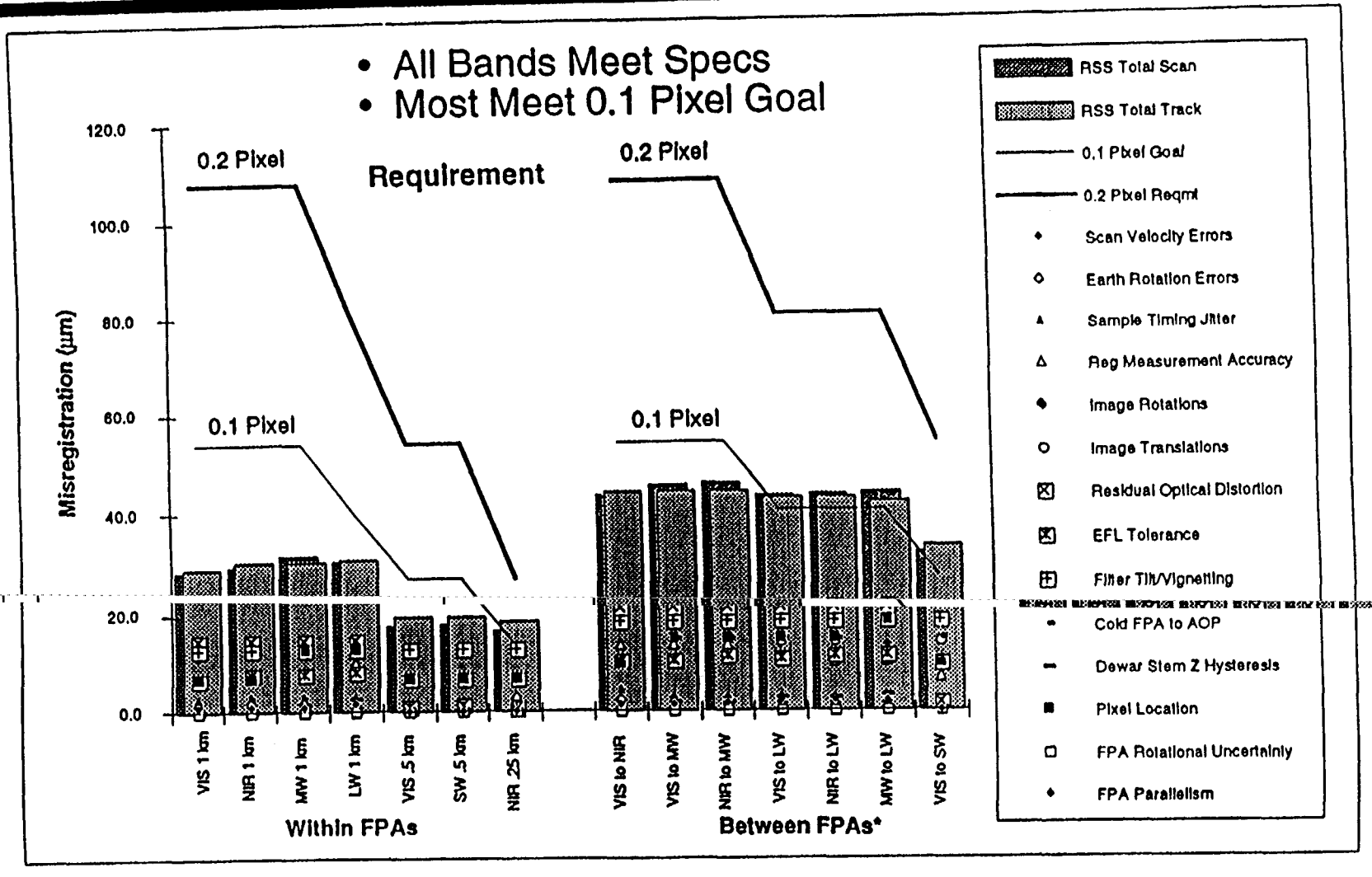

SCAN DIRECTION REGISTRATION BUDGET IDENTIFIES CONTRIBUTORS

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SPECTRAL BAND REGISTRATION BUDGET:SCAN DIRECTION					WITHIN-FPA							BETWEEN-FPAs						
					VIS 1 km	NIR 1 km	MW 1 km	LW 1 km	VIS .5 km	SW .5 km	NIR .25 km	VIS to NIR	VIS to MW	NIR to MW	VIS to LW	NIR to LW	MW to LW	VIS to SW
Scan Rate		243.71	°/s															
Orbit Altitude		705.295	km		VIS	NIR	MW	LW	VIS	SW	NIR	VIS	VIS	NIR	VIS	NIR	MW	VIS
Bands					VIS	NIR	MW	LW	VIS	SW	NIR	NIR	MW	MW	LW	LW	LW	SW
Ground Resolution			km		1.0	1.0	1.0	1.0	0.5	0.5	0.25	1.0	1.0	1.0	1.0	1.0	1.0	0.5
Maximum Displacement (x)			Pixels		18	21	21	29	.6	8	7	29	21	21	29	29	29	8
Maximum Displacement (x)			°		1.46	1.71	1.71	2.36	0.24	0.32	0.14	2.36	1.71	1.71	2.36	2.36	2.36	0.32
Maximum Time Delay			ms		6.000	7.000	7.000	9.667	1.000	1.333	0.583	9.667	7.000	7.000	9.667	9.667	9.667	1.333
IFOV			mr		1.418	1.418	1.418	1.418	0.709	0.709	0.354	1.418	1.418	1.418	1.418	1.418	1.418	0.709
Pixel Size			µm		540.0	540.0	540.0	400.0	270.0	270.0	135.0	540.0	540.0	540.0	400.0	400.0	400.0	270.0
EFL			mm		380.9	380.9	380.9	282.1	380.9	380.9	380.9	380.9	380.9	380.9	282.1	282.1	282.1	380.9
	Type			Specification	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)	(µm)
System Level Errors																		
Scan Velocity Errors	Fab	0.005	rads/s	151766/3.4.1.2	11.4	13.3	13.3	13.6	1.9	2.5	1.1	18.4	13.3	13.3	13.6	13.6	13.6	2.5
Earth Rotation Errors	Syst	6.58E-04	rads/s	N/A	1.5	1.8	1.8	1.8	0.3	0.3	0.1	2.4	1.8	1.8	1.8	1.8	1.8	0.3
Sample Timing Jitter	Fab	0.1	µs	151783/TBD	2.9	3.4	3.4	3.5	1.0	1.3	1.1	4.7	3.4	3.4	3.5	3.5	3.5	1.3
Reg Measurement Accuracy	Test	0.025	Pixel	151874/3.2.1.1	13.5	13.5	13.5	10.0	6.8	6.8	3.4	13.5	13.5	13.5	10.0	10.0	10.0	6.8
Opto-Mechanical Errors																		
Image Rotations	STOP	0.075	°	151771/3.2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Image Translations	STOP			151771/3.2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	18.0	18.0	14.1	14.1	18.0	14.1
Residual Optical Distortion	Fab			151771/3.2.9	15.0	15.0	15.0	15.0	7.0	7.0	7.0	21.2	21.2	21.2	21.2	21.2	21.2	9.9
EFL Tolerance	STOP	0.14 per Obj	%	151771/3.2.10	6.8	7.9	7.9	8.1	1.1	1.5	0.7	10.5	10.5	11.2	10.6	11.4	11.4	1.9
Filter Tilt/Vignetting	Assy	13	µm	151771/3.2.11	13.0	13.0	13.0	13.0	13.0	13.0	13.0	18.4	18.4	18.4	18.4	18.4	18.4	18.4
Radiative Cooler Errors																		
Cold FPA to AOP (x,y)	STOP	10	µm	151779/3.3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	10.0	0.0	10.0
Dewar Stem X-Y Hysteresis	Assy	11.2	µm	151779/3.3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	11.2	11.2	11.2	0.0	11.2
Dewar Stem Z Hysteresis	Assy	32	µm	151779/3.3.8	0.0	0.0	1.9	2.6	0.0	0.4	0.0	0.0	1.9	1.9	2.6	2.6	3.2	0.4
Focal Plane Errors																		
Pixel Location	Fab			151780/3.3.10	7.0	7.0	13.0	13.0	7.0	7.0	7.0	9.9	14.8	14.8	14.8	14.8	18.4	9.9
FPA Rotational Uncertainty	Assy	0.025	°	151780/ICD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FPA Parallelism	Assy	20	µm	151780/ICD	1.0	1.2	1.2	1.6	0.2	0.2	0.1	1.6	1.6	1.7	1.9	2.0	2.0	0.3
RSS Total Scan			µm		28.5	29.7	31.7	30.7	17.8	18.0	16.8	43.3	45.2	45.4	43.1	43.3	43.5	31.9
0.2 Pixel Reqmt			µm		108.0	108.0	108.0	80.0	54.0	54.0	27.0	108.0	108.0	108.0	80.0	80.0	80.0	54.0
Margin to Spec			%		73.6	72.5	70.6	61.7	67.0	66.7	37.9	59.9	58.1	57.9	46.2	45.9	45.6	41.0
0.1 Pixel Goal			µm		54.0	54.0	54.0	40.0	27.0	27.0	13.5	54.0	54.0	54.0	40.0	40.0	40.0	27.0
Margin to Goal			%		47.2	45.0	41.3	23.4	33.9	33.4	-24.3	19.9	16.2	15.9	-7.7	-8.2	-8.9	-18.1

DYNAMIC MODE DATA HIGHLIGHT CO-REGISTRATION

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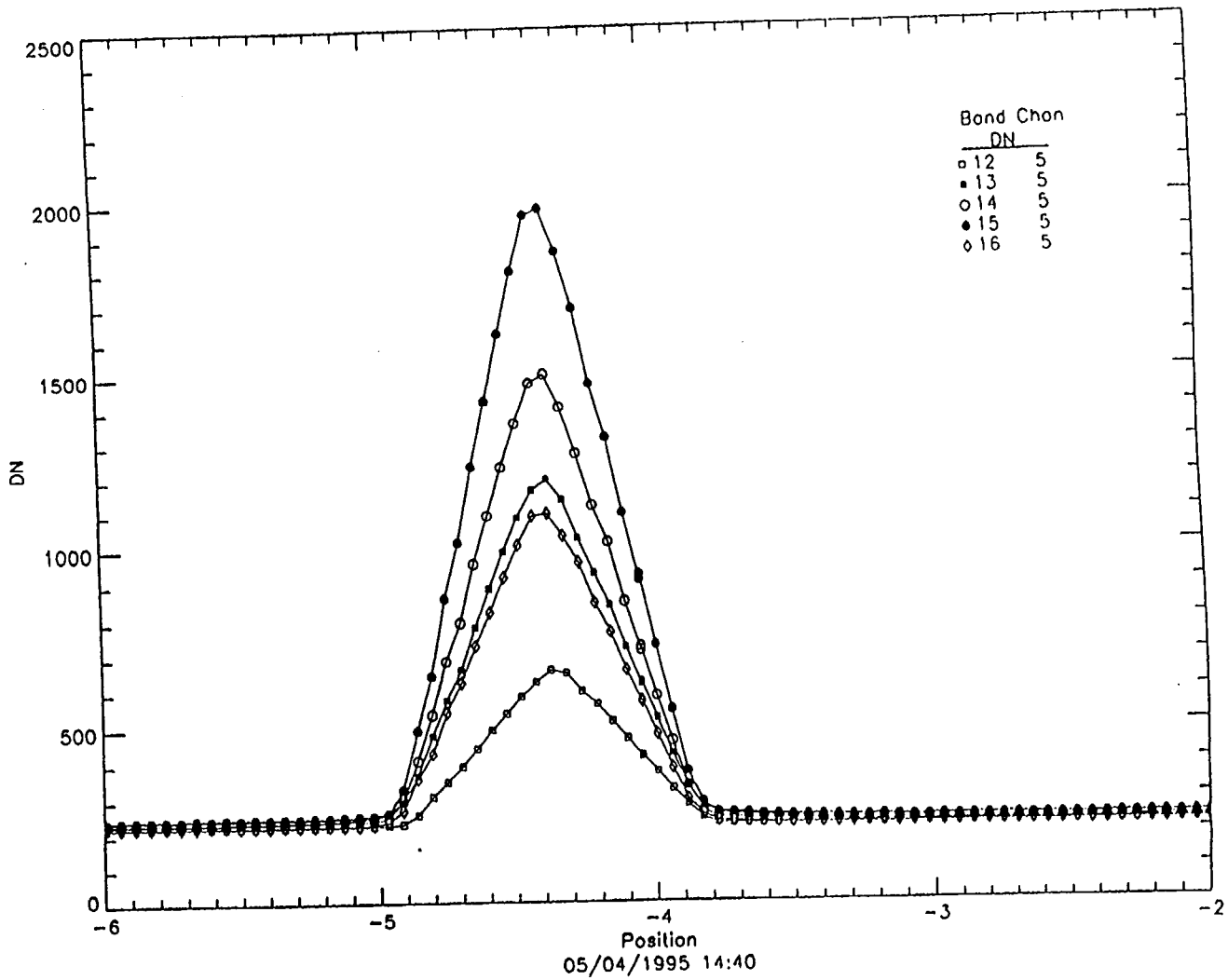
- Triangular response
- Bands electronically co-registered
- TDI in bands 13 & 14 working properly



REVISED PLAN FOR PF LIMITS STATIC LSF ACQUISITIONS

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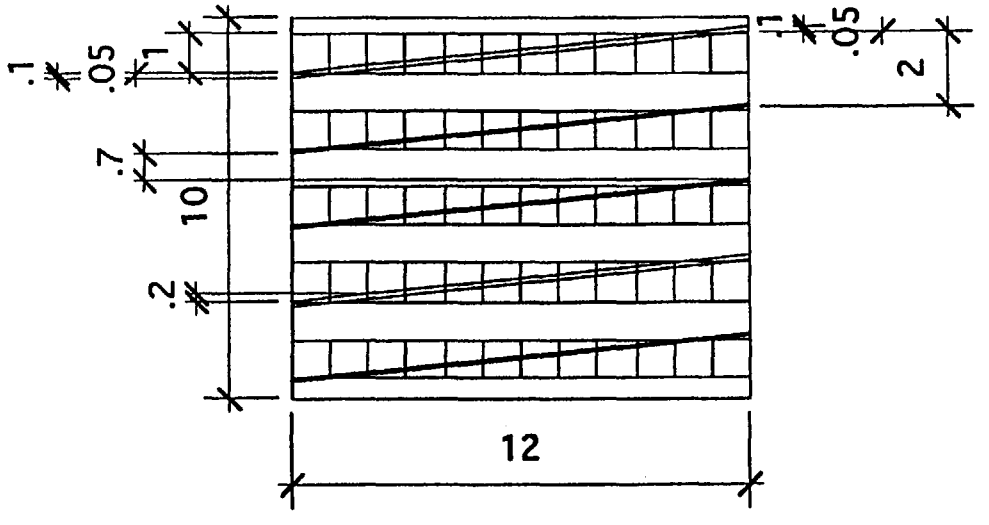
- Emphasis will be on dynamic (scan mirror rotating) data acquisitions to assess registration
- FPA integration time will be incrementally (minimum 2%) phase delayed to generate LSF curve
- New integration and alignment collimator (IAC) reticle slit will be manufactured for track direction LSF measurement



IAC Track Reticle Concept
All dimensions in 1 km pixel IFOVs

PF VIS/NIR FPA OPTICS ALIGNMENT SUCCESSFULLY COMPLETED

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VIS_ F (8/23/95)

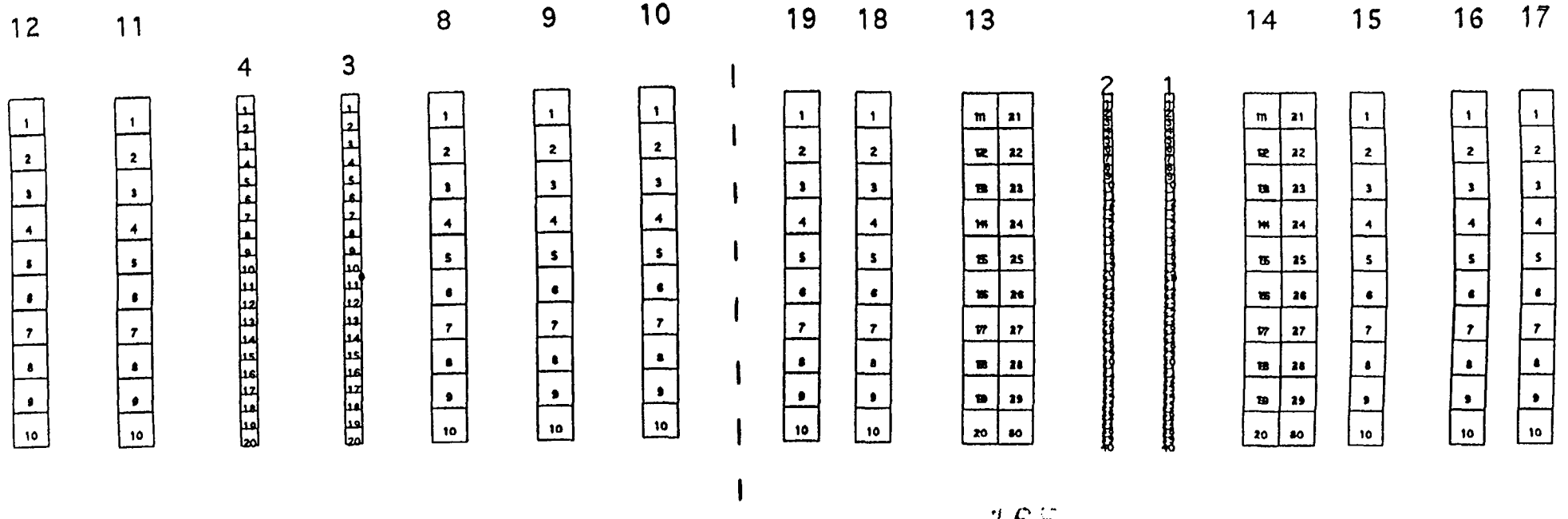
Correction Factors:

Scan 4.37 µm
Track 2.06 µm
Theta .0148°
EFL 1.00007

NIR_F (8/23/95)

Correction Factors:

Scan -7.52 µm
Track 3.02 µm
Theta .0496°
EFL .99983



REGISTRATION ERRORS WELL WITHIN 10% GOAL (54 μm)

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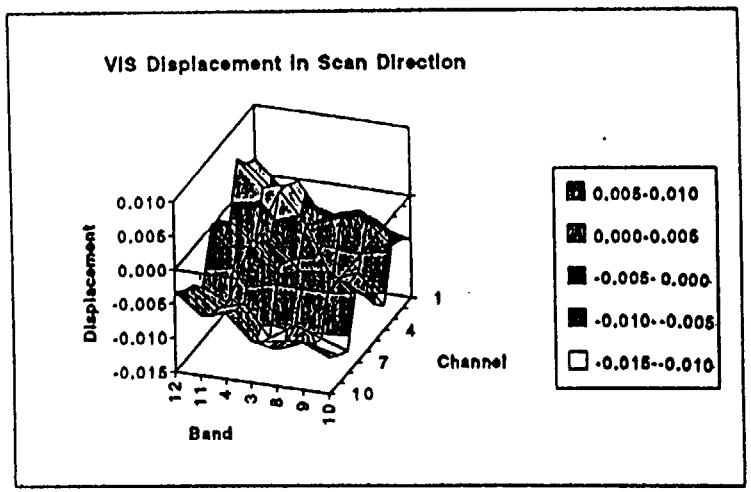

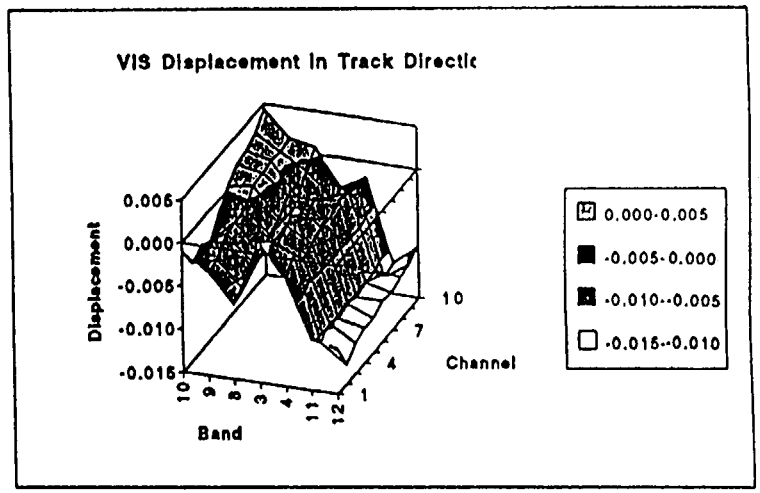

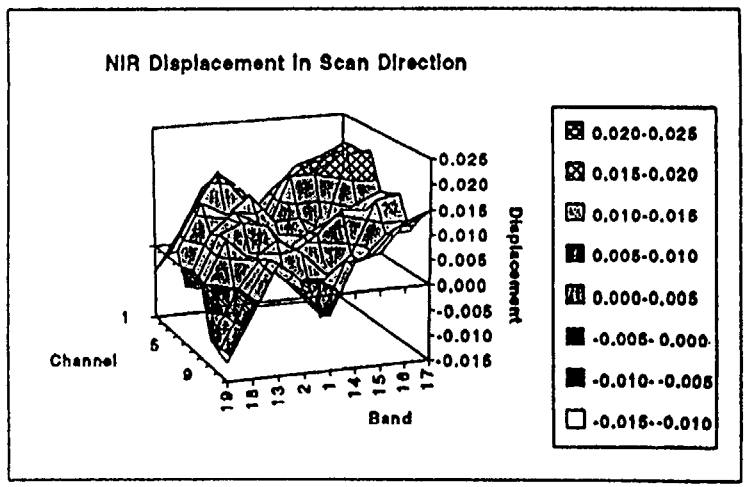

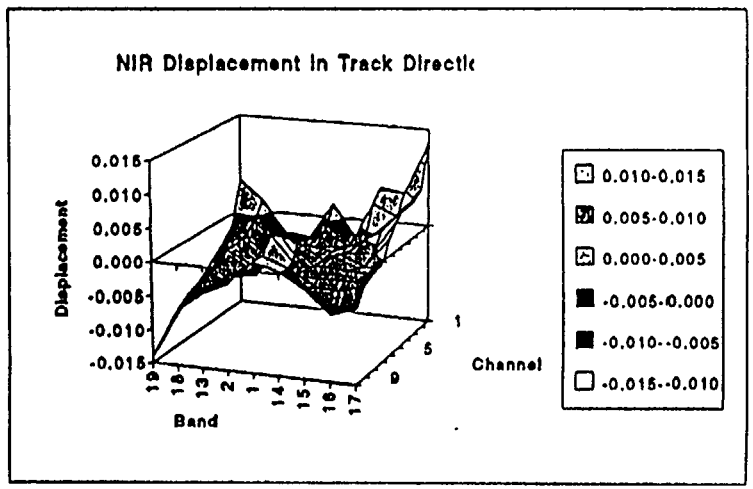

VIS/NIR 1000m BANDS COMPLIANT

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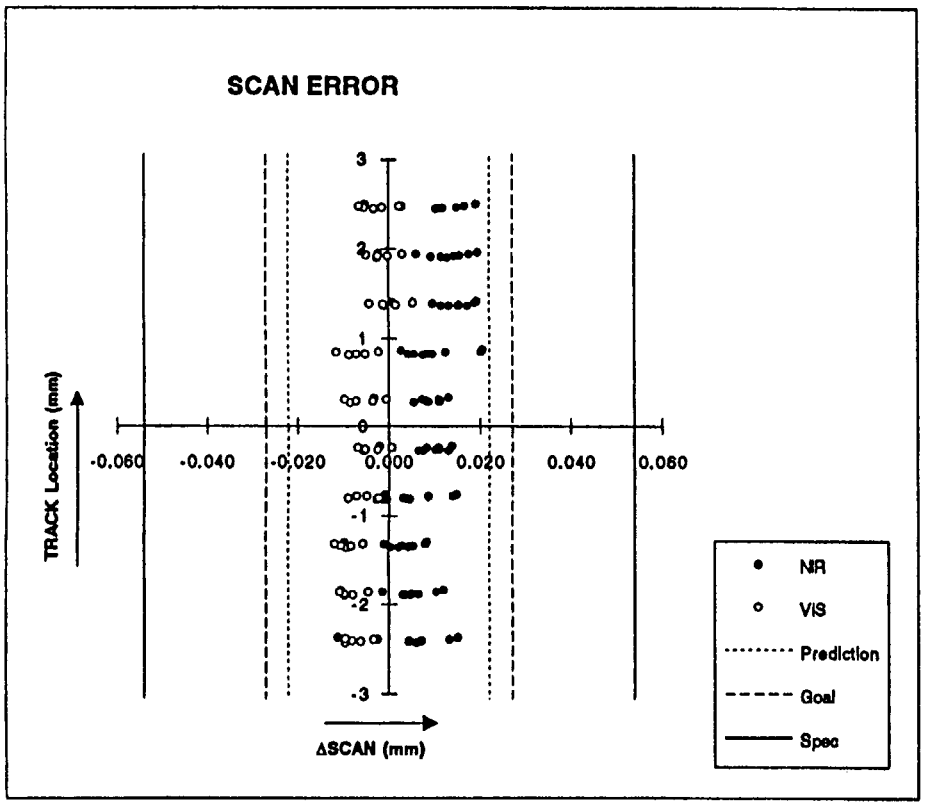

