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# CALIBRATION

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92-0163-02

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# CALIBRATION TOPICS

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- CALIBRATION REQUIREMENTS
- CALIBRATION PLAN
- ON BOARD CALIBRATION (OBC)
  - OBC FUNCTIONS
  - BLACKBODY
  - SOLAR ILLUMINATED DIFFUSER
  - SPECTRORADIOMETRIC CALIBRATION ASSEMBLY (SRCA)
  - SOLAR DIFFUSER STABILITY MONITOR (SDSM)
- CONTAMINATION EFFECTS ON CROSS TRACK CALIBRATION
- PREFLIGHT CALIBRATION
  - PERFORMANCE CHARACTERIZATION
  - THERMAL VACUUM CONFIGURATION
  - GSE OPTICAL STIMULI
    - SPHERICAL INTEGRATOR SOURCE (SIS)
    - CALIBRATOR

11/91  
91-0908-802

Parameter	Phase C/D Requirement	Predicted	
		Preflight	On-Orbit
<b>Radiometric Calibration</b>			
Below 1.0 $\mu\text{m}$	5%	4%	3%**
1.1 to 3.0 $\mu\text{m}$	5%	4%	3%**
Above 3 $\mu\text{m}$	1%	1%	1%
Reflectance	2%	4%	2%
<b>Spectral Calibration</b>			
Center Wavelength	0.5 nm preflight 1.0 nm on-orbit	0.5 nm	1.0 nm*
Spectral Band-to-Band Stability	0.5% FS 1.0% HS	0.5% FS 1.0% HS	0.5% FS
<b>Geometric Calibration</b>			
Band-to-Band Registration	0.1 IFOV	0.1 IFOV	0.1 IFOV
<b>Diffuser BRDF</b>			
<2.0 $\mu\text{m}$	1.0%		
2.0 to 2.5 $\mu\text{m}$	1.5%		
FS = Full Scale    HS = Half Scale * Dependent on good correlation with full aperture ground measurement and SRCA sub-aperture measurements ** Multiple calibration methodologies are required			

*(includes vicarious)*



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# CALIBRATION REQUIREMENTS AND PERFORMANCE PREDICTIONS REMAIN UNCHANGED



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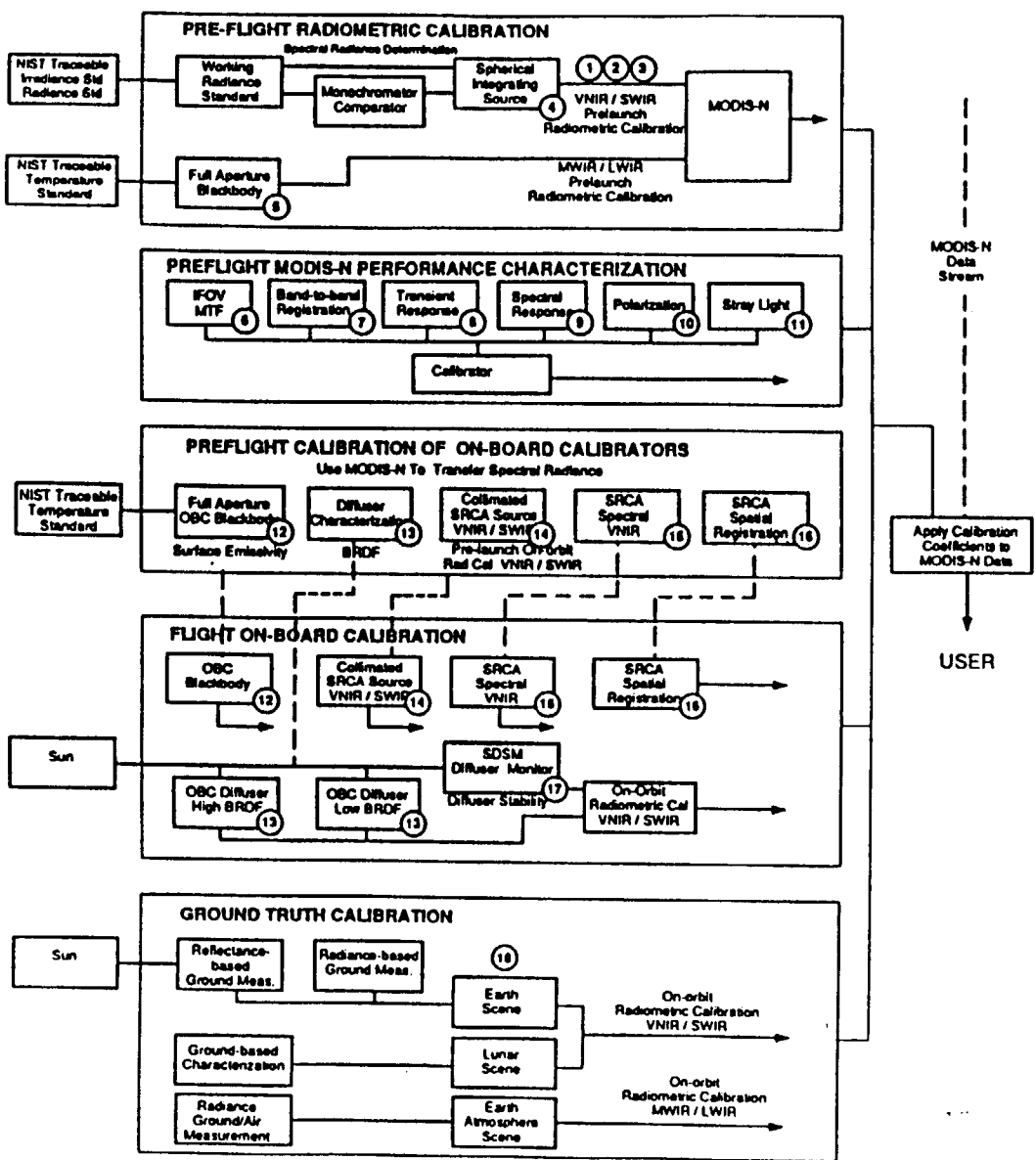