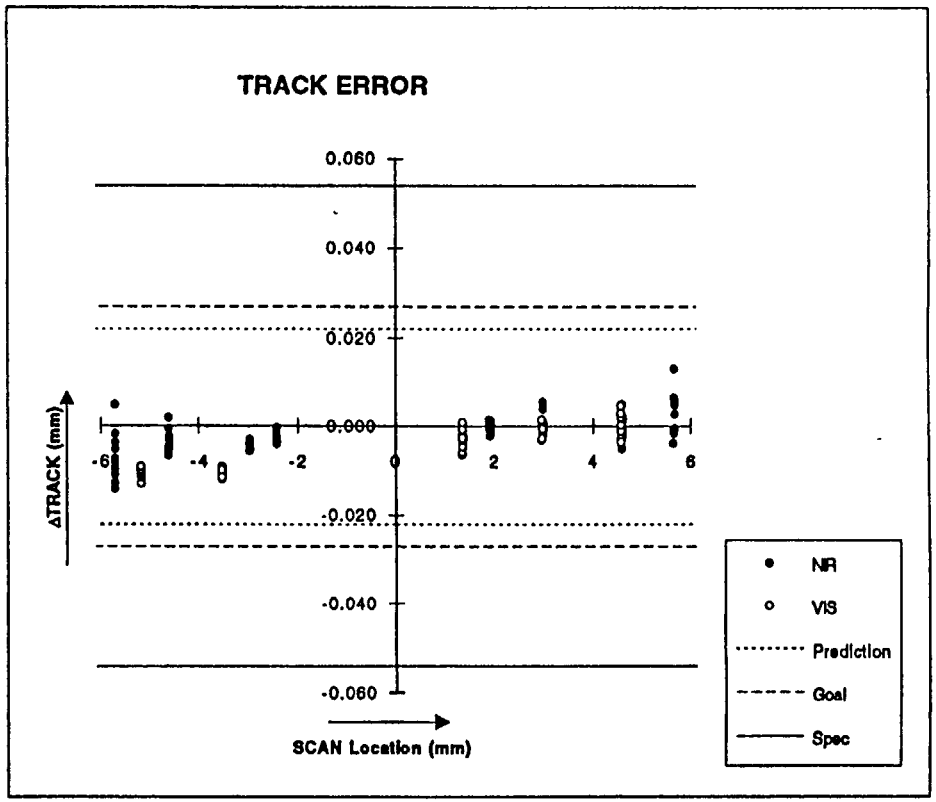

VIS BANDS 3 AND 4 (500M) COMPLIANT

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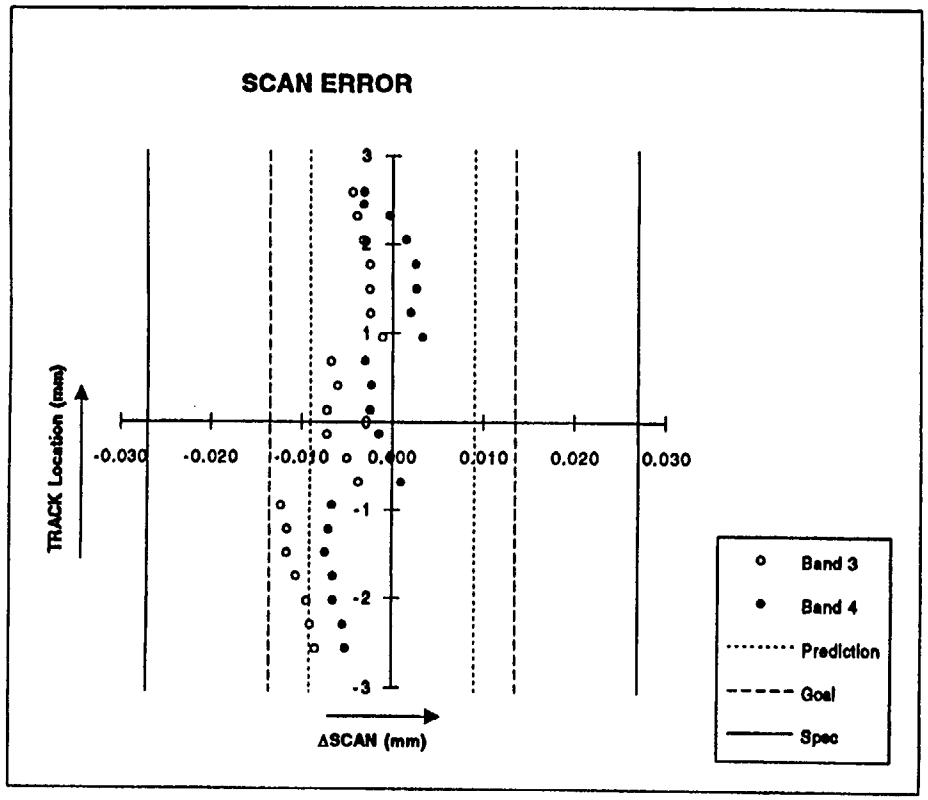

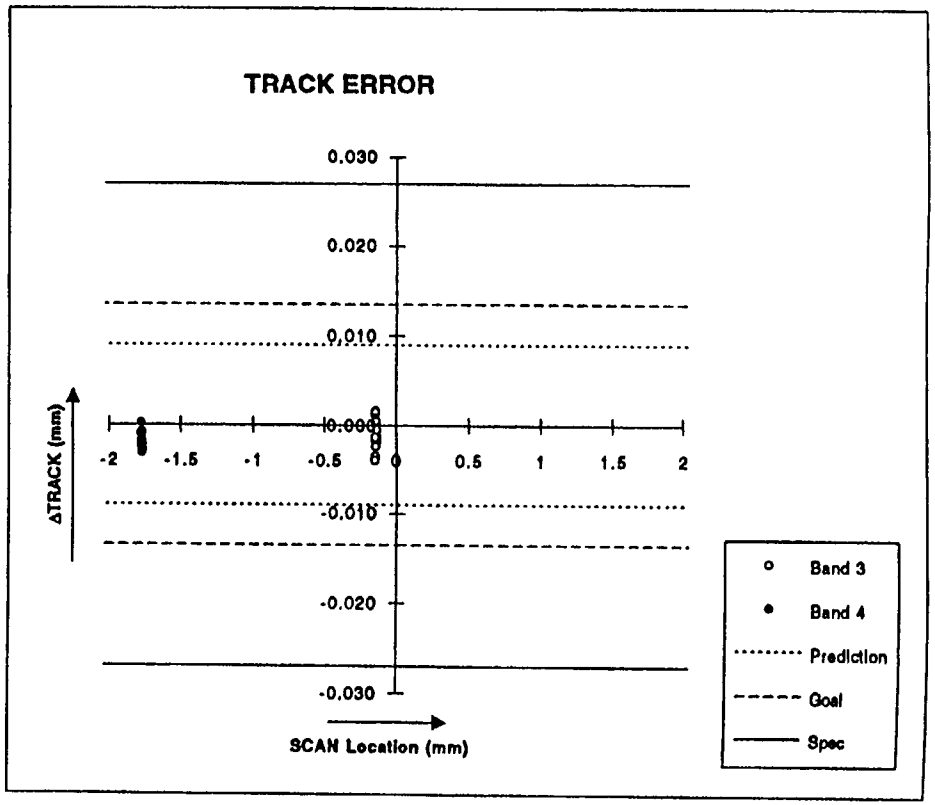

NIR BANDS 1 AND 2 (250m) COMPLIANT

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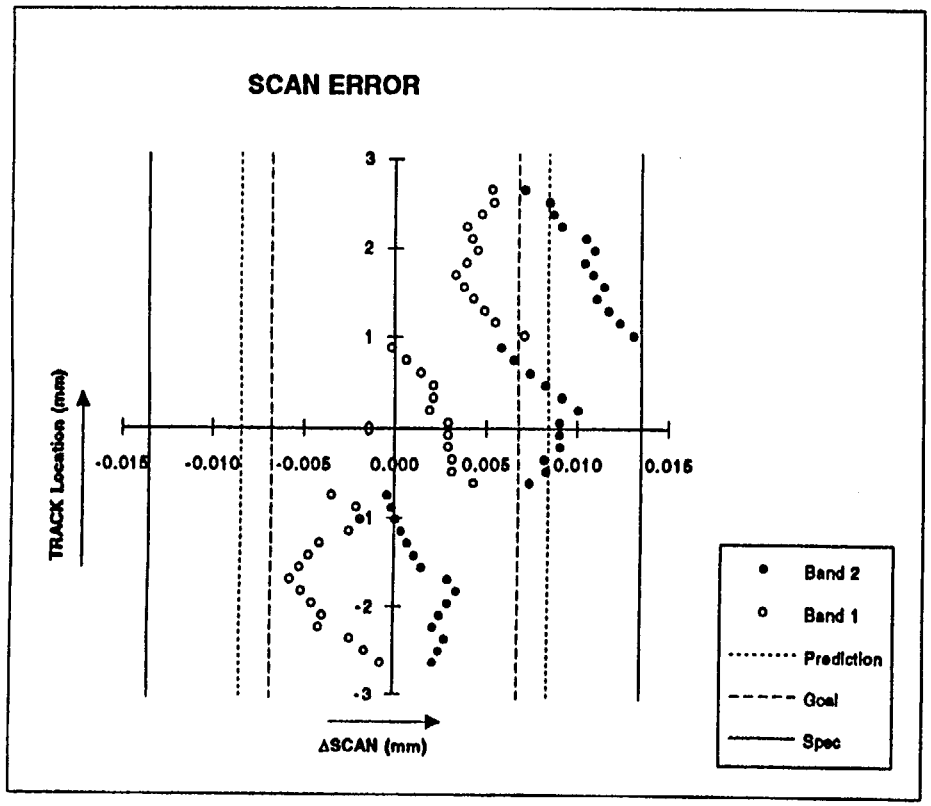
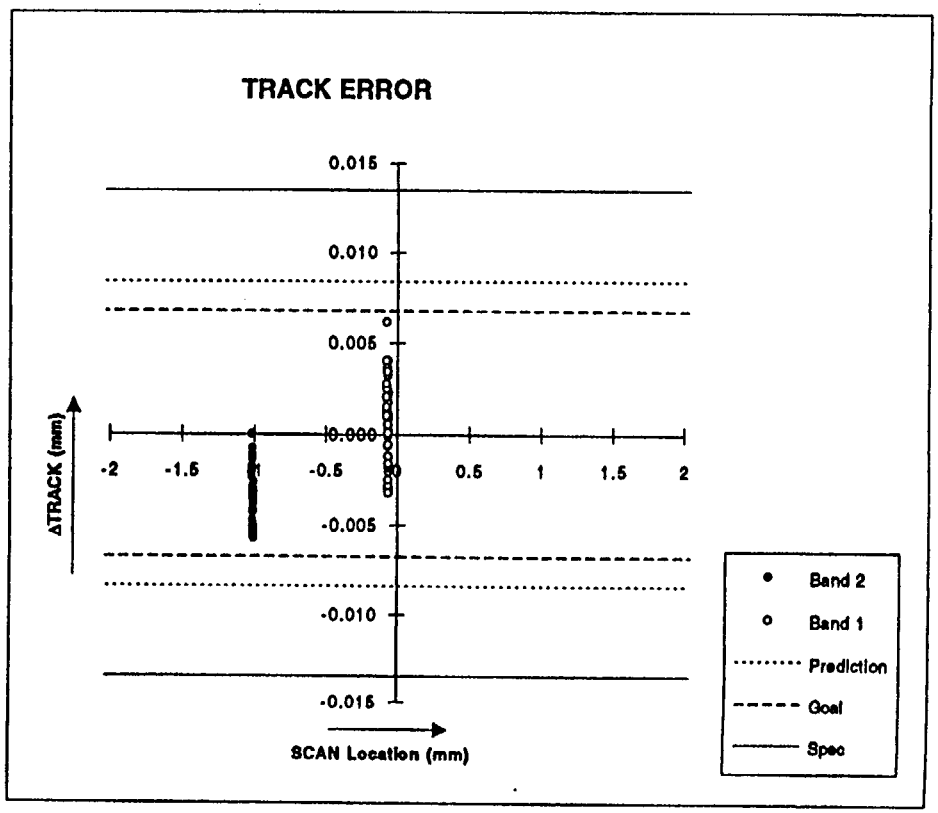
- Residual, IAC-induced offset, observed for each of the three scans acquired





POINTING ACCURACY AND KNOWLEDGE IN SPECS

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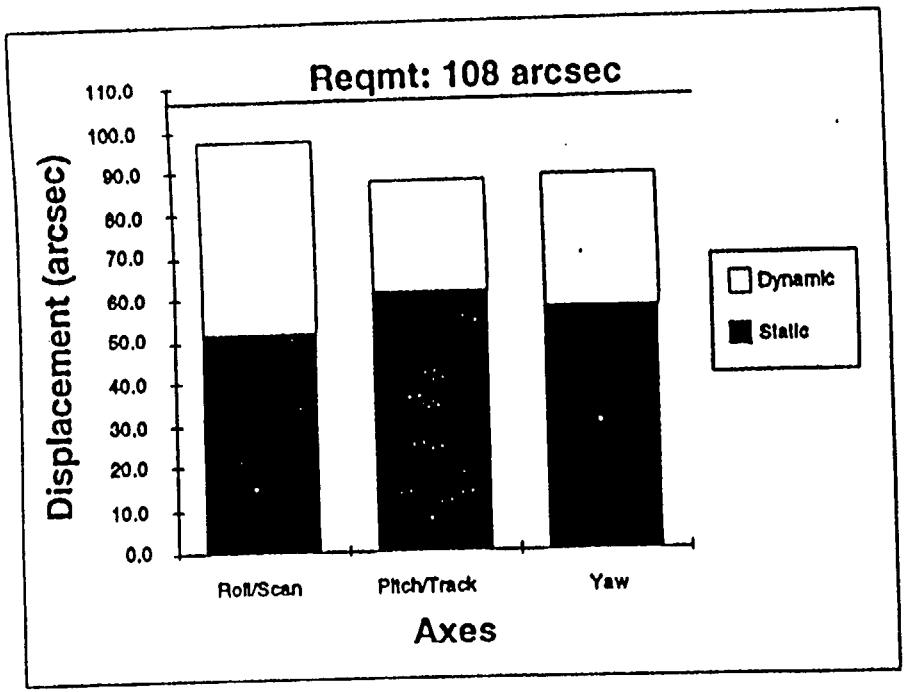
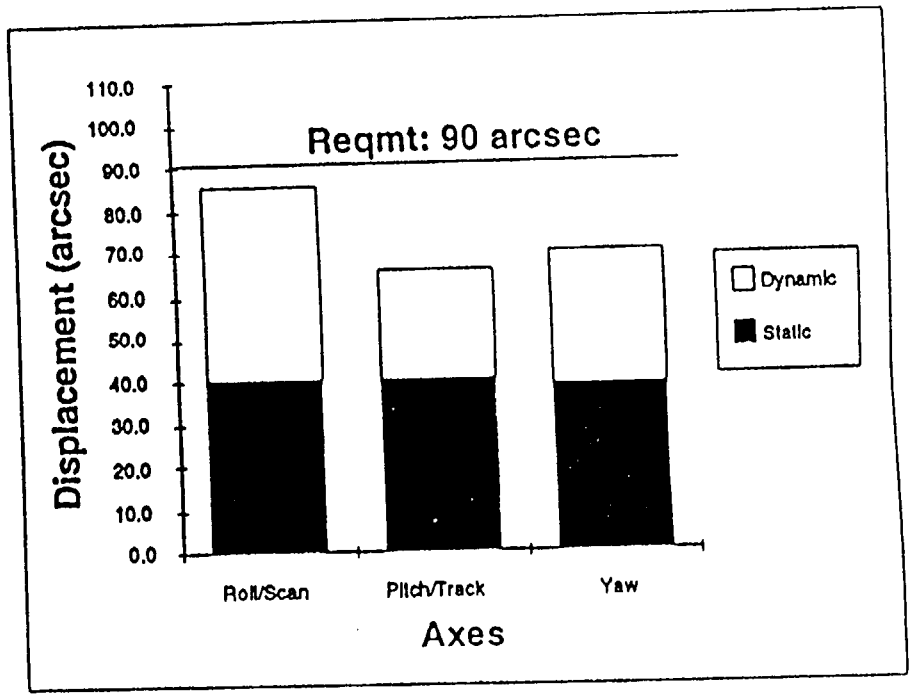
Pointing Accuracy (arcsec)



Pointing Knowledge (arcsec)



- All MODIS Systems Meeting Flowdown at this Time
- Includes 20 arc-sec Random Disturbance from Spacecraft

POINTING ACCURACY AND KNOWLEDGE DEFINED IN THREE AXES

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• All Subsystems Predict Meeting Pointing Budgets At This Time

MODIS POINTING BUDGETS: ACCURACY

POINTING ACCURACY	Component Specification	Specification Paragraph	Object Space Angles: Theta X Roll/Scan (arcsec) (3 Sigma)	Theta Y Pitch/Track (arcsec) (3 Sigma)	Theta Z Yaw (arcsec) (3 Sigma)
STATIC					
Mirror Wedge Half Angle	15.0 arcsec	151766/3.6.4.2	0.0	21.2	21.2
Alignment: Wedge Bisector-Axis	10.0 arcsec	151766/3.2.1.2	0.0	14.1	14.1
Thermal/Structural Effects SMA	10.0 arcsec	151766/3.2.3.1	10.0	10.0	10.0
Timing Induced Scan Underlap	75.7 m	151766/3.4.1.1	0.0	22.1	0.0
Registration Error	0.100 Pixels	151759/3.4.6.3	29.2	29.2	29.2
FPA to Optical Axis	10.0 µm	151771/3.2.9	5.4	5.4	5.4
SMA to OBA Alignment	10.0 arcsec	151800/tbd	10.0	10.0	10.0
SMA to OBA Measurement	5.0 arcsec	151800/tbd	5.0	5.0	5.0
Scan Axis to Mounting Feet Alignment	10.0 arcsec	151800/tbd	10.0	10.0	10.0
Instrument 1g Residual	20.0 arcsec	STOP	20.0	20.0	20.0
Instrument Thermal	20.0 arcsec	STOP	20.0	20.0	20.0
MF Kinematic Mounts	5.0 arcsec	TBD	5.0	5.0	5.0
OBA Hygroscopic	15.0 arcsec	STOP	15.0	15.0	15.0
OBA Kinematic Mounts	5.0 arcsec	TBD	5.0	5.0	5.0
Cube Installation Error	9.0 arcsec	151800/tbd	9.0	9.0	9.0
Cube Angle Measurment Error	5.0 arcsec	151800/tbd	5.0	5.0	5.0
Instr/Spacecraft Mate Error	15.0 arcsec	TBD ICD	15.0	15.0	15.0
Other Static Errors			10.0	10.0	10.0
Static (RSS Total)			**52.1**	**62.1**	**58.0**
DYNAMIC					
Bearings	9.8 arcsec	151766/3.4.1.3	0.0	9.8	19.6
Mirror Control System	90.0 µr	151766/3.4.1.2	37.1	0.0	0.0
Scan Angle Measurement	11.1 arcsec	151766/3.4.1.4	11.1	0.0	0.0
Instrument Thermal Dynamic	5.0 arcsec	STOP	5.0	5.0	5.0
Spacecraft Induced Disturbances	20.0 arcsec	TBD UIID	20.0	20.0	20.0
Other Dynamic Errors			10.0	10.0	10.0
Dynamic (RSS Total)			**45.0**	**24.9**	**30.2**
Dynamic Error Requirement	x1.477s Scan	UIID/3.4	1279.1	28.1	1279.1
Total (Static + Dynamic)			**97.1**	**87.0**	**88.2**
Pointing Accuracy Requirement		151759/3.4.6.1	**108.0**	**108.0**	**108.0**

*Thermal/Structural Errors include 1g sag, thermal distortion & hygroscopic effects: (STOP Budget)
**Dyn[illegible]ermal/[illegible]al Erro[illegible] In-orbi[illegible]al varie[illegible]

MODIS POINTING BUDGETS: KNOWLEDGE

POINTING KNOWLEDGE	Component Specification	Specification Paragraph	Object Space Angles: Theta X Roll/Scan (arcsec) (3 Sigma)	Theta Y Pitch/Track (arcsec) (3 Sigma)	Theta Z Yaw (arcsec) (3 Sigma)
STATIC					
Mirror Wedge Half Angle		151766/3.6.4.2	0.0	0.0	0.0
Alignment: Wedge Bisector-Axis		151766/3.2.1.2	0.0	0.0	0.0
Shaft to Motor		151766/3.2.3.1	0.0	0.0	0.0
Timing Induced Scan Underlap		151766/3.4.1.1	0.0	0.0	0.0
Registration Error	0.025 Pixels	151759/3.4.6.3	7.3	7.3	7.3
FPA to Optical Axis	0.0 µm	151771/3.2.9	0.0	0.0	0.0
SMA to OBA Alignment	0.0 arcsec	151800/tbd	0.0	0.0	0.0
SMA to OBA Measurement	5.0 arcsec	151800/tbd	5.0	5.0	5.0
Scan Axis to Mounting Feet Alignment	10.0 arcsec	151800/tbd	10.0	10.0	10.0
Instrument 1g Residual	20.0 arcsec	STOP	20.0	20.0	20.0
Instrument Thermal	20.0 arcsec	STOP	20.0	20.0	20.0
MF Kinematic Mounts	5.0 arcsec	TBD	5.0	5.0	5.0
OBA Hygroscopic	15.0 arcsec	STOP	15.0	15.0	15.0
OBA Kinematic Mounts	5.0 arcsec	TBD	5.0	5.0	5.0
Cube Installation Error	0.0 arcsec	151800/tbd	0.0	0.0	0.0
Cube Angle Measurment Error	5.0 arcsec	151800/tbd	5.0	5.0	5.0
Instr/Spacecraft Mate Error	15.0 arcsec	TBD ICD	15.0	15.0	15.0
Other Static Errors			10.0	10.0	10.0
Static (RSS Total)			**40.0**	**40.0**	**40.0**
DYNAMIC					
Bearings	9.8 arcsec	151766/3.4.1.3	0.0	9.8	19.6
Mirror Control System	90.0 µr	151766/3.4.1.2	37.1	0.0	0.0
Scan Angle Measurement	11.1 arcsec	151766/3.4.1.4	11.1	0.0	0.0
Instrument Thermal Dynamic	5.0 arcsec	STOP	5.0	5.0	5.0
Spacecraft Induced Disturbances	20.0 arcsec	TBD UIID	20.0	20.0	20.0
Other Dynamic Errors			10.0	10.0	10.0
Dynamic (RSS Total)			**45.0**	**24.9**	**30.2**
Dynamic Error Requirement	x1.477s Scan	UIID/3.4	1279.1	28.1	1279.1
Total (Static + Dynamic)			**65.1**	**65.0**	**70.2**
Pointing Knowledge Requirement		151759/3.4.6.1	**90.0**	**90.0**	**90.0**

*Thermal/Structural Errors include 1g sag, thermal distortion & hygroscopic effects: (STOP Budget)
**Dynamic Thermal/Structural Errors from In-orbit thermal variations

POINTING VERIFICATION COMBINES MECHANICAL AND OPTICAL DATA

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- MECHANICAL
  - Spacecraft coordinates are imposed on the mainframe and MODIS top level assembly
  - Alignment cube is mounted and related to the mainframe spacecraft mounting datums
  - Scan mirror assembly orientation is related to alignment cube normals
- OPTICAL
  - Relative spectral band registration data is acquired and reduced (Both IAC and SRCA)
- Pointing knowledge from registration tests are transferred to alignment cube and SRCA fiducials

FPA MEASURED POINTING WILL BE TRANSFERRED TO ALIGNMENT CUBE

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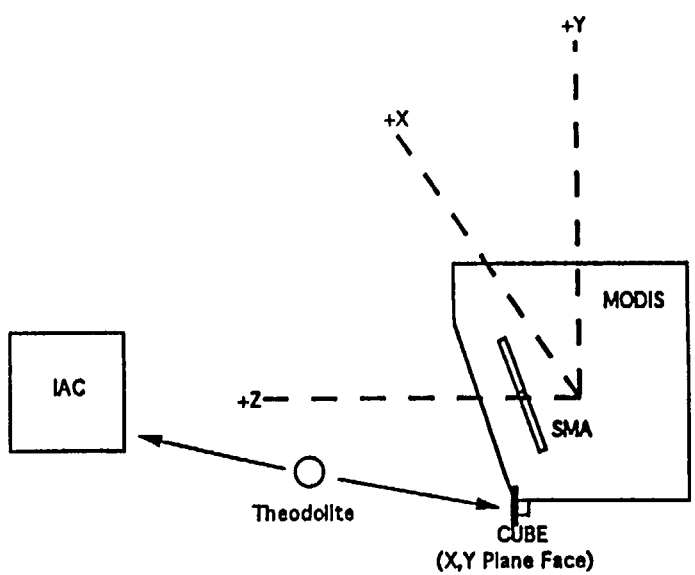
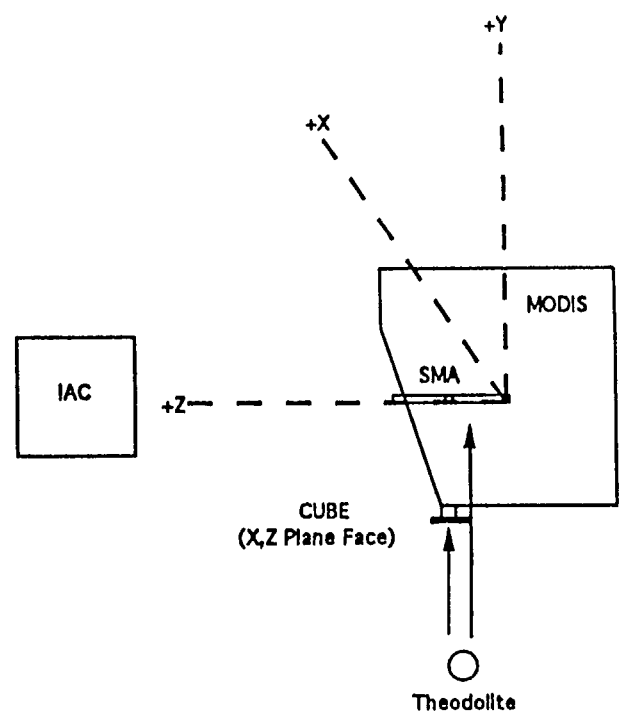
FPA BORESIGHT SCAN (ΔY) and TRACK (ΔX) TRANSFERRED TO CUBE ØX AND ØY



FPA BORESIGHT CLOCKING (ØZ) TRANSFERRED TO CUBE ØZ



SRCA USED TO VERIFY POINTING CHANGES DURING 1G RELEASE

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- MODIS is rotated about ØZ 180° (from +X up to -X up)
- Measurements of alignment cube facets are re-taken
- SRCA fiducials are re-measured
- Registration data re-acquired from SRCA
- Data reduced, compared to baseline to quantify change

EM RESULTS SHOW SPURIOUS SIGNALS BETWEEN BANDS 1 AND 2

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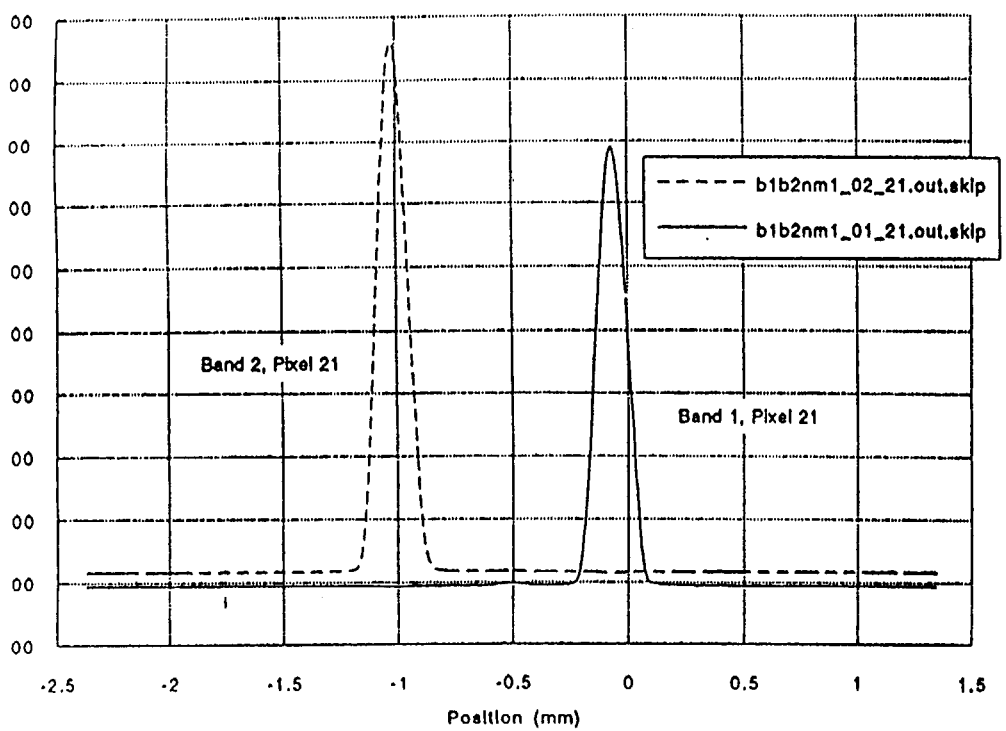
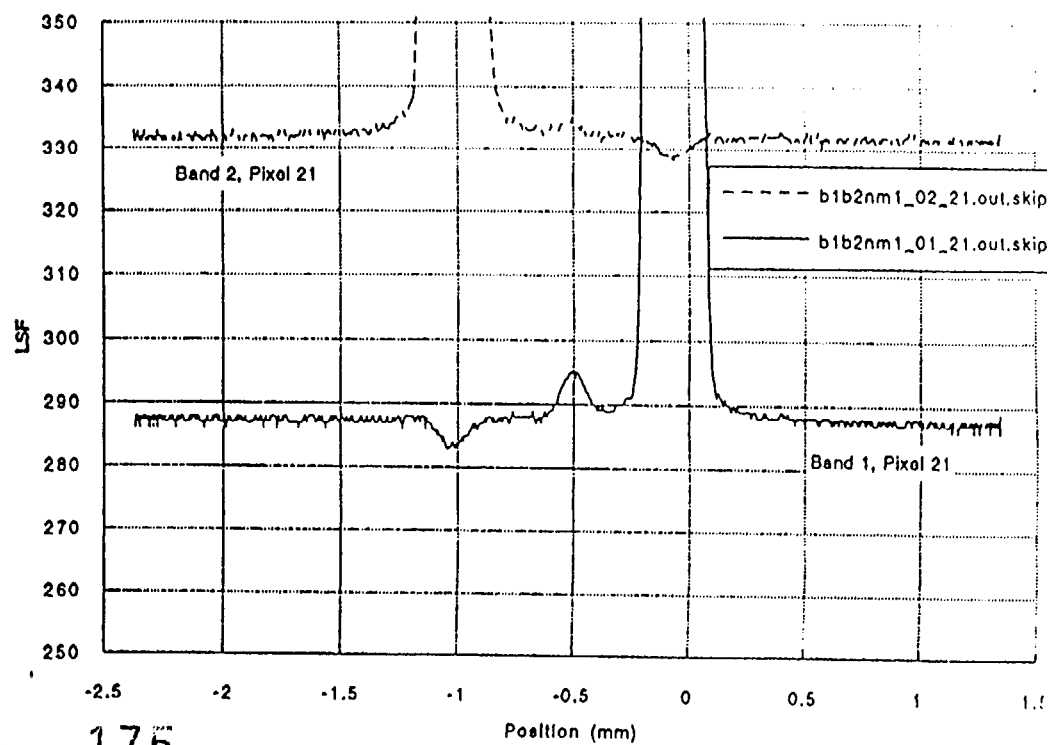
- **0.5% to 1% crosstalk observed**

Nominal



Expanded Scale



PF AOA RESULTS SHOW SUCCESSFUL CORRECTIVE ACTION

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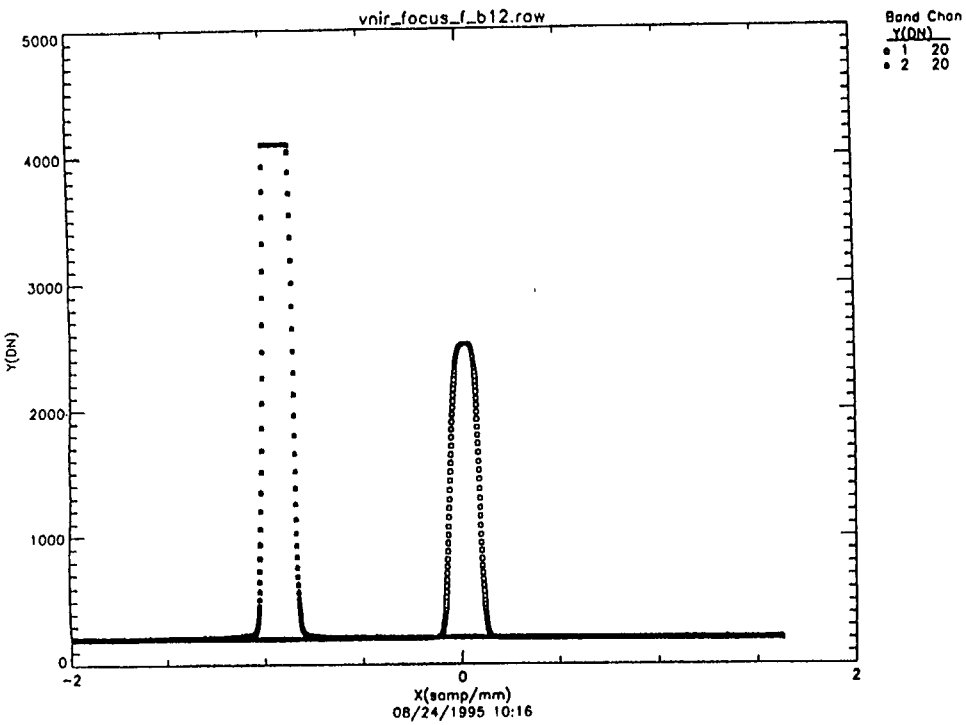
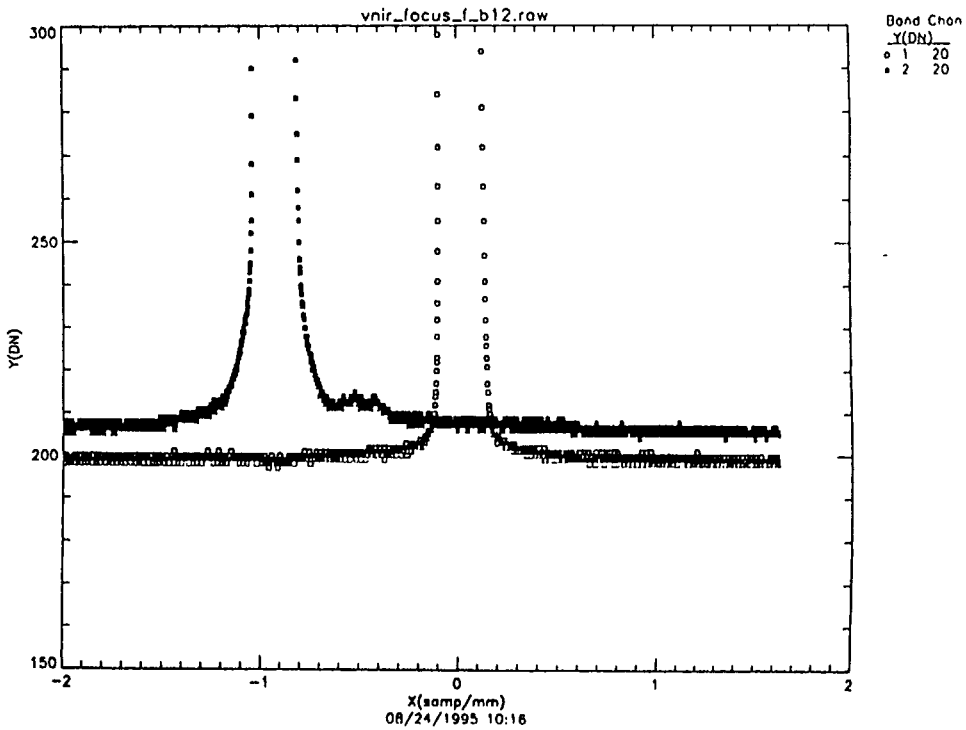
- Inversion of NIR filter mask (optical crosstalk)
- Separation of band 1 and 2 electrical outputs within FPA (electrical crosstalk)





CONCLUSIONS/SUMMARY

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- No significant changes in spatial budgets since the CDR
- All PF spatial performance parameters currently within budgets and spec
  - VIS/NIR meets requirements for IFOV, MTF, and SBR
- Spurious signal between NIR bands 1 and 2 eliminated
  - Small (<.2%) residual error shown in band 2
    - Predicted from modelling corrective action (inverting mask)
- Conceptual pointing verification plan established

Spectral Performance

Jim Young

SPECTRAL CHARACTERIZATION

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- SPMA Anomalous Behavior
- Modeling of Anomaly
- Atmospheric Transmission Effects
  - SIS (100) calibration
  - Relative spectral response
- PFM Measurement Methodology
  - Monochromator usage
  - Out-of band measurements purging

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EM ANOMALOUS RSR CAUSED BY SPMA

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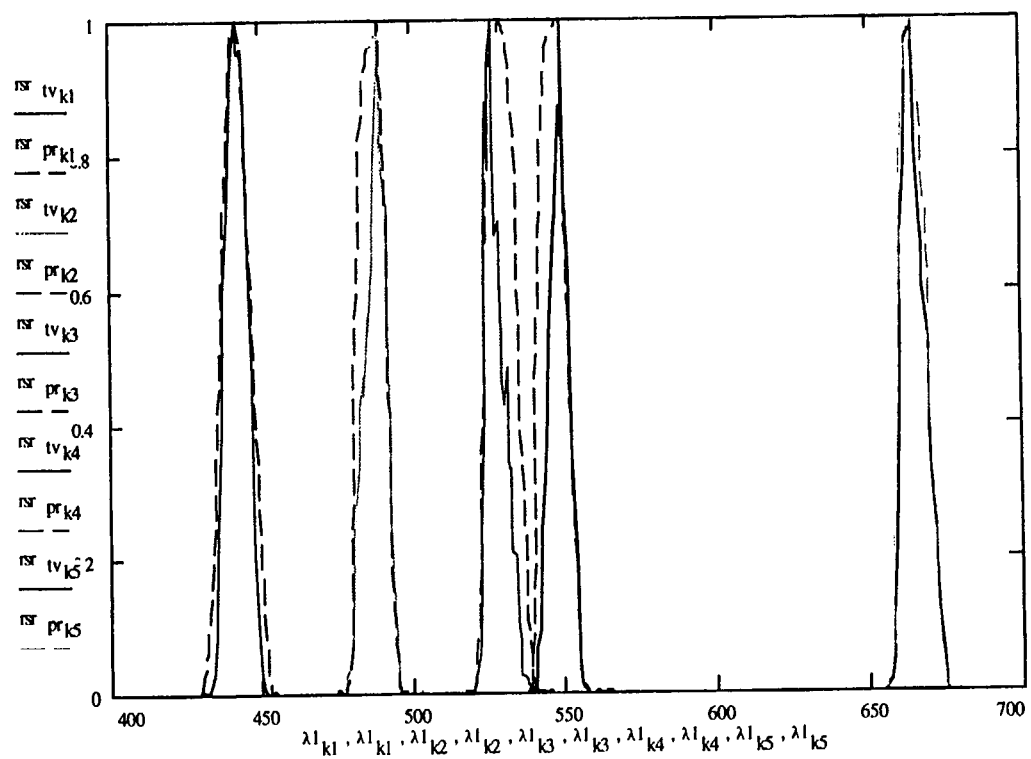
- Measured RSR vs Predicted RSR based on Component Data
- VIS / NIR Bands - 9 through 13
- Dashed curves based upon component measurements
- Solid curves measured RSR in TV using SPMA



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SPMA ANOMALOUS SPECTRAL BACKGROUND USING SIPD

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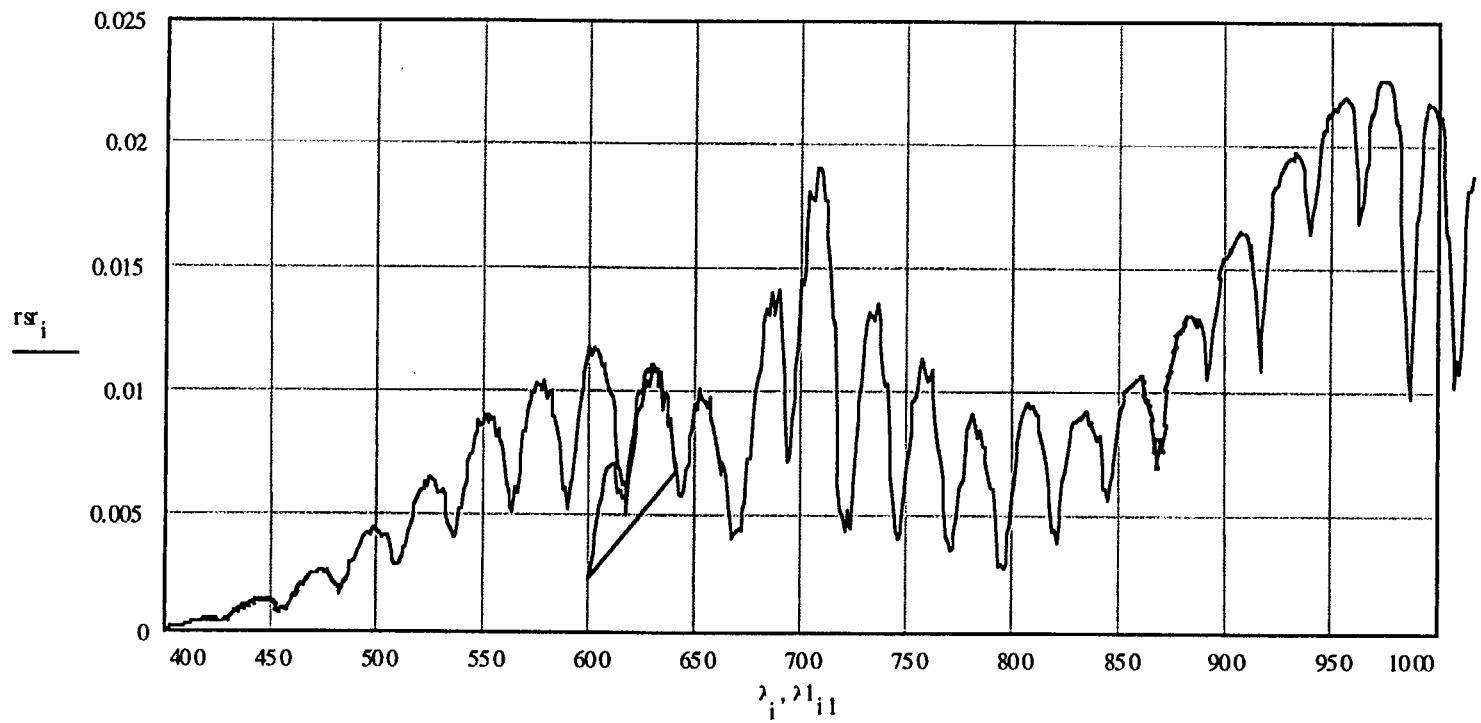

- Double monochromator spectral output as measured with a SiPD
- Alignment of double monochromator was "similar" to that used in T/V tests
- Note cyclic phenomena with a period ≈ 25 nm.

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ANOMALOUS DOUBLE MONOCHROMATOR FUNCTION

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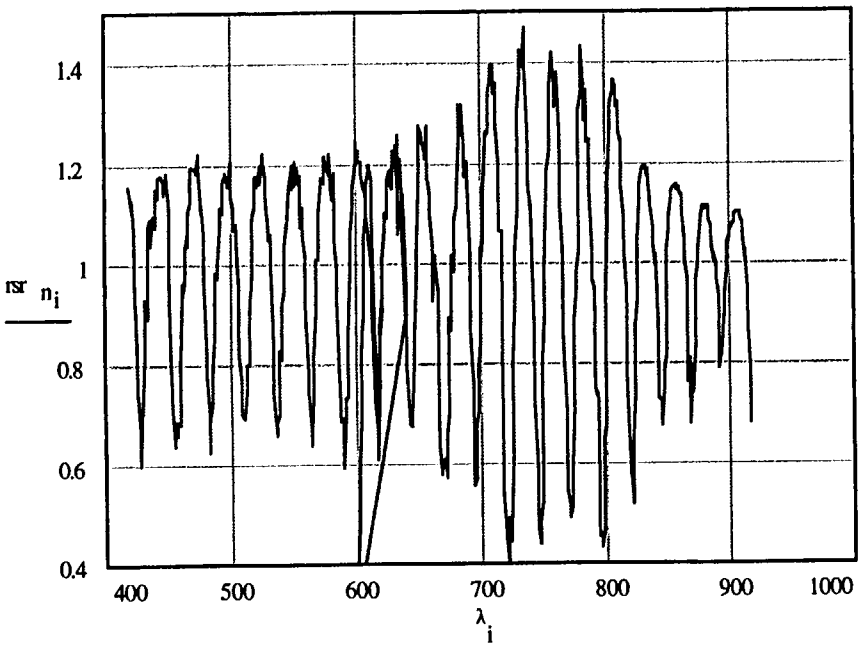

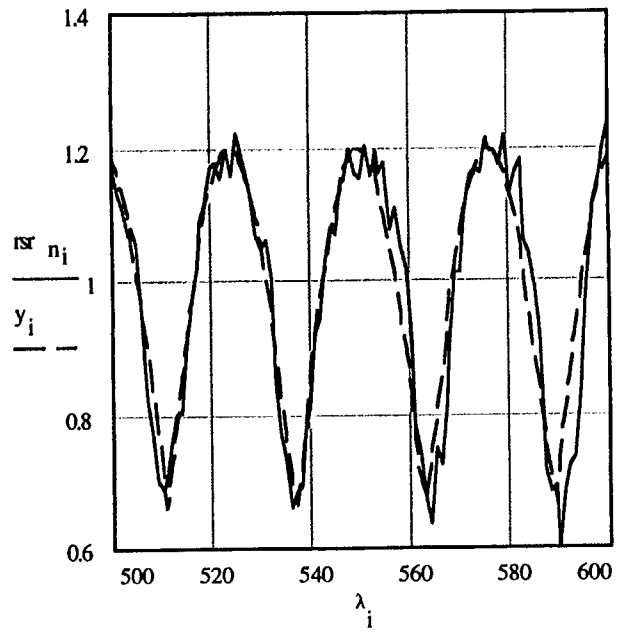

- Original SiPD function averaged with a 25 nm window
- The result averaged function used to normalize SiPD background function
- The resultant function is considered anomalous double monochromator function
- Cyclic phenomena fitted to a rectified sinusoidal function on a pedestal

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HYPOTHESIS FOR THE ANOMALOUS RSR MEASUREMENT

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- Constant spectral misalignment between sections 1 and 2, ≈ 0.35 nm
- One monochromator section has a cyclic misalignment - 1° period
  - Grating is mounted on a 360 tooth gear platform
  - Grating platform gear is driven by a worm
- Spectral effects dependent upon band location and spectral slit width

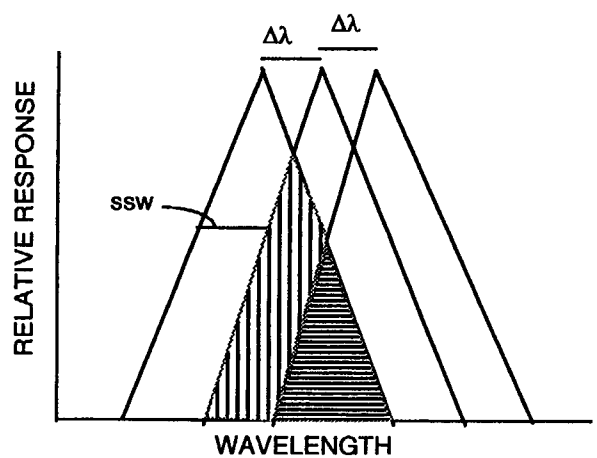

Figure 7 Illustration of how the throughput of a double monochromator is influenced by a combination of constant and variable misalignment factors between the two monochromator sections

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SPMA ANOMALOUS SPECTRAL RESPONSE FUNCTION

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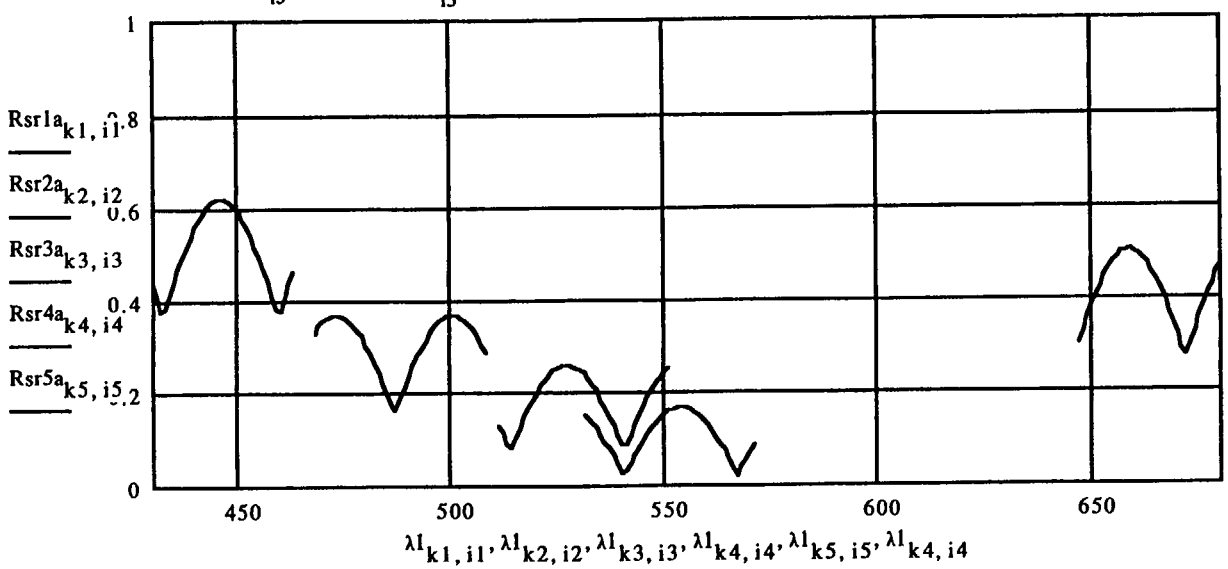
$i1 \equiv 1 \quad i2 \equiv 3 \quad i3 \equiv 4 \quad i4 \equiv 5 \quad i5 \equiv 8$