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# MODIS-N CALIBRATION PLAN



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MODIS-N CALIBRATION MANAGEMENT PLAN BLOCK DIAGRAM COVERING PREFLIGHT AND ON-ORBIT ACTIVITIES INCLUDING MATH MODEL INDEX

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# PERFORMANCE CHARACTERIZATION AND CALIBRATION MATH MODEL

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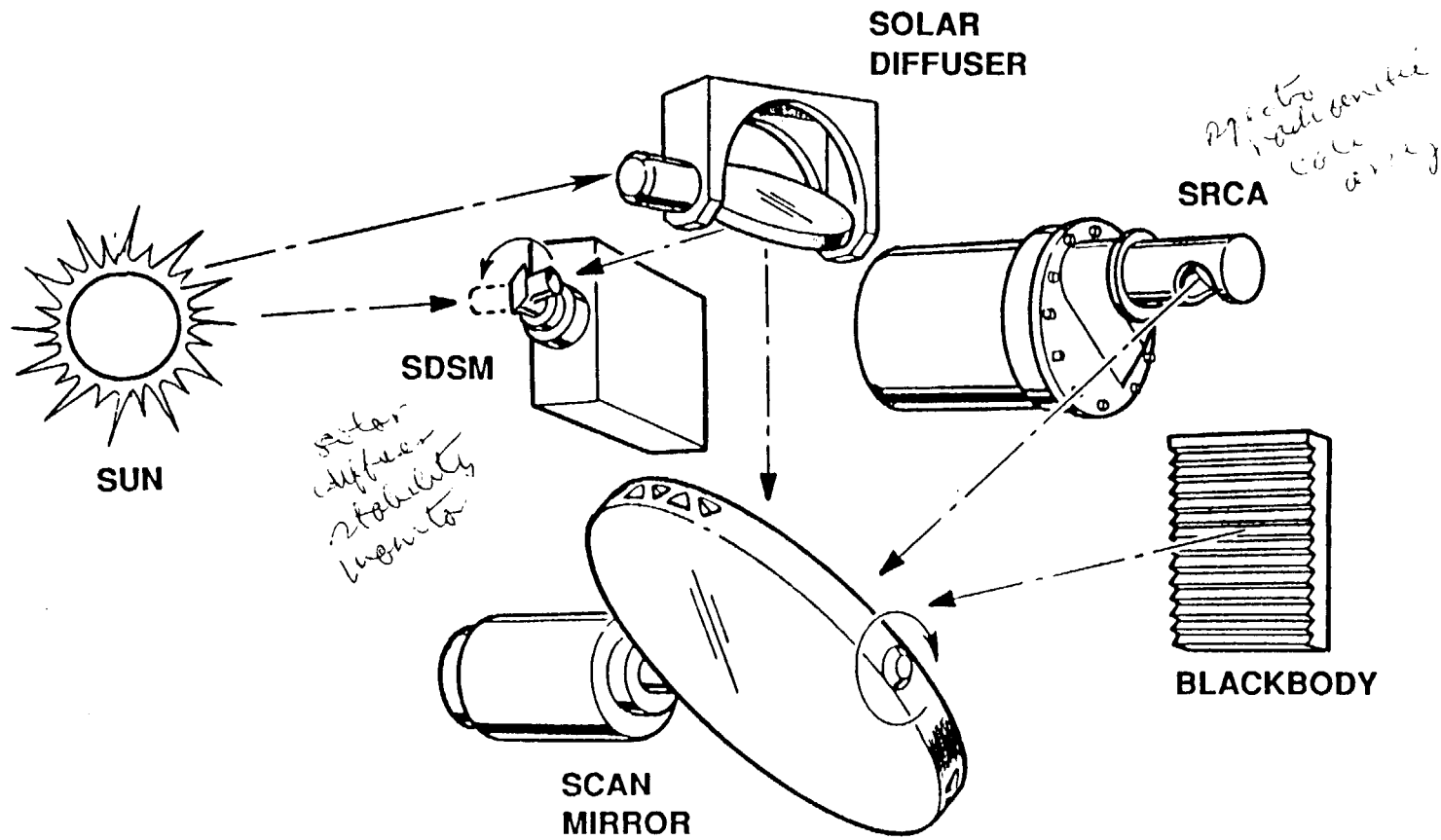
Model	Purpose	Model Number
Transfer spectral radiance/irradiance to spherical integrator source (SIS) via monochromator comparator – multiple methodologies	Source calibration, VIS/NIR/SWIR	1a, 2a, 3a, 1b, 2b, 3b
SIS – MODIS-N	Instrument calibration, VIS/NIR/SWIR	4a, 4b
Full aperture blackbody – MODIS-N	Instrument calibration, MWIR/LWIR	5
MTF/IFOV – calibrator (phased reticles) – MODIS-N	Instrument characterization, all bands	6
Band-to-band registration – calibrator and phased reticle (CT/AT) – MODIS-N	Instrument characterization, all bands	7
Transient response – calibrator – MODIS-N	Instrument characterization, all bands	8
Spectral response – monochromator – MODIS-N	Instrument characterization, all bands	9
Polarization – calibrator – MODIS-N	Instrument characterization, all bands	10
Stray light response/calibrator/SIS/large aperture IR source – MODIS-N	Instrument characterization, all bands	11a, 11b
OBC blackbody – MODIS-N	Instrument calibration, MWIR/LWIR	12
OBC diffuser calibration	BRDF 0.4-2.40 $\mu\text{m}$ , angle	13a
OBC solar-illuminated diffuser – MODIS-N	Instrument calibration, VIS/NIR/SWIR	13b
SRCA – filtered incandescent source – MODIS-N	Calibration transfer, VIS/NIR/SWIR	14a