$band_{i1} = 9$	$\lambda_{ctr_{i1}} = 443$	$BW_{i1} = 10$	$ssw_{i1} = 0.935$	$E \equiv 10$
$band_{i2} = 10$	$\lambda_{ctr_{i2}} = 488$	$BW_{i2} = 10$	$ssw_{i2} = 0.672$	$\lambda_{00} \equiv 405$
$band_{i3} = 11$	$\lambda_{ctr_{i3}} = 531$	$BW_{i3} = 10$	$ssw_{i3} = 0.555$	$\Delta\lambda_c \equiv 0.35$
$band_{i4} = 12$	$\lambda_{ctr_{i4}} = 551$	$BW_{i4} = 10$	$ssw_{i4} = 0.448$	$\Delta\lambda_v \equiv 0.35$
$band_{i5} = 13$	$\lambda_{ctr_{i5}} = 667$	$BW_{i5} = 10$	$ssw_{i5} = 0.816$	



Anomalous spectral response function attributable to SPMA malfunction

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PREDICTED RSR BASED UPON ANOMALOUS SPMA MODEL

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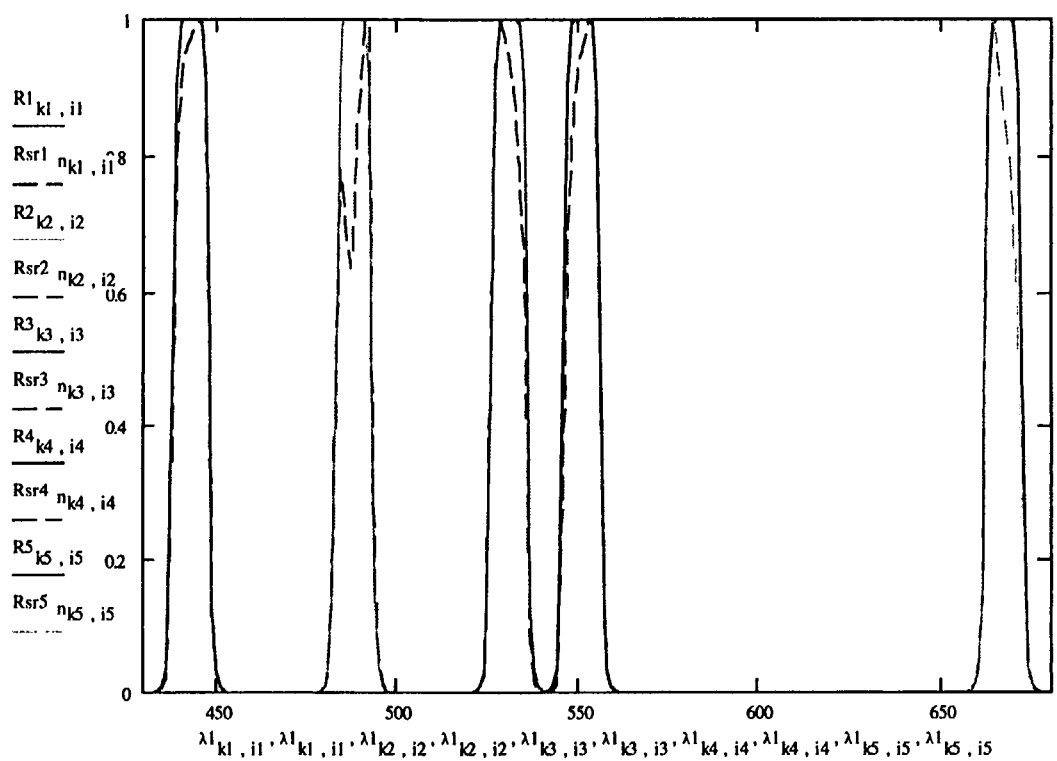
- The SPMA model qualitatively demonstrates the anomalous behavior
- Spectral bands 9 through 13
- Assumed misalignment - 0.35 nm constant and 0.35 nm variable



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MODIS BANDS THAT ARE AFFECTED BY ATMOSPHERIC TRANSMISSION

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- LOWTRAN 7 used in modeling
- Parameters - five meter path with 30% relative humidity
- Additional details documented in PL3095-N05082 "Atmospheric Transmittance Effects on Calibration" dated 28 June 1995

Band	Center wavelength, μm	Atmospheric absorption, %
18	0.936	2.7
19	0.940	1.6
20, 21	3.750	0.7
24	4.465	4.4
25	4.515	2.1
26*	1.375	20.7
27*	6.715	62.7
28*	7.325	18.4
29	8.550	1.2
33*	13.335	2.6
34*	13.635	3.8
35*	13.935	5.8
36*	14.235	18.5

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ATMOSPHERIC EFFECTS ON SIS(100) OUTPUT FOR BAND 26

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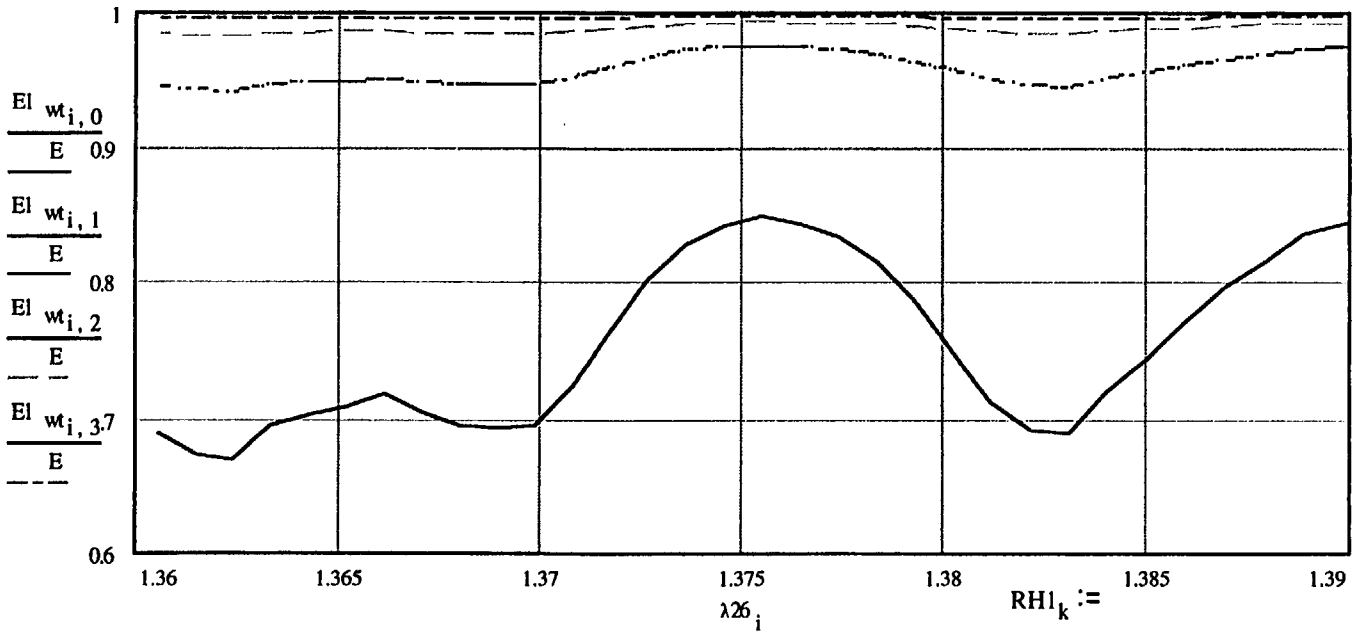
- Radiometric calibration of SIS(100) dependent upon relative humidity level
- Model accounts for variable path length within SIS
- LOWTRAN 7 output fit to an analytical expression
- Relative humidity levels: 0.3, 0.01, 0.001, and 0.0001



$$El_{wt_{i,k}} := \sum_j \rho \cdot \frac{A_{ex}}{A_T} \cdot \left(\rho \cdot \frac{A_w}{A_T}\right)^j \cdot e^{-\left[\alpha 26_{avg_i} \cdot \left(path1_j \cdot RH1_k\right)^{0.564}\right]}$$

$RH1_k :=$

0.3
0.01
0.001
0.0001

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ATMOSPHERIC EFFECTS ON RSR FOR BAND 27

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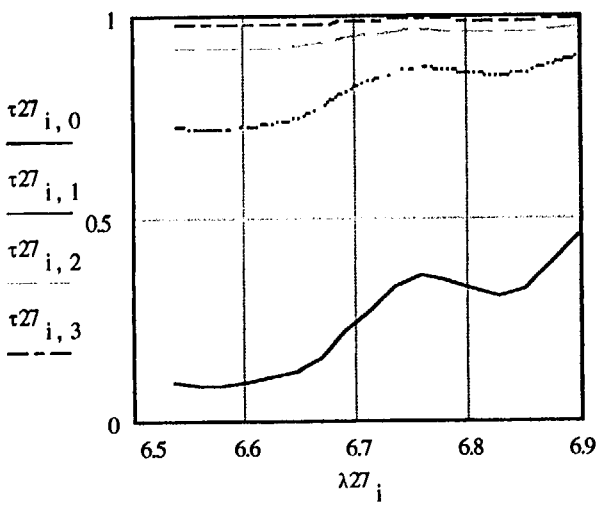
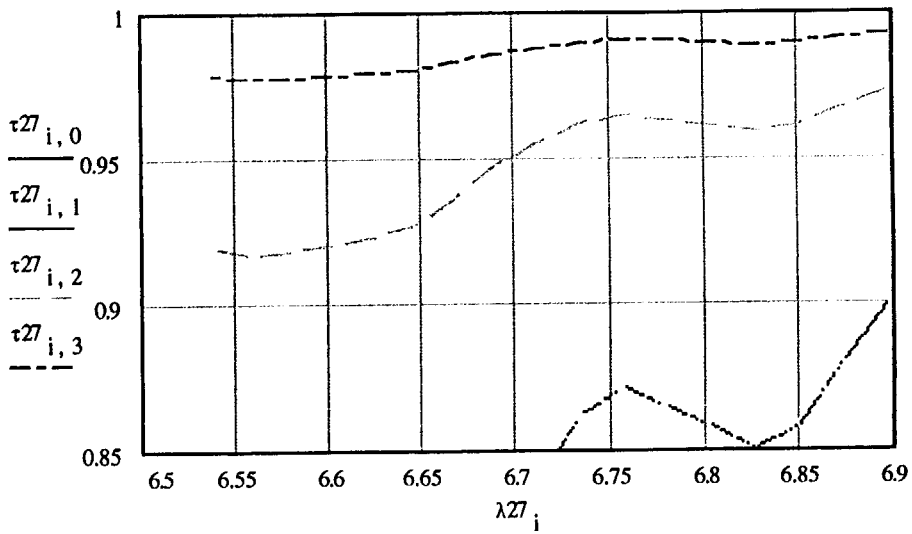
- RSR characterization of band 27 dependent upon relative humidity level
- Model assumes 5 meter path length
- LOWTRAN 7 output fit to an analytical expression
- Relative humidity levels: 0.3, 0.01, 0.001, and 0.0001





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ATMOSPHERIC EFFECTS ON RSR FOR BAND 33 through 36

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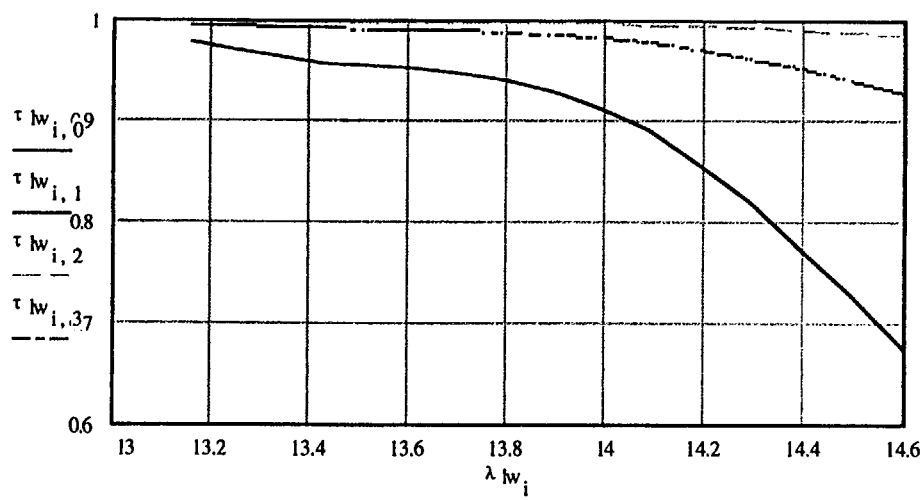
- RSR characterization of band 33 - 36 are affected by carbon dioxide
- Model assumes 5 meter path length
- LOWTRAN 7 output fit to an analytical expression
- Relative carbon dioxide levels: 1.0, 0.1, 0.01, 0.0001

$i := 0..15 \quad path1 := 7 \quad k := 0..3 \quad r_{co2_k} :=$

1.0
0.1
0.01
0.0001

$$\tau_{lw_{i,k}} := e^{-\alpha lw_{avg_i} \cdot \left(path1 \cdot r_{co2_k}\right)^{0.71}}$$



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OOB MEASUREMENT METHODOLOGY USES TWO MODES

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- Set of broadband filters used to obtain integrated OOB response - SPMA without gratings used
- Spectral measurement using SPMA in dispersive mode (limited by available SNR)

ID	Substrate	Thickness (mm)	Transmission >50% edges (nm)	Block ≤ 0.1 %
1	BG-40	2	Schott color glass	> 750
2	RG-610	2	Schott color glass	400 - 550
3	Silicon	≤ 2	1500 - 5100 LWP	900 - 1200
4	Ge	2	2300 - 5100 LWP	900 - 2100
5	Glass as reqd	as reqd	<1000 - 3200 SWP	3500 - 5100
6	Silicon	as reqd	1000 - 5000 SWP	5100 - 5300
7	Silicon	2	1000 - 2200 SWP	2500 -5200
8	Ge	2	2000 - 14500 uncoated	< 1900
9	Ge	as reqd	8200 - 14500 LWP	<8000 - 5000
10	MgF2	as reqd	2000 - 10000 SWP	> 11000
11	CaF2	as reqd	2000 - 12000 SWP	> 13000
12	Ge	2	2800 - 5100 LWP	900 - 2700
13	Ge	2	4600 - 5200 LWP	2700 - 4500
14	Ge	≤ 2	6400 - 10100 SWP	<5000-6200, 10500- 12000
15	Ge	≤2	10500 - 14600 LWP	<6000 - 10000
16	RG N9	as reqd	Schott color glass	<700
17	RG 665	as reqd	Schott color glass	<650
18	RG 780	as reqd	Schott color glass	<750

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DIFFERENCE IN PFM AND EM SPECTRAL CHARACTERIZATION

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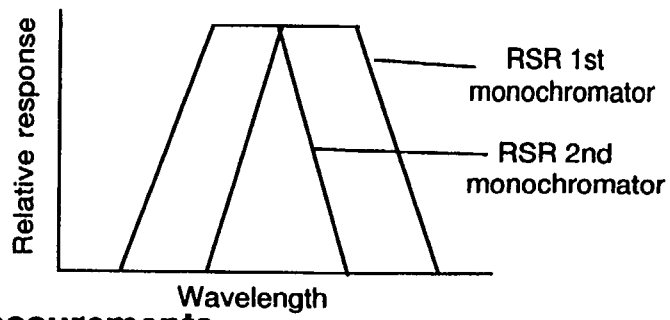
- Optical path purging philosphy is different
  - No purging used in EM tests
  - No planned optical purging in high bay clean room - PFM
  - SIS(100) radiometric calibration in optics lab will be purged
  - Purge SIS(100) - MCC optical path
  - Purge SPMA - MCC
- Elimination of SPMA modulation
  - First monochromator section has larger spectral slit width, 3x
  - Second monochromator section has spectral slit width used in EM, 1x.



- Out-of-band RSR measurements
  - EM used broadband optical filters to assess integrated OOB response
  - PFM will use SPMA dispersive mode in addition to broadband optical filter set

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Stray Light

JIM YOUNG

BRIGHT / DARK TARGET WITHIN FIELD

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- Test will only be done in ambient environment
- MODIS will be operating with the scan mirror running
- Simulate stray light originating from sunlight that is reflected from the earth
- Earth subtends an effective solid angle of approximately 2.5 sr as seen by MODIS nadir aperture door
- Simulate the earth as a "far field stray light source"
- SIS(100) shall be positioned between MODIS and a light trap
- Three positions of the SIS(100) shall be used
- Illuminating solid angles at points on nadir aperture plane - 0.5 to 1.5 sr
- This data will be merged with NFR that covers $\pm$ 6.6°
- Data reduction approach
  - Pixel centered in a 21 km x 21 km region, the surround is changed from Ltyp to Lcloud
  - Difference in signal shall not be greater than 0.004 Lcloud

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STRAY LIGHT TEST CONFIGURATION I

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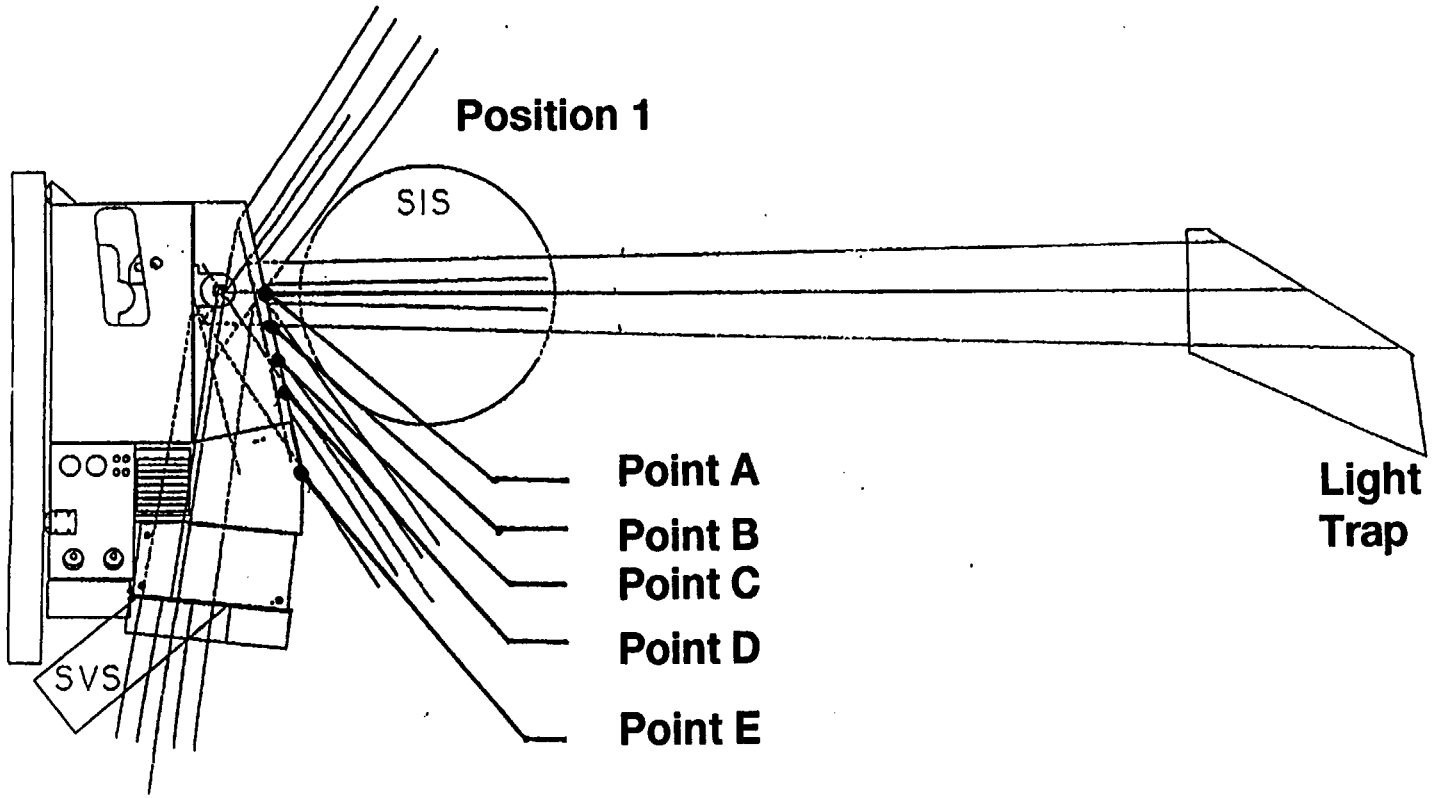

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STRAY LIGHT TEST CONFIGURATION II

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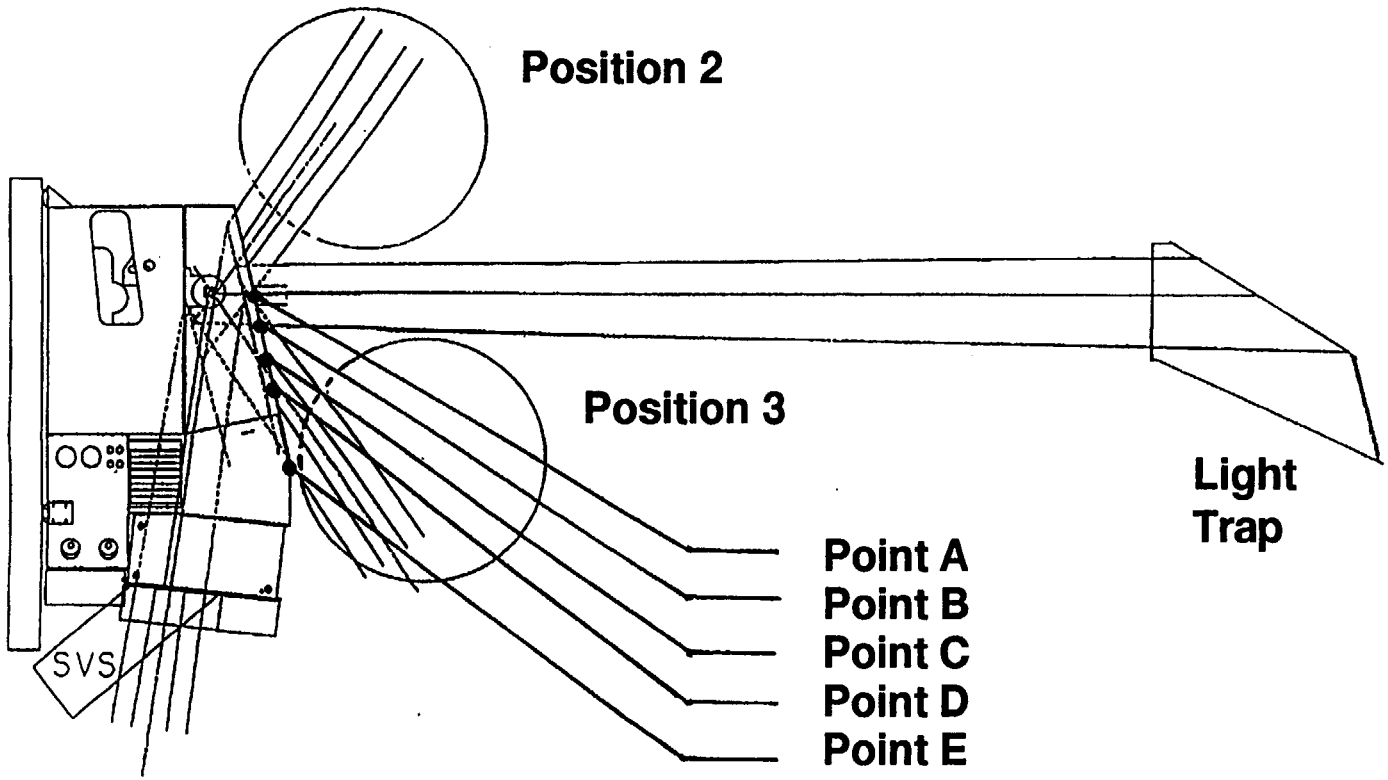

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SNR LEVELS AVAILABLE WITH PROPOSED INTEGRATED STRAY LIGHT METHOD

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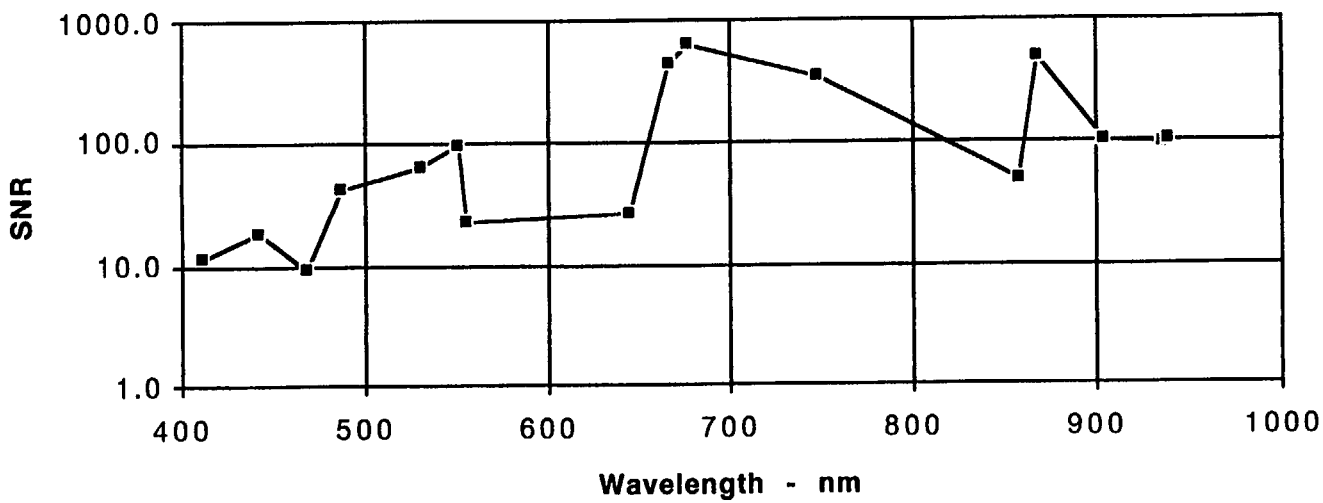
SNR assuming MODIS just meets stray light and SIS(100) simulates earth solid angle illumination. (SNR can be enhanced by signal averaging- multiple scans)



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WARM TARGET WITHIN FIELD DIFFRACTED LIGHT

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- Test will be done only in ambient
- This test evaluates diffracted light - MWIR & LWIR
- Two reticles patterns used with the IAC blackbody source
  - 5 x 5 IFOV central target of Ltypical
  - 20 x 20 IFOV surround target of 0.1 Ltypical
  - 20 x 20 IFOV surround target of Ltypical
  - Signal change by less than 1 % Ltypical
- Equivalent radiance differences will be used since low radiance in ambient conditions results in water condensation problems

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IN-FLIGHT CALIBRATION

IN-FLIGHT CALIBRATION TOPICS

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- Blackbody (Johnson and Bauer)
  - Performance requirements
  - Performance tests
  - Build status
  - Characterization/calibration
- Solar Diffuser (Johnson and Young)
  - Performance requirements
  - Build status
  - Round robin
  - Stray light modeling
  - Verification/calibration

IN-FLIGHT CALIBRATION TOPICS (cont)

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- Solar Diffuser Stability Monitor (Johnson)
  - Performance requirements
  - Build status
  - Verification/calibration
- Spectroradiometric Calibrator Assembly (Johnson)
  - Performance requirements
  - Build status
  - Verification/calibration

BLACKBODY

MODIS EM BLACKBODY ASSEMBLY

94-12-147

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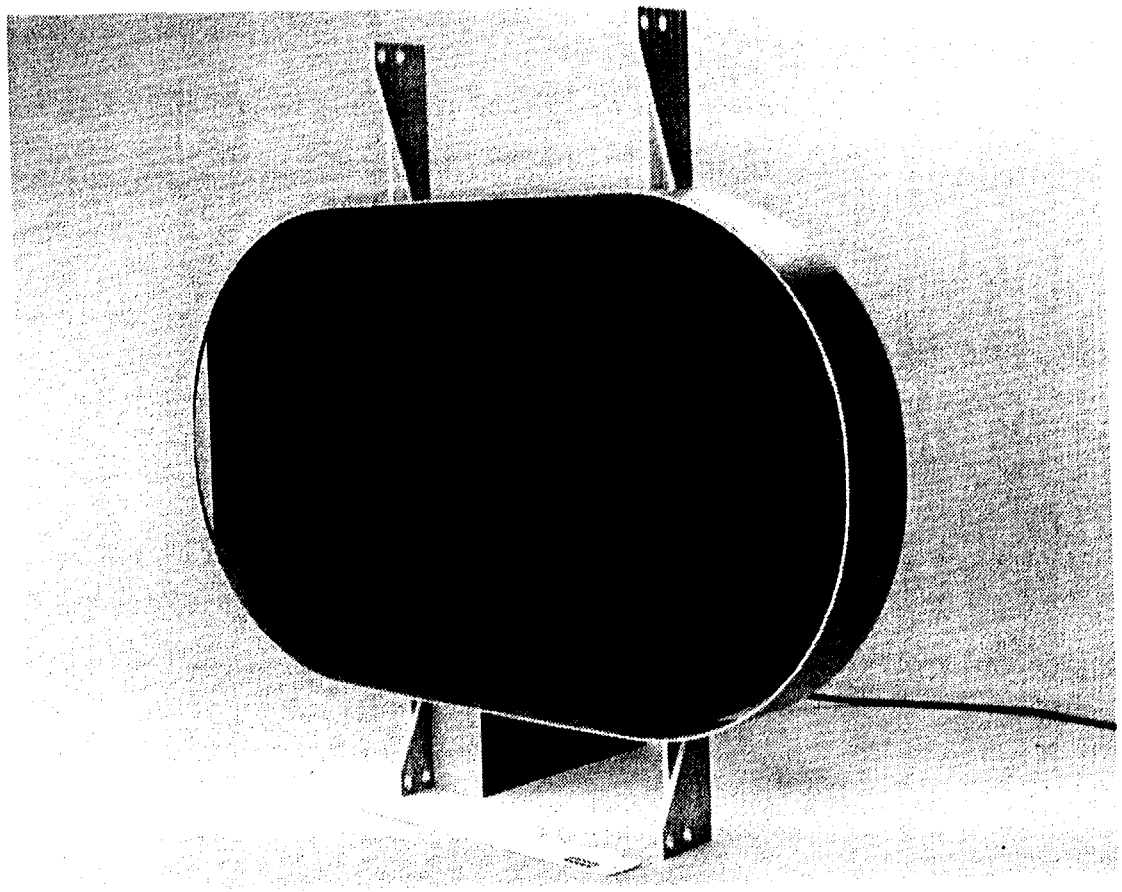

P/N E405360.00

BLACKBODY DESIGN CONSISTENT WITH REQUIREMENTS

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TOP SYSTEM REQUIREMENTS

- ABSOLUTE 1% (1 Sigma) RADIOMETRIC CALIBRATION OF MWIR AND LWIR BANDS (0.75% Band 20; 0.5% Bands 31,32)
- DC RESTORATION VIEW FOR ALL BANDS

BLACKBODY CONSTRAINTS / DERIVED REQUIREMENTS (SPEC 151790)

- FULL APERTURE ILLUMINATION FILLING 46 IFOVS ALONG-SCAN
- LIMITED PACKAGING VOLUME PRECLUDES TRADITIONAL CAVITY DESIGN
- EFFECTIVE EMITTANCE $\geq$ 0.992 AND KNOWN TO WITHIN 0.004 FOR INSTRUMENT VIEW ANGLES OVER 3.5 - 14.4 μm
- EFFECTIVE TEMPERATURE KNOWLEDGE $\leq$ 0.1K OVER 280K TO 320K
- TEMPERATURE SENSORS' CALIBRATION TRACEABLE TO NIST
- AMBIENT AND 315K TEMPERATURE CONTROL MODES

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V-GROOVE BLACKBODY ACHIEVES HIGH EMISSIVITY

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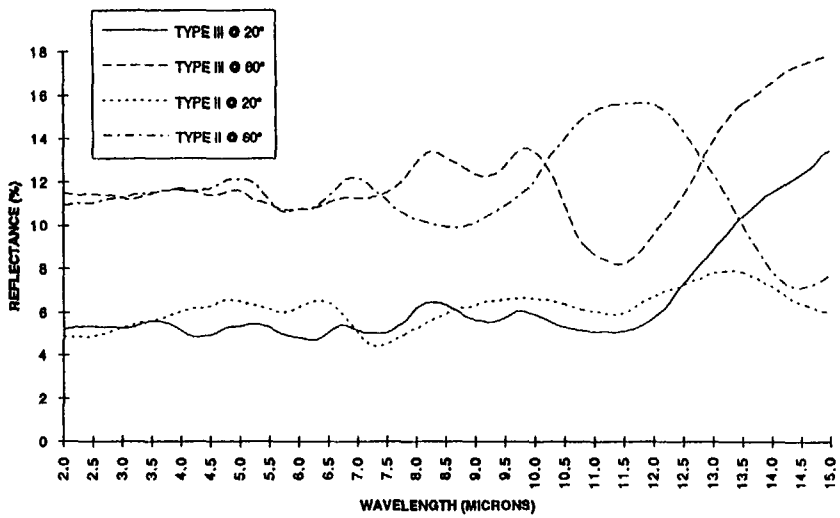
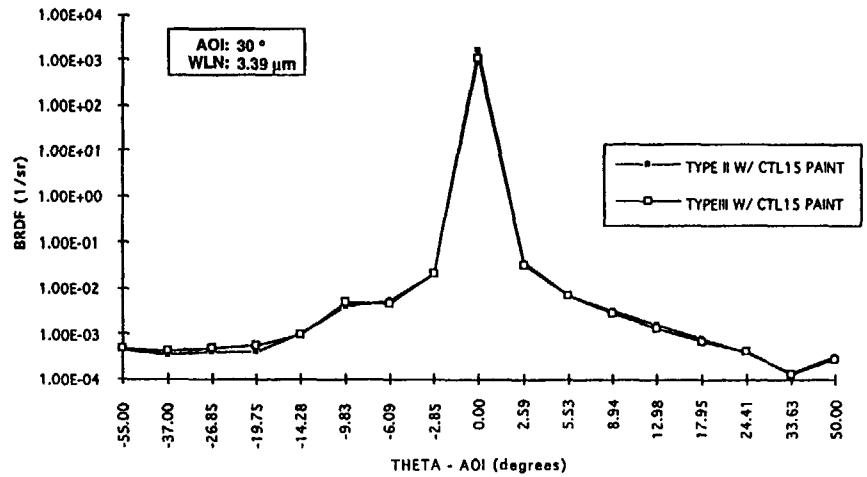
- **BB SURFACE HIGHLY SPECULAR W/ LOW REFLECTANCE (ρ) OVER 3.5 - 14.4 μ m**

REFLECTANCE & BRDF FOR ANODIZED ALUMINUM W/ THIN LAYER CTL15 PAINT



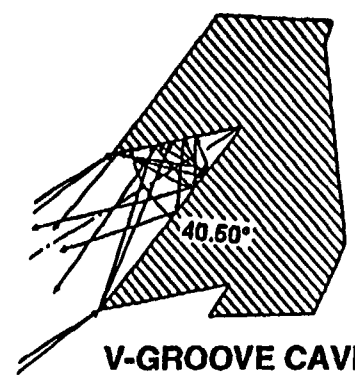


OARDAS MODEL PREDICTS EMISSIVITY OF SINGLE CAVITY

- PREDICTIONS FOR MODIS VIEW ANGLES (4 reflections min)
- S AND P POLARIZATIONS TREATED SEPARATELY
- REFLECTANCE DOMINATES SCATTER AS CONTRIBUTOR
- WORST CASE REFLECTANCE VALUES USED
- PERFECT CAVITY GEOMETRY ASSUMED
- DIFFRACTION EFFECTS NOT INCLUDED

PREDICTED ε_{cavity}

WLN	TYPE II	TYPE III
4 μm	.9991	.9991
14 μm	.9971	.9957



V-GROOVE CAVITY

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PROCESS	ENG MODEL	PF MODEL
SUBSTRATE MATERIAL	1100 AL ALLOY	1100 AL ALLOY
SUBSTRATE FORMING	WIRE EDM	WIRE EDM
FINISH	HAND POLISHED T0 4 μINCH RMS	HAND POLISHED T0 600 GRIT LEVEL
ANODIZE	TYPE II (.0015 " THICK) W/ HOT WATER SEAL	TYPE III (.0023 " THICK) W/ HOT WATER SEAL
POST-ANODIZE	HAND POLISHED TO REMOVE SMUDGES	N/A (TO HARD TO POLISH)
PAINT	SINGLE LAYER (<.001") CTL15 GLOSS BLACK EPOXY	SINGLE LAYER (<.001") CTL15 GLOSS BLACK EPOXY
POST-PAINT	HAND POLISHED TO REMOVE 'ORANGE PEEL' AND DUST	HAND POLISHED TO REMOVE 'ORANGE PEEL' AND DUST
ENVIRONMENTAL EXPOSURE	VACUUM BAKE AT 60° C FOR >48 HRS	VACUUM BAKE AT 60° C FOR >48 HRS
EVALUATION OF SAMPLE PIECES	VISUAL @ 50X TO 200X BRDF @ 3.39 μm REFLECTANCE 2 - 15 μm	VISUAL @ 50X TO 200X BRDF @ 3.39 μm REFLECTANCE 2 - 15 μm

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BLACKBODY SURFACE FINISH:

EM VERSUS PFM

MODIS
GSFC SBRC

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BB TEMPERATURE PROFILE DEMONSTRATES HEATER CONTROL

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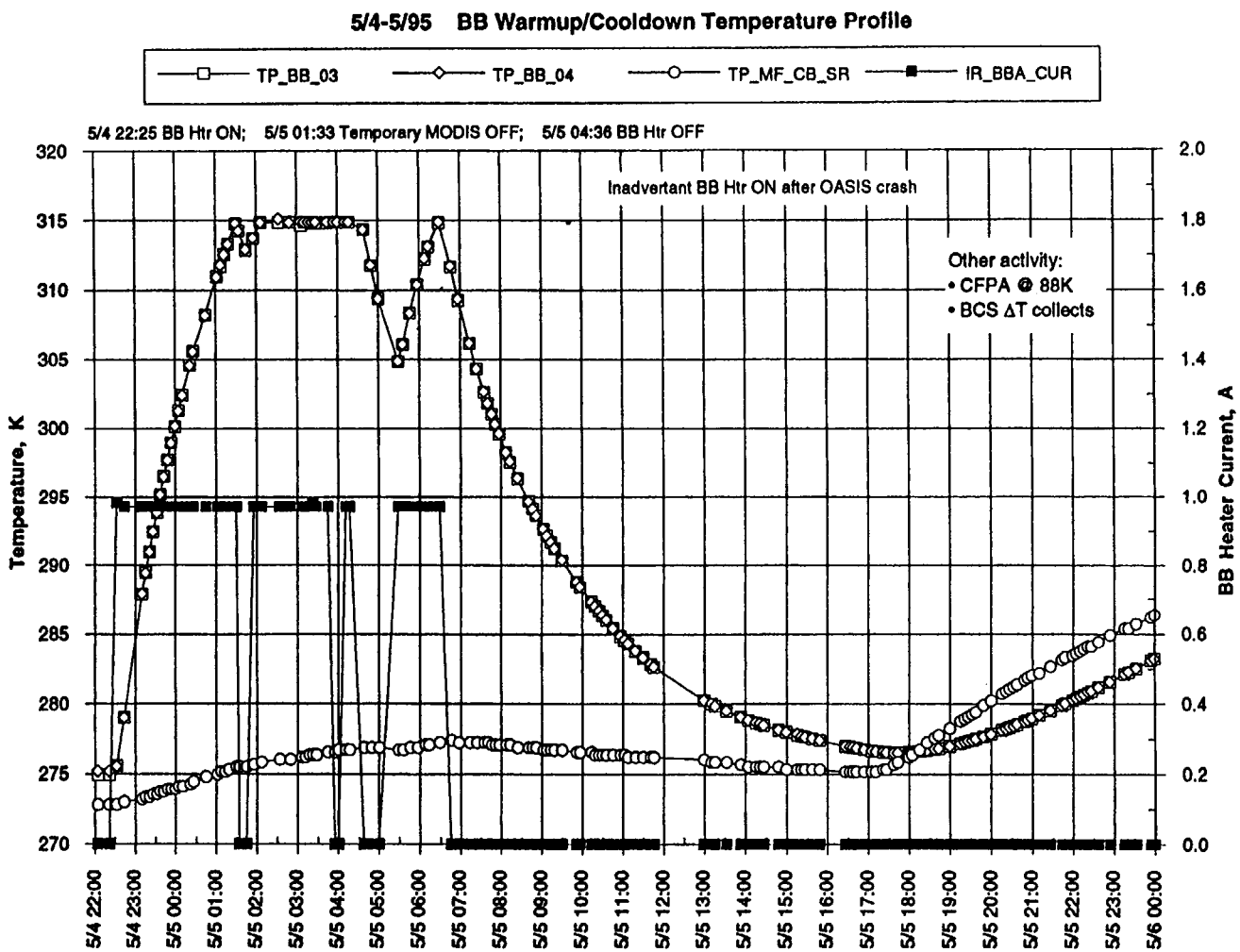

MODIS EM TVØ: 5.04-05/95 bb t profile.a Chart 1

PFM BLACKBODY BUILD STATUS

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- ALL HARDWARE COMPONENTS IN-HOUSE OR ON-ORDER
  - PARTS NOT YET RECEIVED: HEATER, THERMISTORS AND FLEX CABLE
  - HEATER PROCUREMENT DRIVES SCHEDULE. WORK AROUND IS TO UP-SCREEN SPARE EM HEATER TO FLIGHT LEVEL
- HAND POLISHING OF PFM ALUMINUM V-GROOVE SUBSTRATE COMPLETE
- PFM BB TO BE NEARLY IDENTICAL TO EM WITH EXCEPTION OF SURFACE FINISH
- PFM SURFACE FINISH METHOD HAS BEEN DEVELOPED FROM EXPERIENCE WITH EM BB
  - USING TYPE III (HARD) ANODIZE DUE TO ITS RESISTANCE TO SURFACE CRAZING
  - FINISH VERIFIED BY MEASURING BRDF AND SPECTRAL REFLECTANCE OF TEST SAMPLES AFTER ENVIRONMENTAL EXPOSURE AND EVALUATING EMISSIVITY W/ MODEL.

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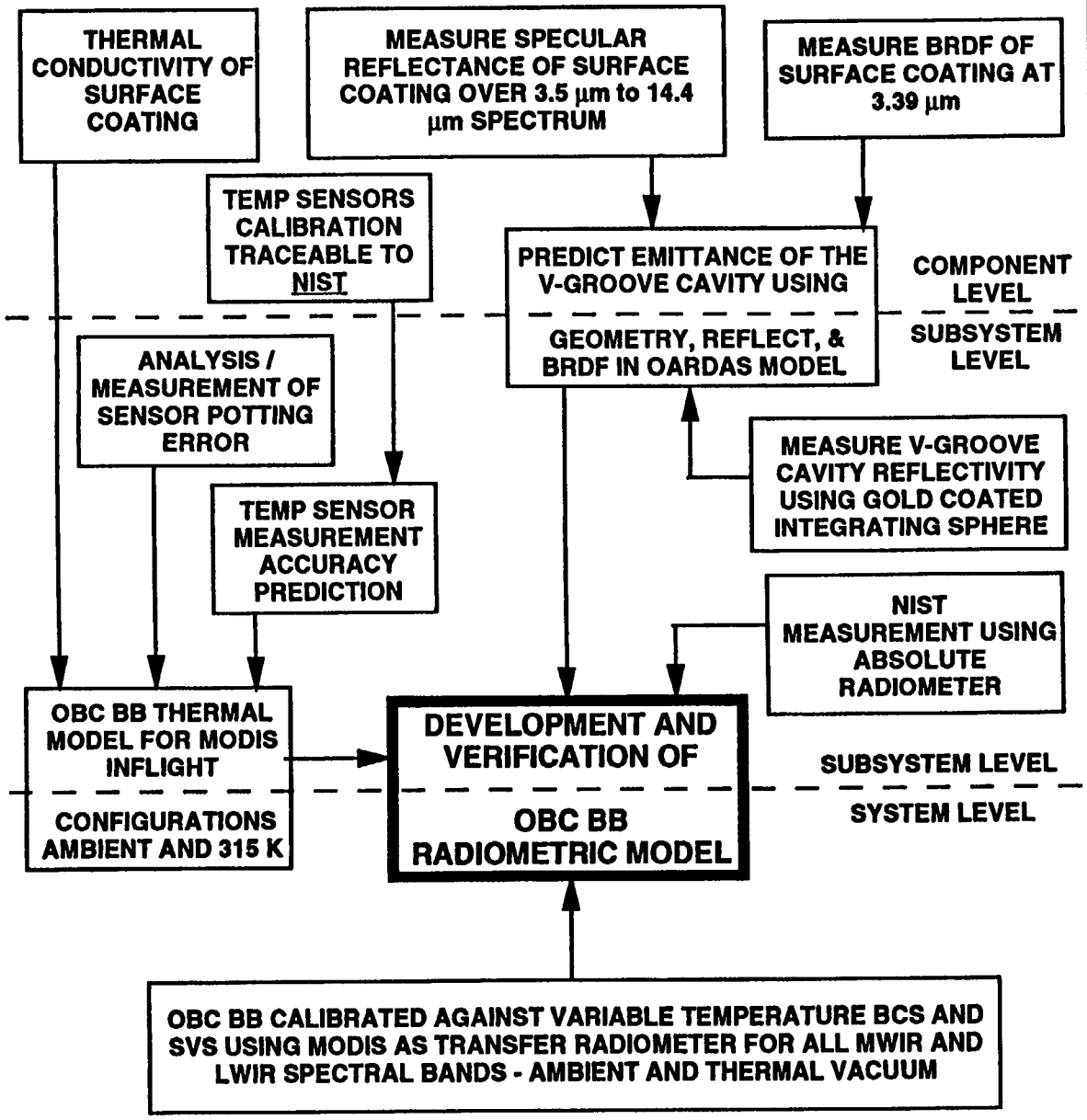
OBC BLACKBODY CHARACTERIZATION / CALIBRATION



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CONVERSION OF RESISTANCE TO DIGITAL NUMBER

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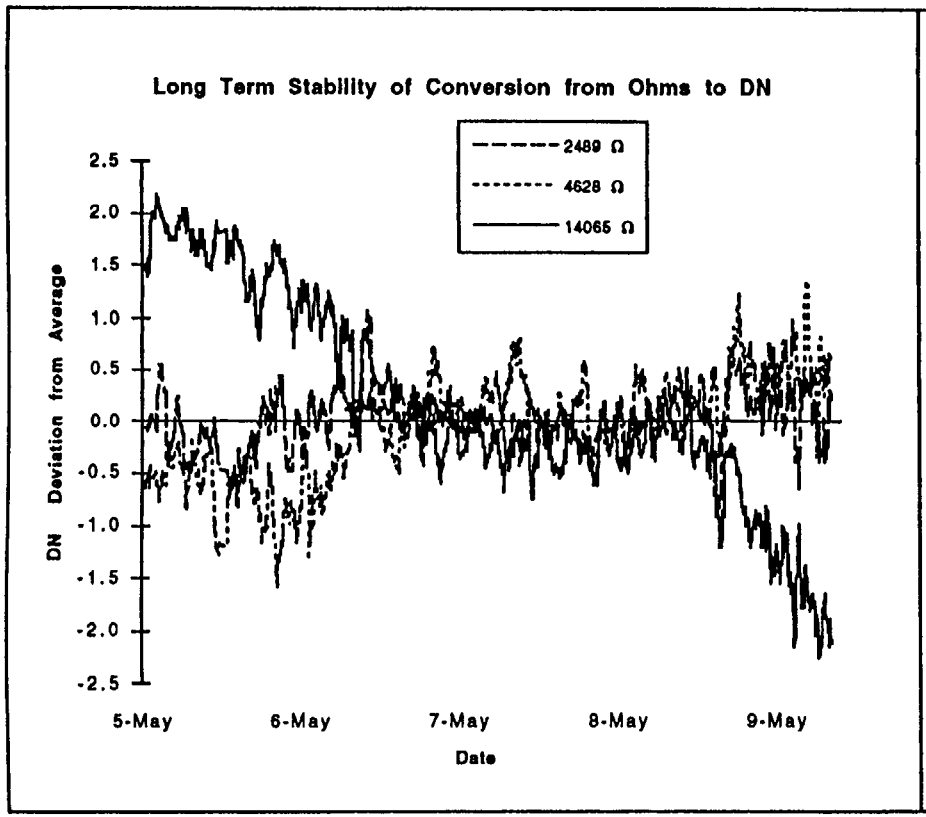

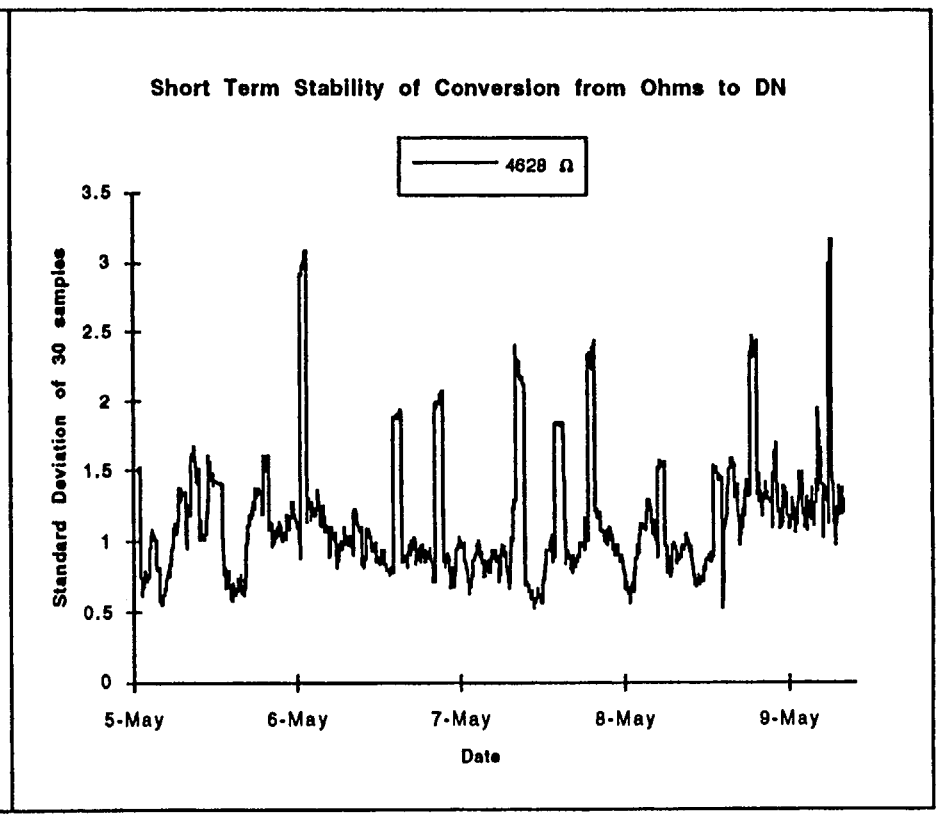

OBC TEMPERATURE CALIBRATION

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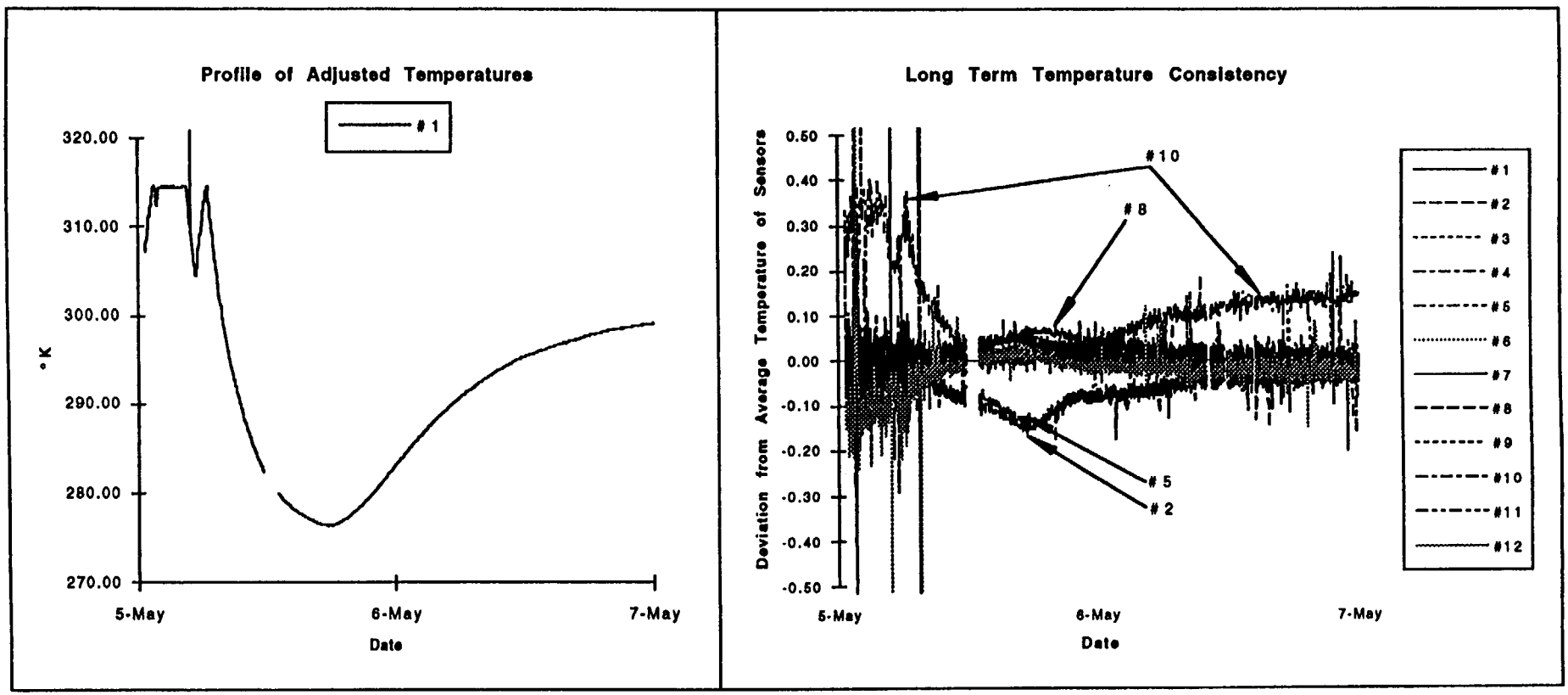

DETERMINING OBC EMISSIVITY FROM BCS RADIOMETRY

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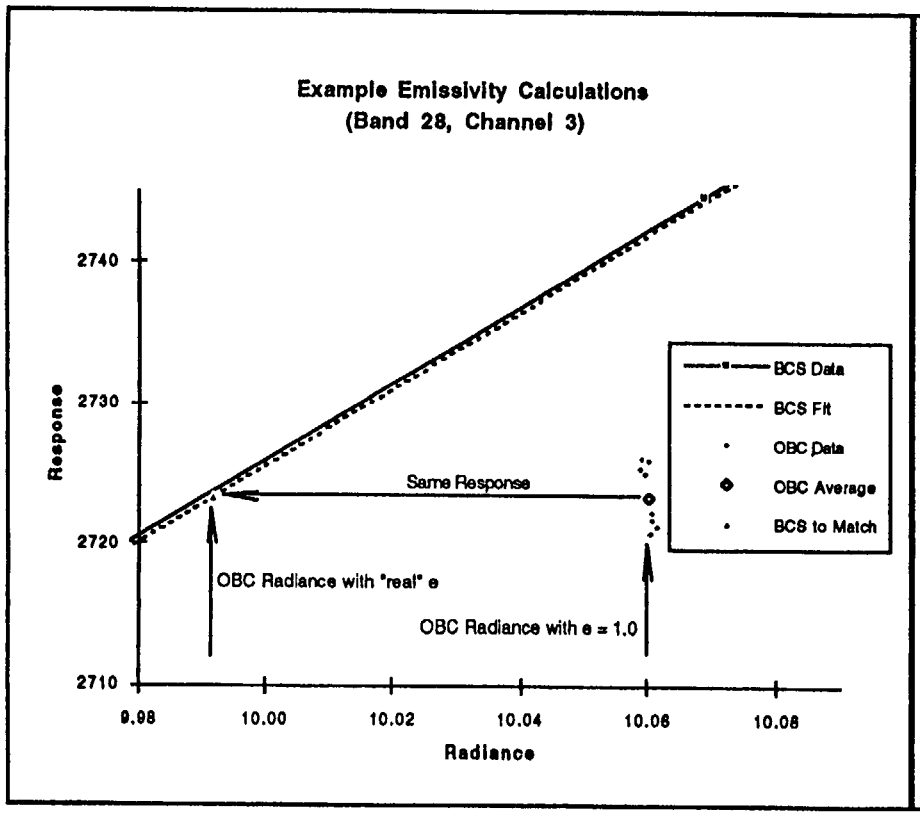

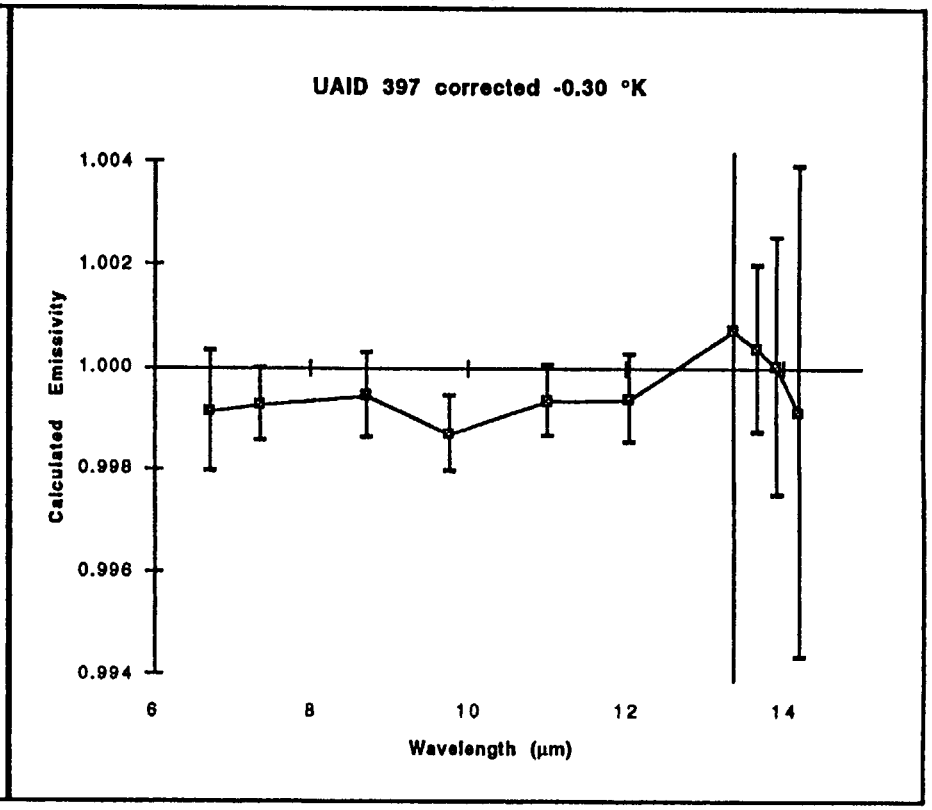

Solar Diffuser Pre-Flight Characterization

Jim Young

SOLAR DIFFUSER CALIBRATION/ CHARACTERIZATION

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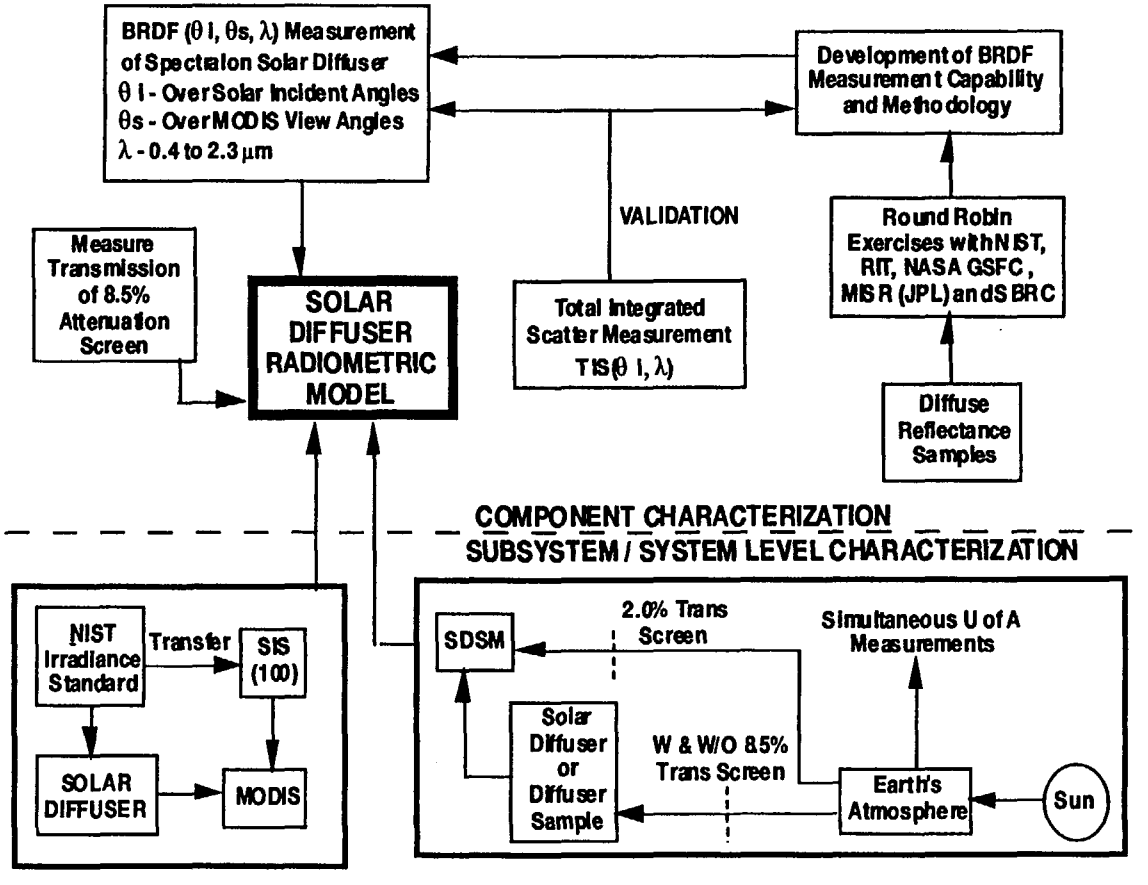

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CHARACTERIZATION NEEDED FOR STANDARDIZATION BETWEEN SENSORS

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- Round robin EOS BRDF/ BRF measurement comparison
- Important due to wide discrepancies in previous comparison exercises
- NASA GSFC is responsible for overseeing this
- Candidate participants: NIST, NASA / GSFC, NASA / JPL, RIT, SBRC / HAC, U of Az / OSC
- Candidate materials: pressed halon, sintered halon, Spectralon, ground aluminum
- Wavelength region: 8 spectral points in 443 nm to 2130 nm
- Incident angles: 0°, 15°, 30°, 45°, and 60°
- Viewing angles: -60° to 60° in 10° steps
- MODIS is a subset of this

  Viewing angles: 13.5° ± 2°

  Incident angles: 53° to 63°

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TWO OPTIONS FOR CHARACTERIZATION

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- Option I: use solar illumination
  - Preferred approach, technically
  - MODIS looks out of B32 in a westerly direction
  - Contamination barriers needed
  - Heliostat (provided by NASA) would redirect sunlight toward MODIS
  - Univ of Az OSC would provide the necessary ancillary atmospheric and solar measurements
  - Complex set-up required
  - Implementation would require time and resources not in the plan.
- Option II: Use NIST irradiance standard
  - Quartz halogen lamp illuminates solar diffuser via refractive collimator
  - Refractive collimator operates at f/3 to f/5
  - Collimated source is calibrated via NIST irradiance standard / halon diffuser
  - Solar diffuser illumination AOI≈ 58°
  - Logistics of option II not as formidable as Option I but still not trivial
- System level test is required to validate calibration

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SOLAR STIMULATION SETUP

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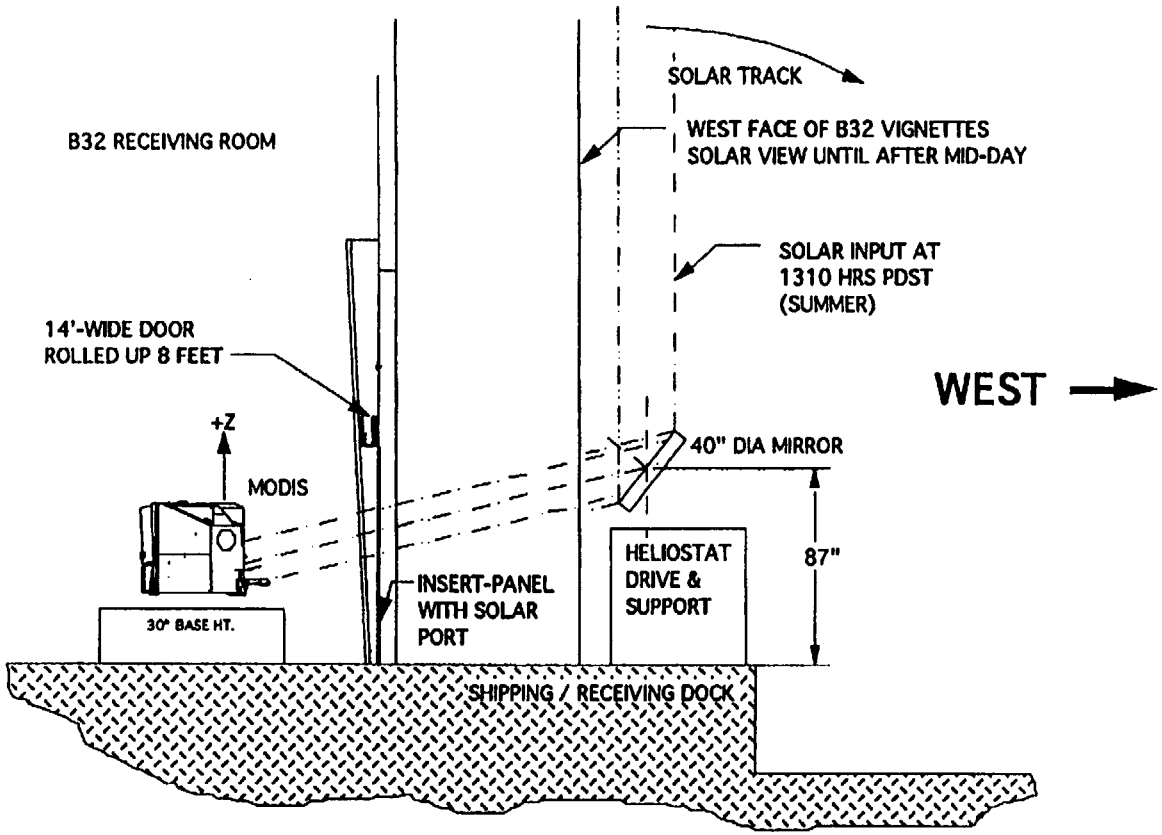
Elevation Section / South Viewing



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OPTION II AVAILABLE SNR AND RADIANCE LEVELS

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- SNR are adequate for good radiometric calibration

Band	λc (nm)	SNR	Lcal / Lmax
8	412	191	0.06
9	443	301	0.11
3	469	140	0.03
10	488	615	0.24
11	531	948	0.43
12	551	1433	0.63
4	555	323	0.08
1	645	334	0.09
13	667	6408	2.09
14	678	8618	2.23
15	748	4581	3.07
2	858	716	0.31
16	869	7352	5.52
17	905	1483	0.48
18	936	1398	0.35
19	940	1476	0.47
5	1240	966	0.64
26	1375	1495	0.67
6	1640	1573	0.60
7	2130	2303	0.95

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SOLAR DIFFUSER STABILITY MONITOR (SDSM)

SDSM TRACKS CHANGES IN SOLAR DIFFUSER

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REQUIREMENTS

TRACK CHANGES IN SOLAR DIFFUSER REFLECTANCE TO 0.5% ACCURACY OVER VIS/NIR SPECTRAL BANDS

STABLE DESIGN

- Sun shall provide reference
- Solar and Diffuser radiant energy shall be measured similarly
- Solar reference signal shall be insensitive to variation in solar angle of incidence and/ or be correctable.

MET BY .....

DESIGN CRITERIA

- 9 narrow bandpass filtered Silcon detectors located in integrating sphere
- Three position fold mirror to view:
  Sun; Diffuser; DC Restore
- Lens at entrance port spreads solar and diffuser illumination similarly over sphere cavity wall
- 2% transmitting screen to attenuate direct Solar irrad
- Square entrance aperture results in a predictable near-cosine variation in effective screen transmittance with variation in Solar AOI. Aperture dimensions are an interger multiple of screen's hole spacing.

PERFORMANCE CRITERIA

- Detector SNRs ≥ 400 for both Solar and Diffuser views
- Bandpass filters distributed across 0.4 to 1.0 μm
- Measurement error due to Out of Band contribution shall be ≤ 0.2% over range of allowed Diffuser degradation

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SDSM SNR IN WORST CASE SIMULATION

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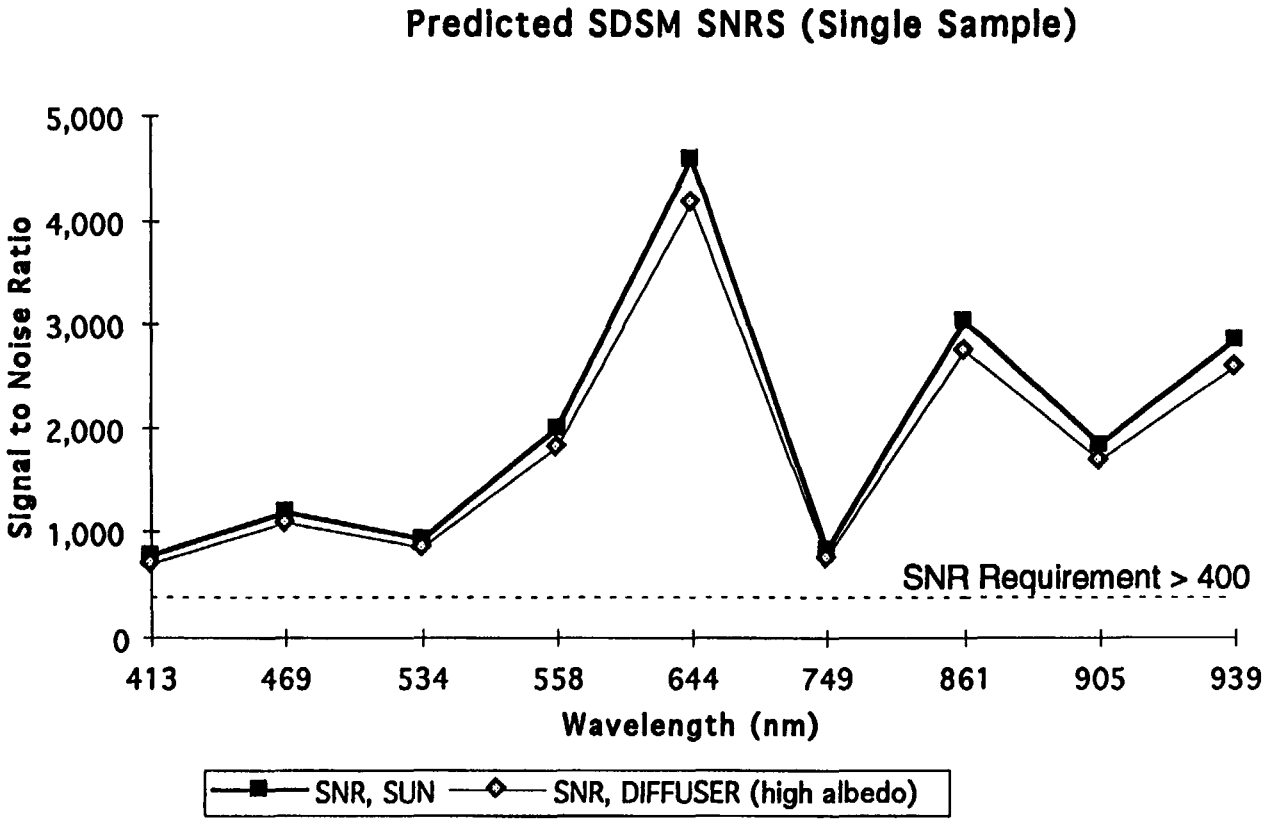

Selected Model Parameters
Solar AOI: 63°
Screen Transmittance:1.33%
Filter Transmittance: 70-92%
Mirror Reflectance: 88%
Lens Transmittance: 92%
Spectralon Reflect.: 97.7-98.3%

Band (nm)	
Center	BW
413	15
469	19
534	12
558	20
644	49
749	10
861	37
905	30
939	47

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SDSM FEATURES
A SIMPLE DESIGN

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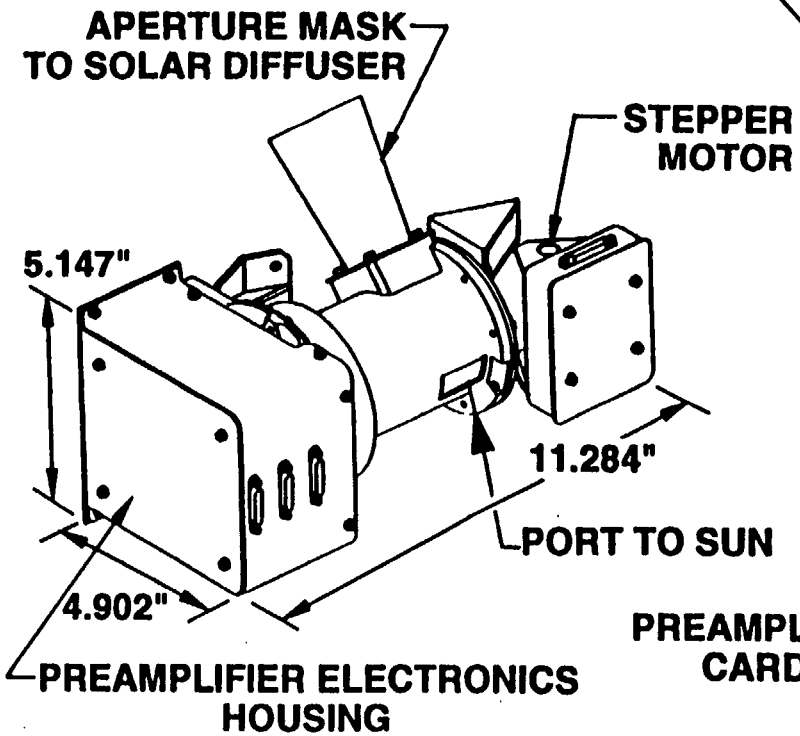
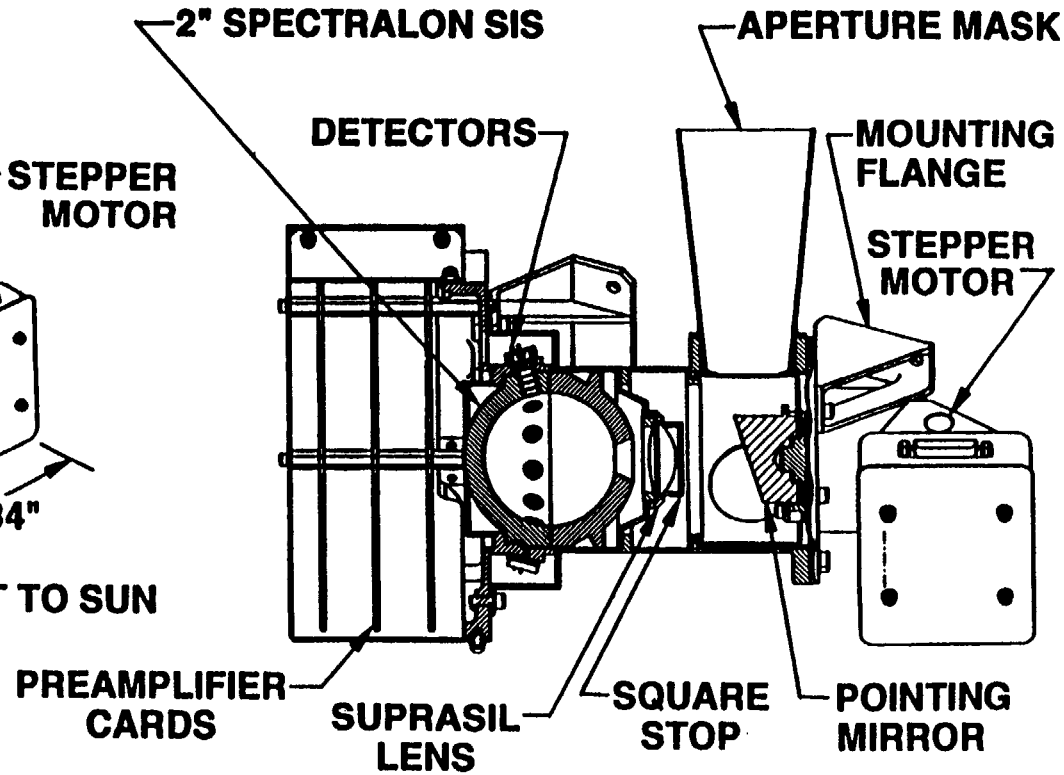


PERSPECTIVE VIEW



DETAILED CROSS SECTION

SDSM BUILD STATUS

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- Material status
  - More than 85% of components needed are in house
    - Including long lead items such as integrating spheres, fold motor, and photodiodes
    - Remaining components due by 15 Sep
- Subassembly status
  - Detector Assembly (P/N 405530) Built to shortages (photodiode just received)
  - Fold Motor Assembly (P/N 405534) Fold motor in check-out; motor controller testing paces completion (due 10 Sep)
  - Lens/Stop Assembly (P/N 405532) In assembly (Suprasil lens paces the build)

SDSM BUILD STATUS
(cont)

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- Subassembly status (cont)
  - Amplifier Assembly (P/N 405525) Planning released
- Dry run of Spectralon™ cleaning procedure and UV exposure test week of 28 August

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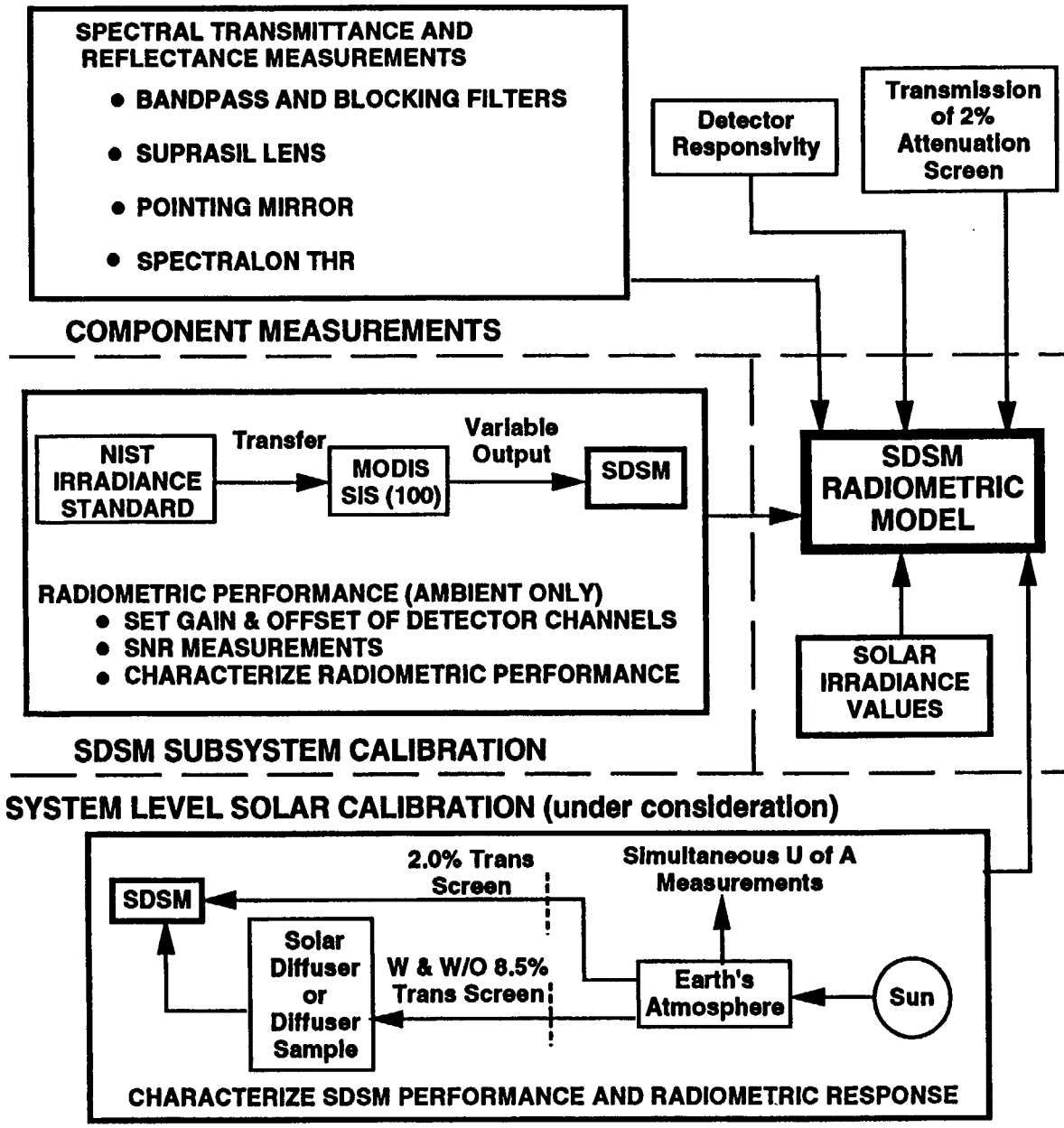
SDSM PERFORMANCE VALIDATION & CHARACTERIZATION



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SPECTRORADIOMETRIC CALIBRATION ASSEMBLY (SRCA)

SRCA IS A MULTIMODE CALIBRATOR

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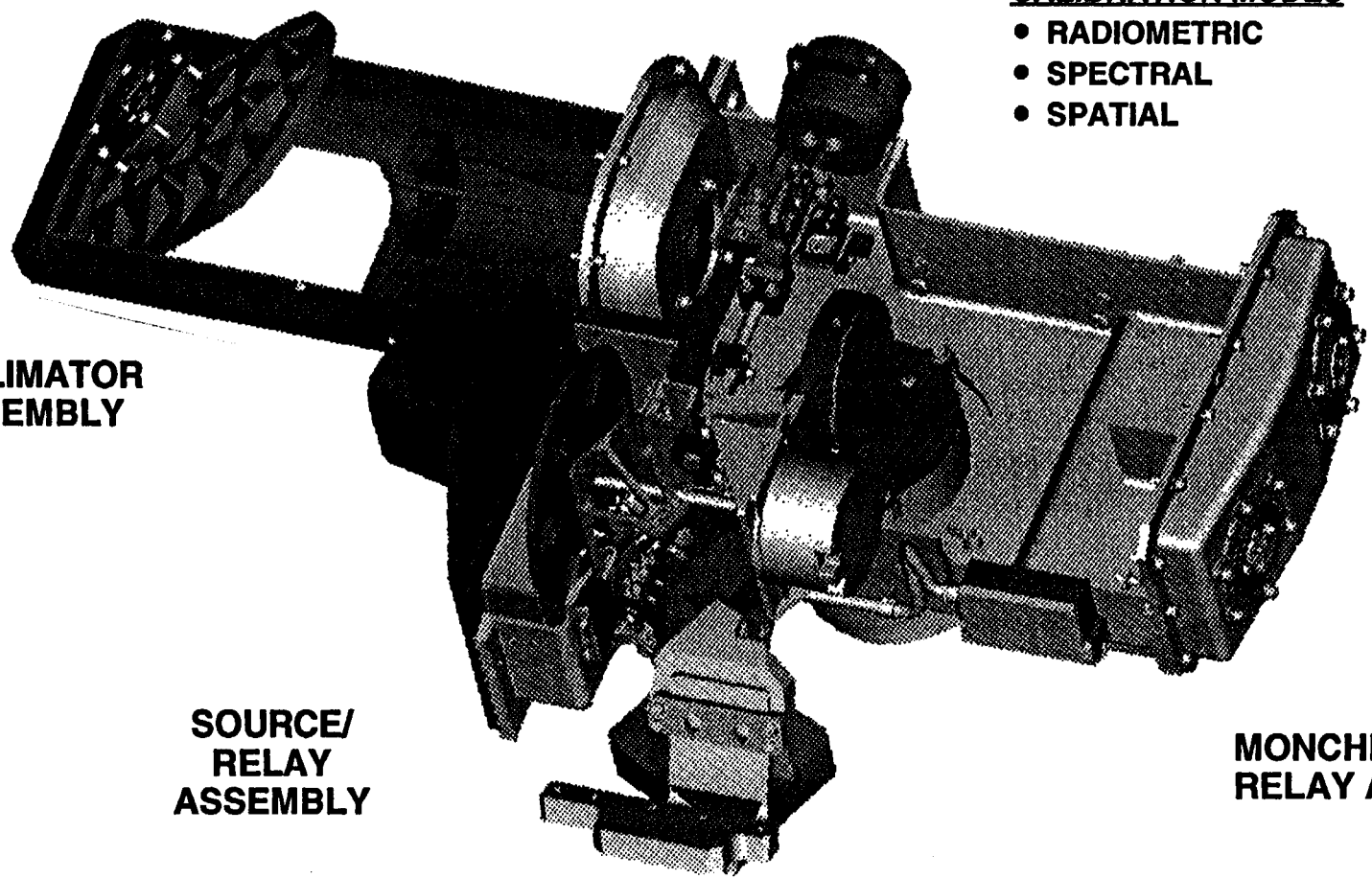
CALIBRATION MODES

- RADIOMETRIC
- SPECTRAL
- SPATIAL



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SRCA ADDRESSES IN-FLIGHT REQUIREMENTS

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CALIBRATION	BNDS	TOP REQUIREMENT	MET BY....
RADIOMETRIC	VIS/ NIR/ SWIR	5% (1σ) ABSOLUTE (SRCA is one component of multiple methods)	
SPATIAL	ALL BNDS	0.2 IFOV (Goal: 0.1 IFOV)	
SPECTRAL (shift of band center wavelengths below 1.0 μm)	VIS/ NIR/ SWIR	Accuracy (1sig): 1.0 nm • (w/n/412) Repeat (1sig): 0.5 nm • (w/n/412)	

PERFORMANCE CRITERIA

- PROVIDE SUITABLE MODIS SIGNAL LEVELS, STABLE TO ≤1% OVER ORBITAL PERIOD (100 min)

CALIBRATION	BANDS	SNR
RADIOMETRIC	VIS/NIR/SWIR	>500
SPECTRAL	VIS/NIR/SWIR	>100
SPATIAL	ALL	>150

- ALONG SCAN RETICLE
  KEs w/ Phase Delay of Detector Sampling to Measure Centroids
- ALONG TRACK RETICLE
  8 Phased KEs (8 Different Detectors Sampled per Band)
- REPEATABILITY OF SPECTRAL BANDPASS CENTROID MEASUREMENTS TO SPECIFIED PRECISION
  Self Calibration of Spectral Output

SYSTEM LEVEL CALIBRATION

- CORRELATION W/ FULL APERTURE MODIS GROUND CAL FOR ABSOLUTE REFERENCE (RAD, SPATIAL & SPECTRAL CAL)
- PERIODIC RADIOMETRIC CALIBRATION UPDATES
  Correlation with SD/SDSM and Ground Truth Calibration of MODIS

SRCA RADIOMETRIC CALIBRATION LEVELS

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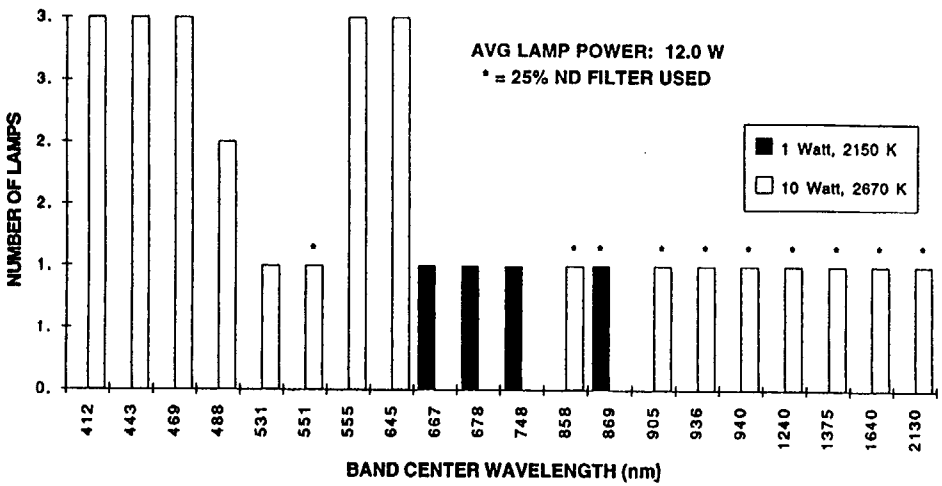
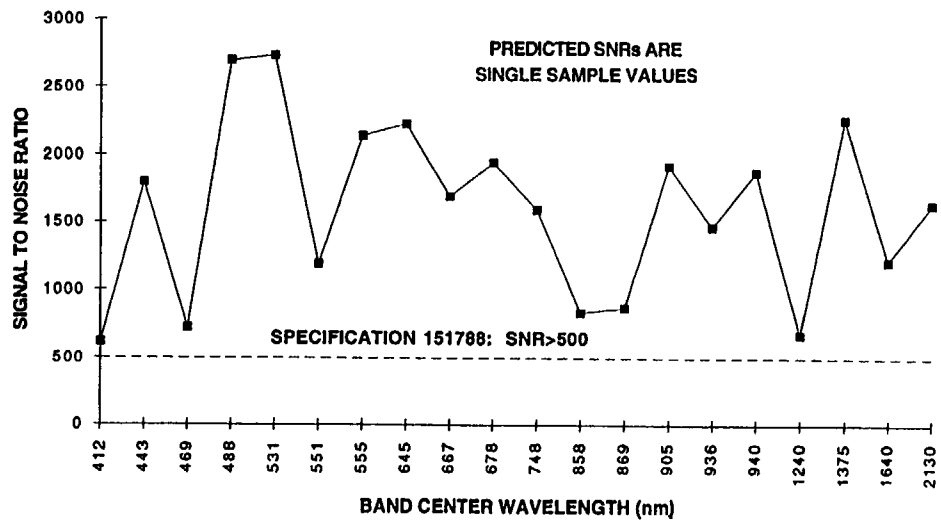
LAMPS USED IN RADIOMETRIC CALIBRATION SNR PREDICTION



SNR RADIOMETRIC CALIBRATION



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SPATIAL CALIBRATION SIGNAL LEVELS

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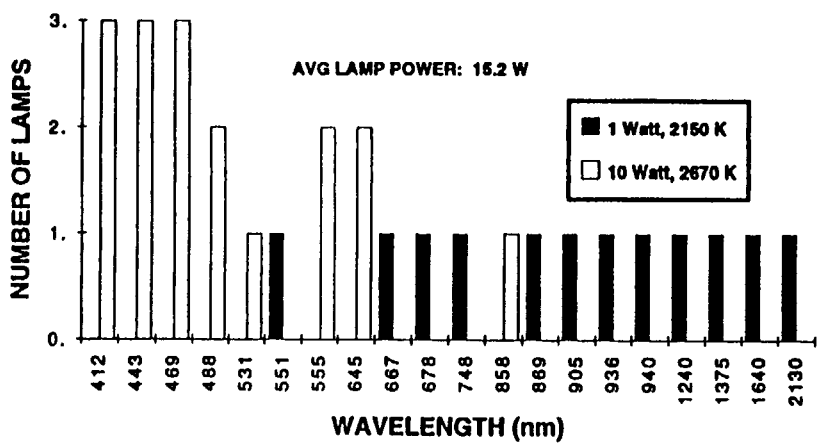
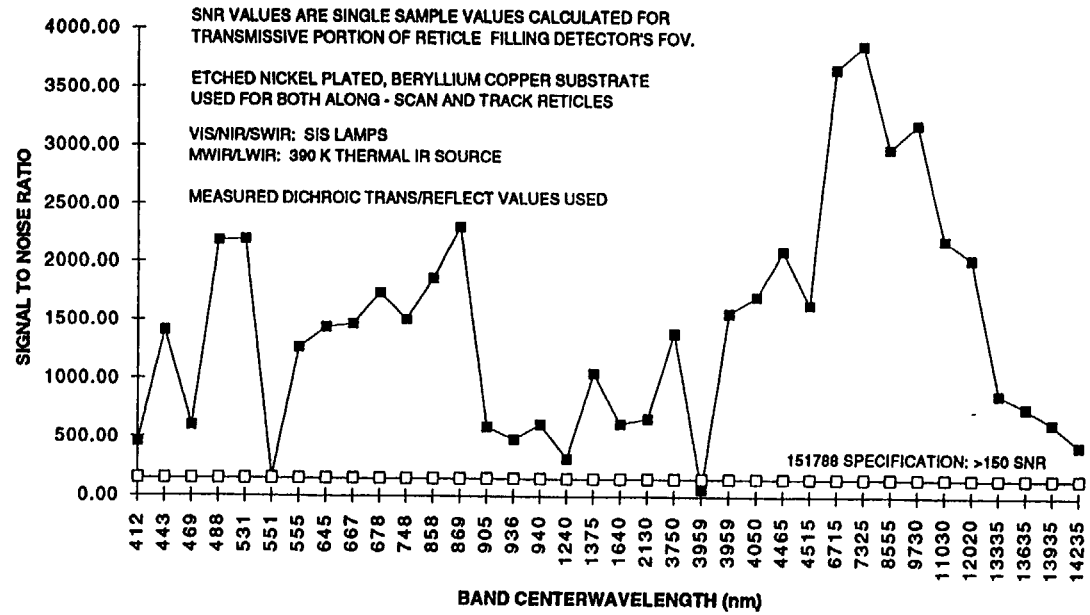
LAMPS USED IN SPATIAL CALIBRATION



SPATIAL CALIBRATION SNR



- SRCA PERFORMS IN-FLIGHT SPATIAL REGISTRATION OF FOCAL PLANES ONLY. NOT ALL BANDS WITHIN A SINGLE FOCAL PLANE REQUIRED FOR REGISTRATION.

SPECTRAL CALIBRATION PERFORMANCE HAS MARGIN

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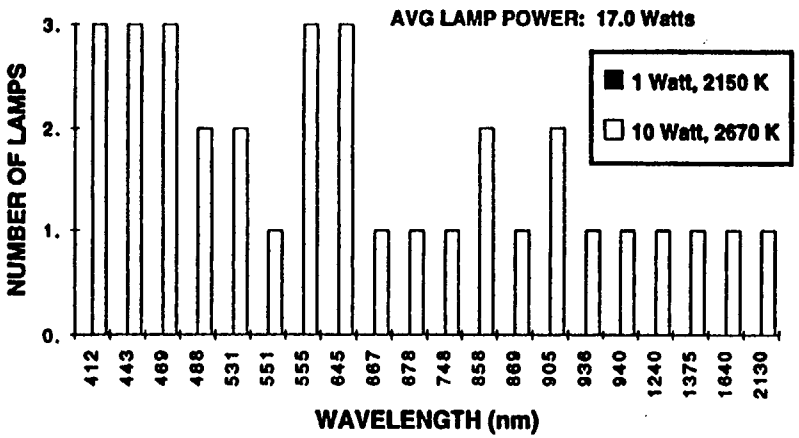
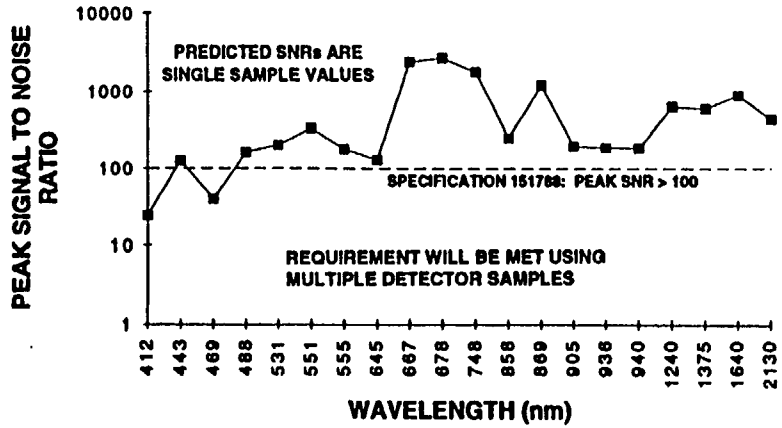
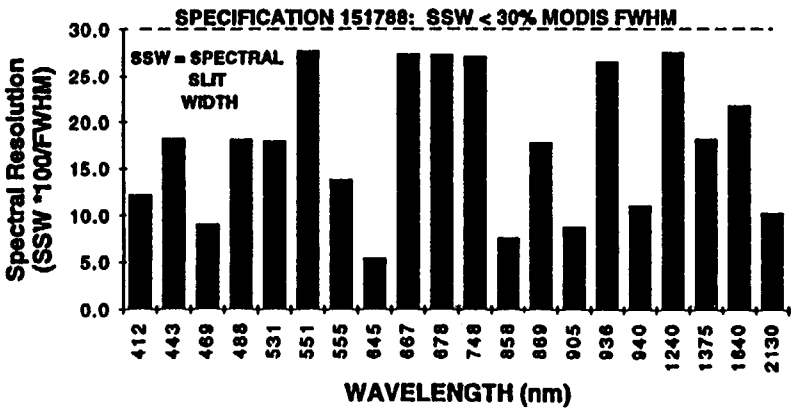
LAMPS USED IN SPECTRAL CALIBRATION



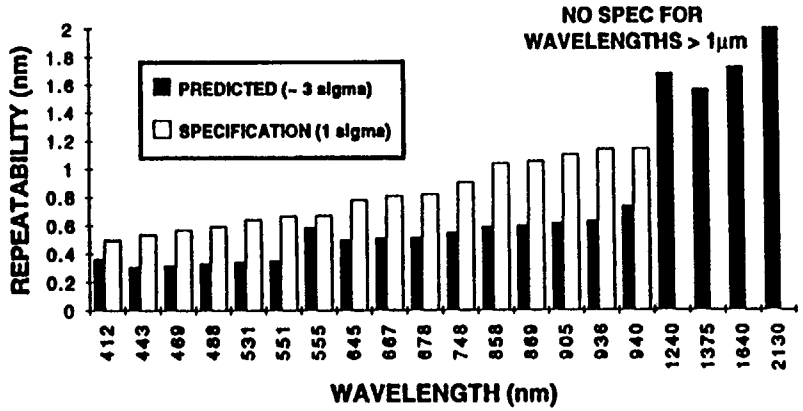
SPECTRAL CALIBRATION SNR



SPECTRAL RESOLUTION COMPARED TO MODIS FWHM



PREDICTED PRECISION OF CENTER WAVELENGTH DETERMINATION



SRCA PROTOFLIGHT MODEL ASSEMBLY WELL UNDERWAY

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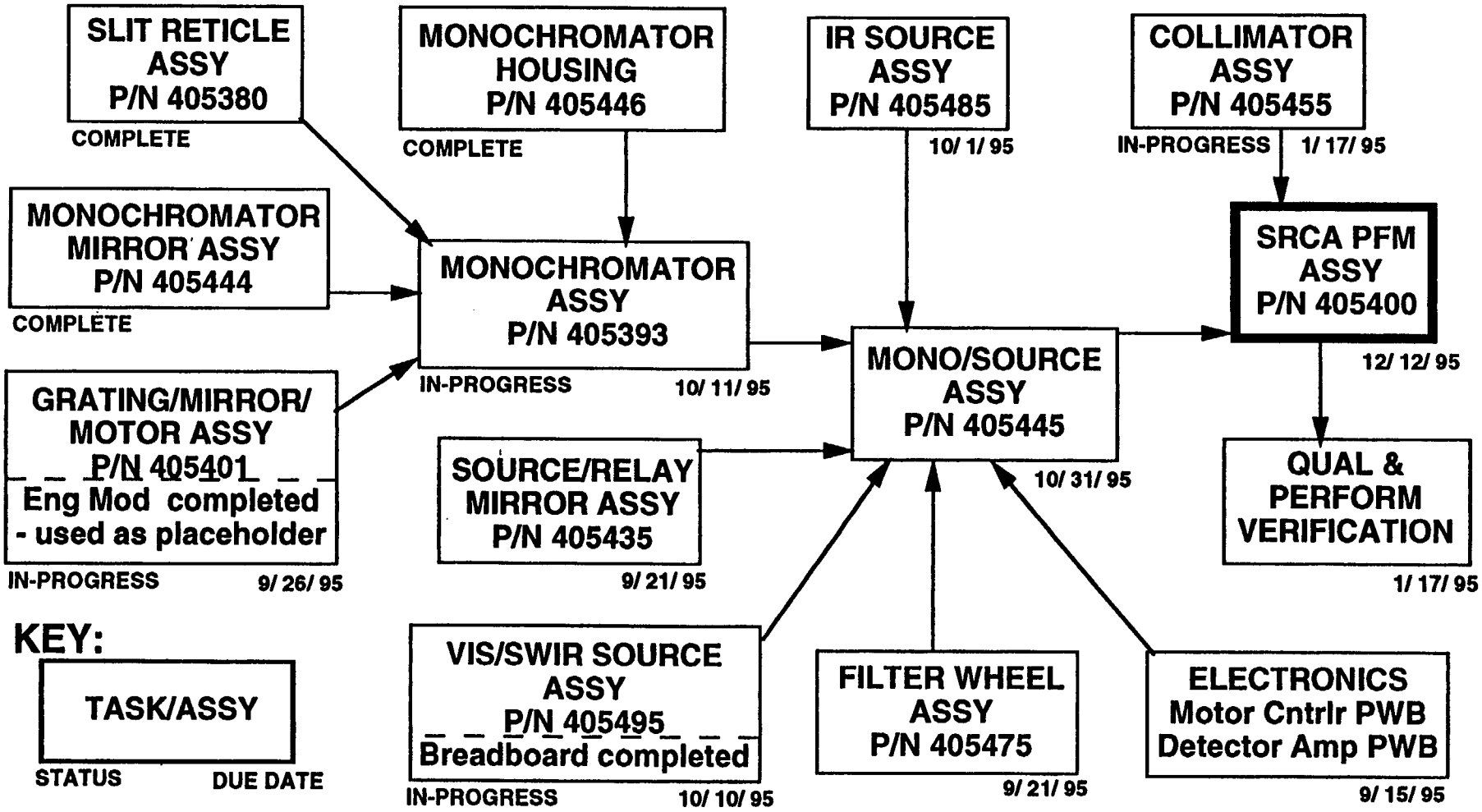

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SRCA SLIT/RETICLE MOTOR ASSEMBLY

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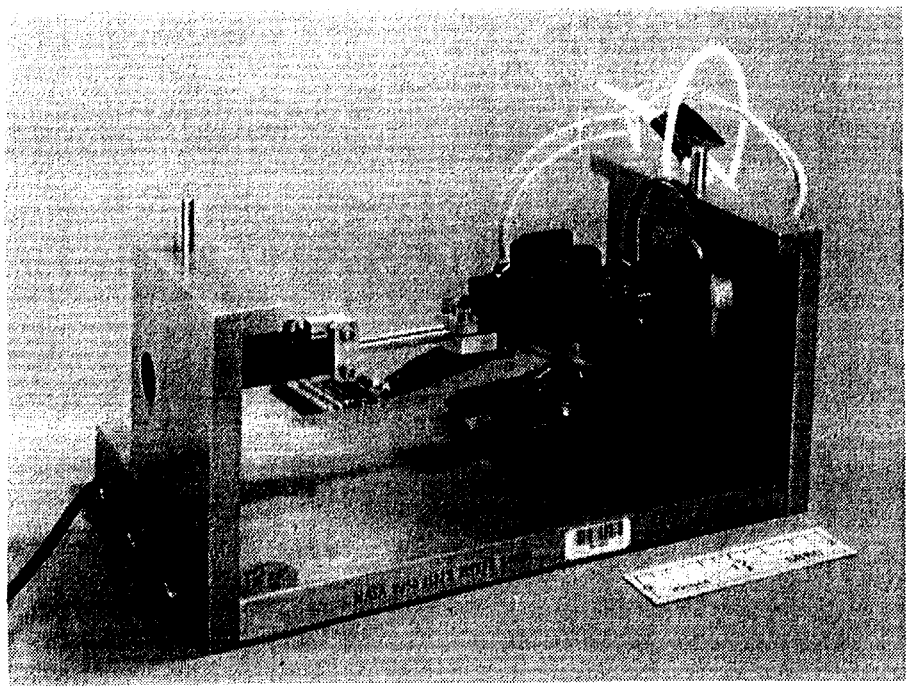

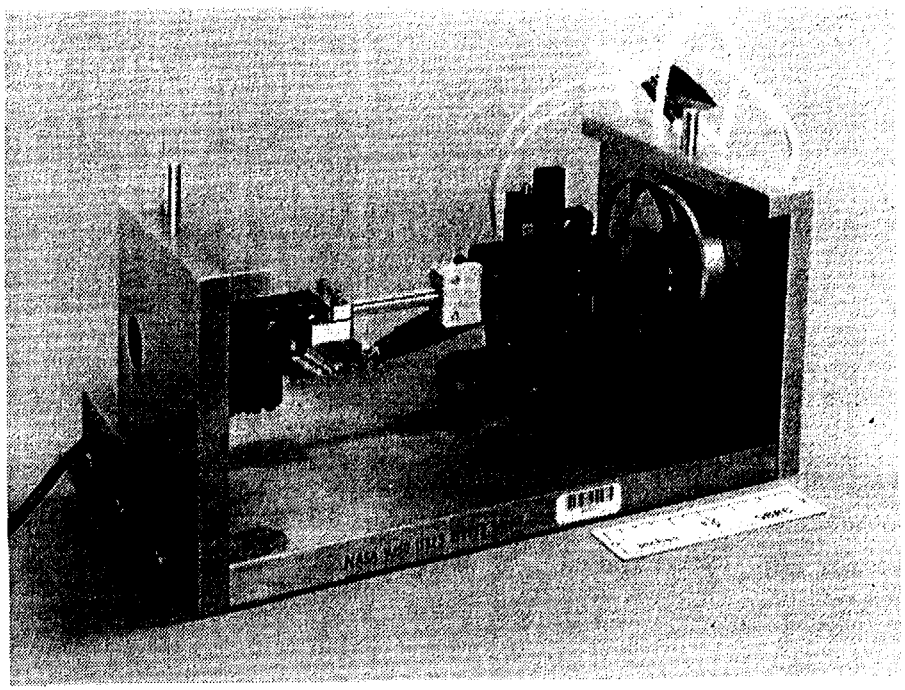

P/N 405380 MOUNTED IN ALIGNMENT FIXTURE

SRCA MONOCHROMATOR MIRROR ASSEMBLY

95-8-101

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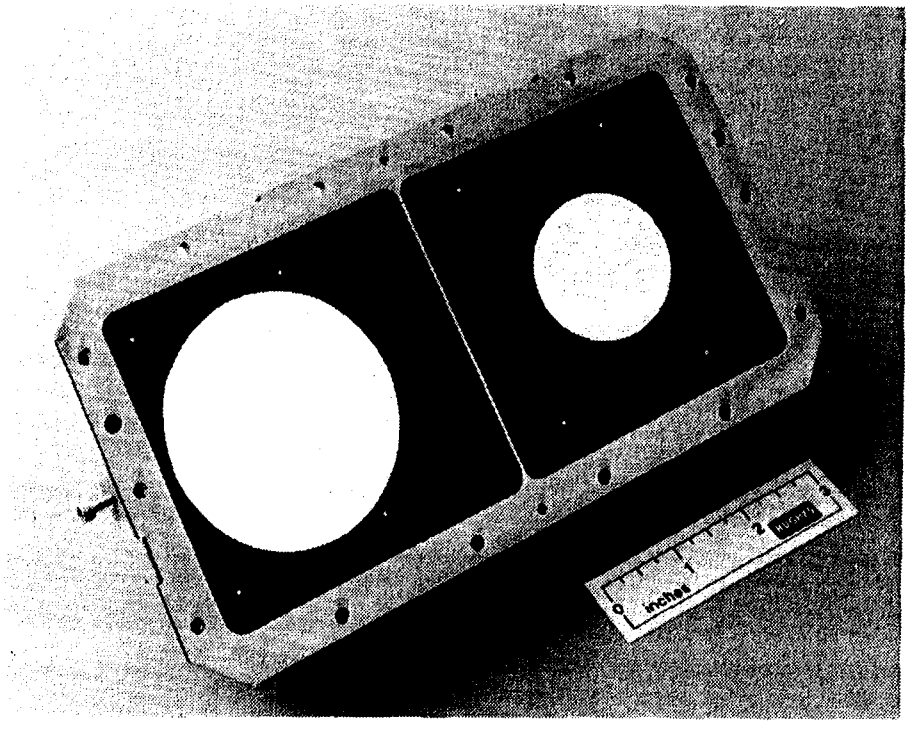
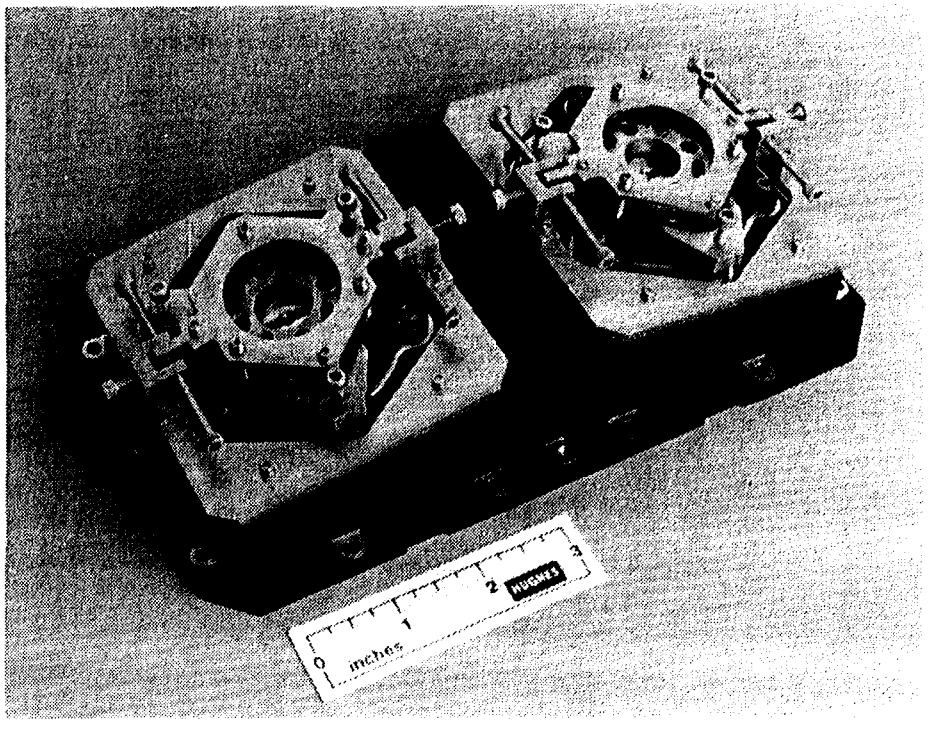


MIRROR ASSEMBLY
P/N 405444



MIRROR ASSEMBLY WITH
ALIGNMENT FIXTURE

SRCA MONOCHROMATOR ASSEMBLY

95-8-103

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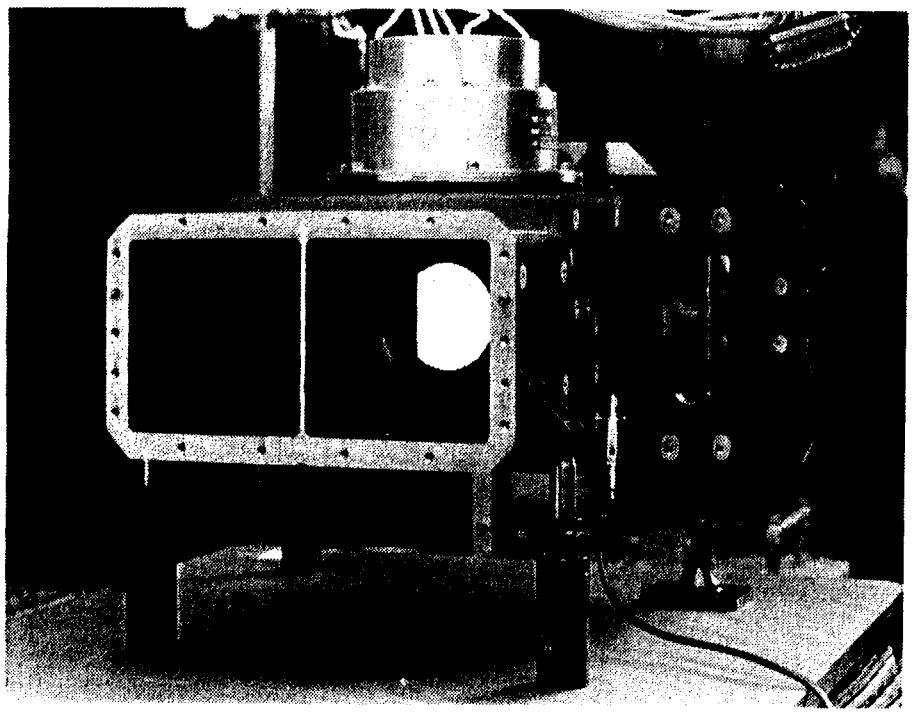
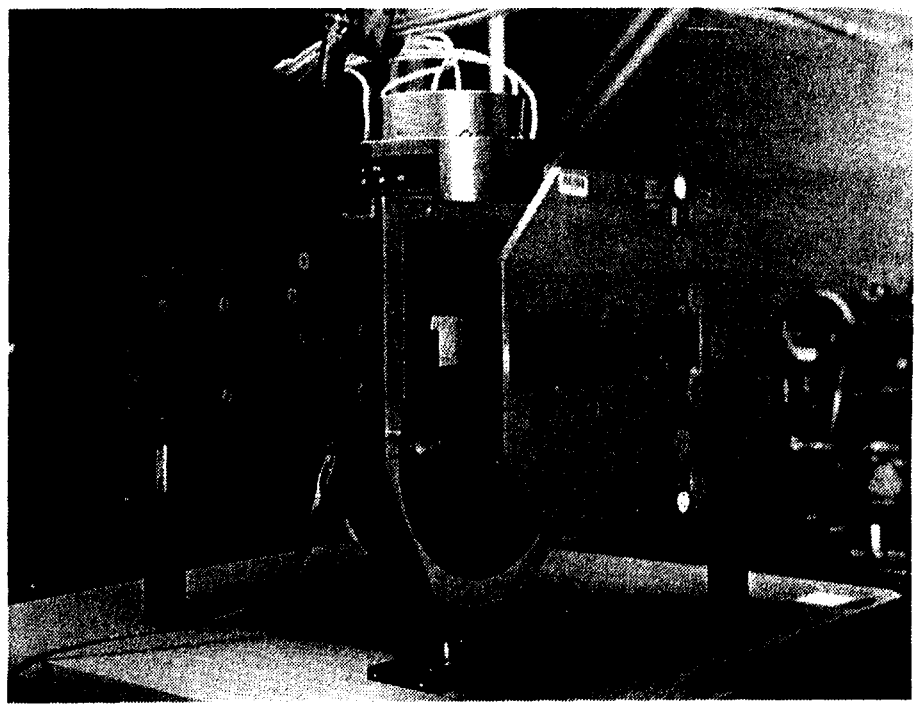


P/N 405393 IN-PROGRESS



ASSEMBLY WITH ALIGNMENT RETICLE

VIS/SWIR SOURCE

93-11-25

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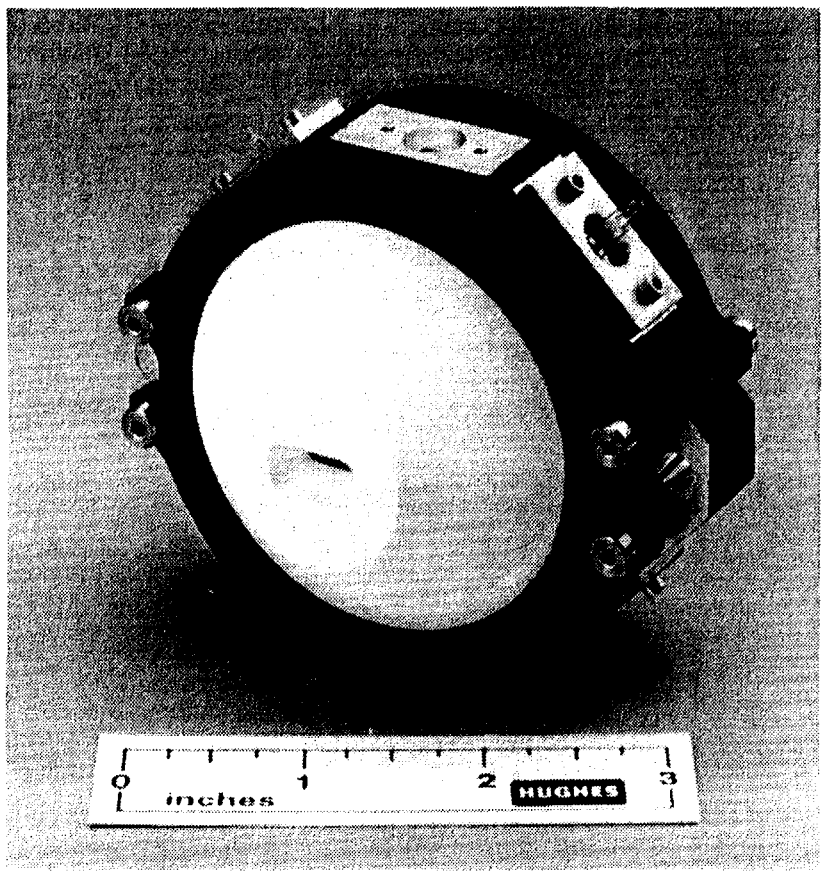
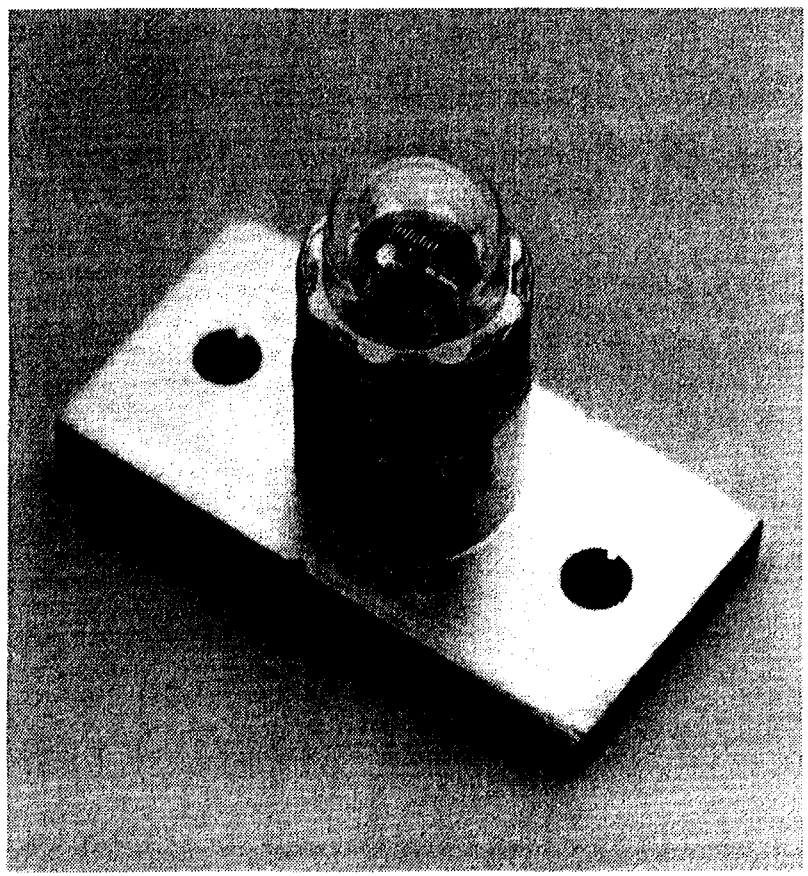


INTEGRATING SPHERE ASSEMBLY



HALOGEN LAMP AND HEATSINK

VALIDATION OF SRCA PERFORMANCE

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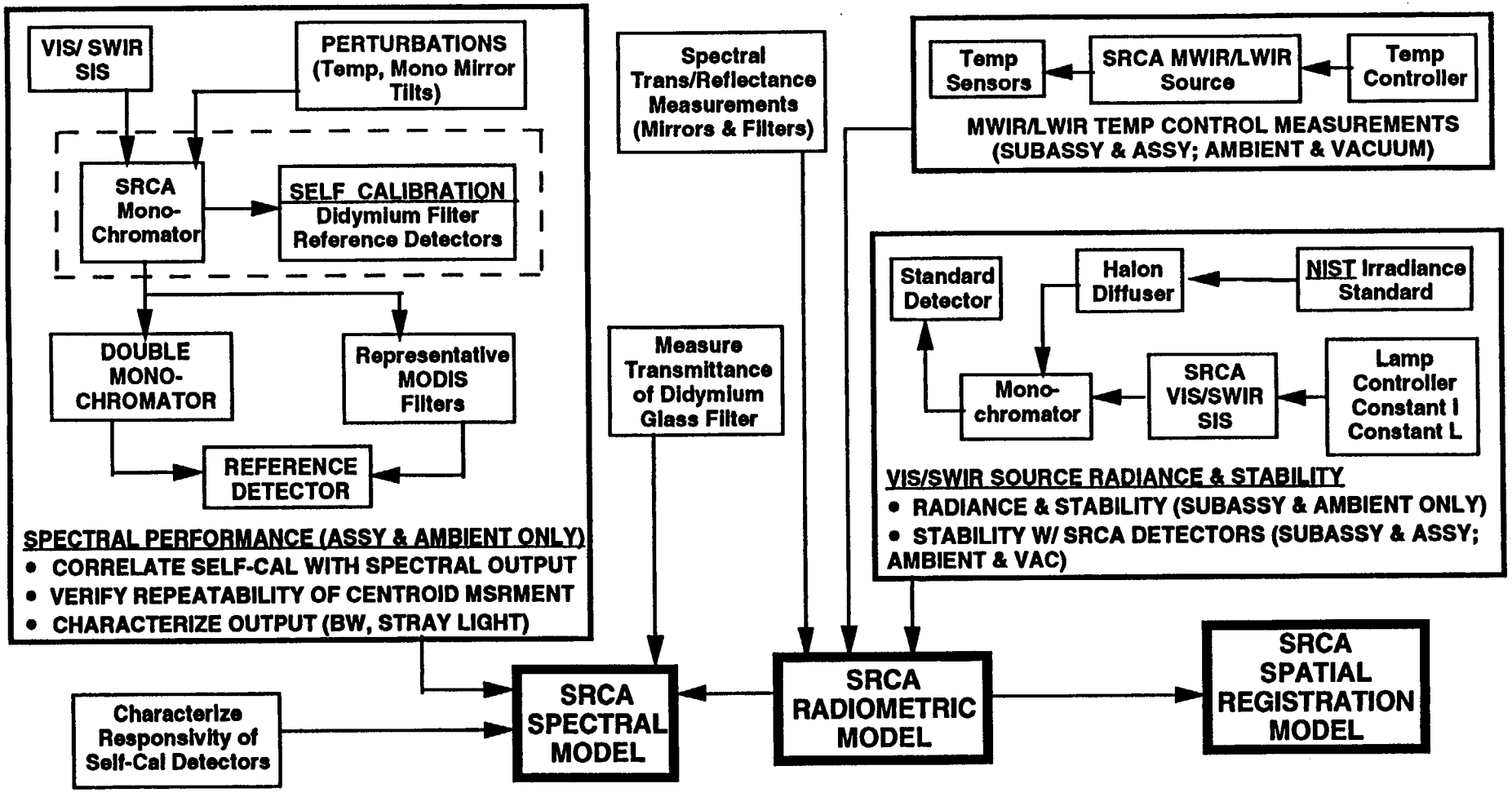

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SRCA WILL BE CALIBRATED AT MODIS INSTRUMENT LEVEL

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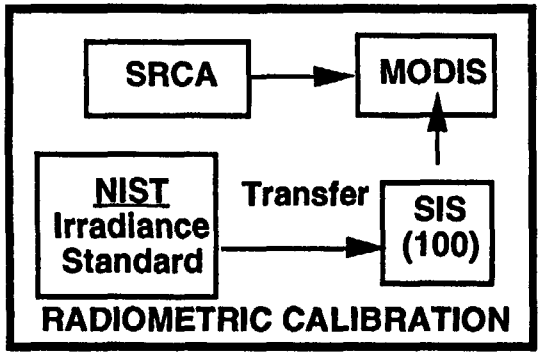
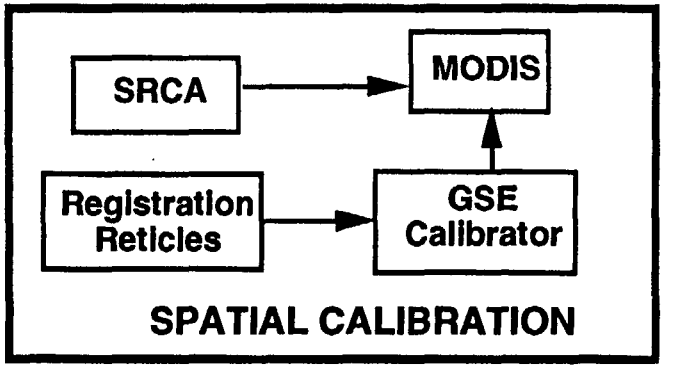
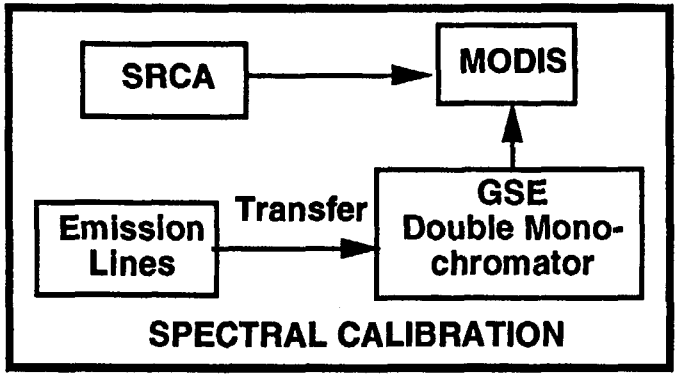
- CALIBRATION (AMBIENT & VAC): SRCA CALIBRATED AGAINST GSE STANDARDS USING MODIS AS TRANSFER
- PERFORMANCE VALIDATION (AMBIENT & VAC): SIGNAL LEVELS, RADIOMETRIC STABILITY (SHORT TERM), REPEATABILITY OF SPATIAL AND SPECTRAL CENTROIDS







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