SRCA – filtered incandescent source – MODIS-N	Instrument calibration check, VIS/NIR/SWIR	14b
Wavelength calibration – SRCA monochromator	$\lambda$ calibration, VIS/NIR	15a
Spectral response – SRCA – MODIS-N	Instrument characterization, VIS/NIR	15b
Band-to-band spatial registration – OBC SRCA – MODIS-N	Instrument characterization, all bands	16
Diffuser – sun – solar illuminated diffuser stability monitor	Diffuser stability check, 0.43-0.90 $\mu\text{m}$	17
Ground truth – Earth/lunar/atmosphere – MODIS-N – several major models	Instrument calibration	18



# MODIS-N IN-FLIGHT CALIBRATORS



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# MODIS-N IN-FLIGHT CALIBRATION CAPABILITY

Type of Calibration	Source	Mechanism	Aperture	Spectral Bands	Usage Frequency (Max)	Other Comments
Zero Radiance	Space		Full	All	Once per scan line	
Radiometric	Sun	Solar illuminated diffuser	Full	VIS/NIR/SWIR Bands 1-7, 17, 18, 19	Once per orbit	Effective albedo $0.46 \pm 0.03$
Radiometric	Sun	Solar illuminated diffuser	Full	VIS/NIR/SWIR	Once per orbit	Effective albedo $0.046 \pm 0.005$
Radiometric & DC Restore	Blackbody	Blackbody	Full	MWIR/LWIR Restore (All)	Once per scan line	
Radiometric (intra-orbit)	Incandescent source	SRCA spectrally shaped collimator	Partial	VIS/NIR/SWIR	Available any time during orbit	
Spatial Registration	Incandescent source and IR source	SRCA	Partial	VIS/NIR/SWIR MWIR/LWIR	Available any time during orbit	
Spectral (MODIS-N)	Incandescent source	SRCA grating monochromator	Partial	VIS/NIR/SWIR	Available any time during orbit	Grating is rotated to produce $\lambda$ scan
Spectral (monochromator)	Incandescent source with didymium glass	SRCA grating monochromator with photodiode	Full	$0.40 \mu\text{m} \leq \lambda \leq 1.00 \mu\text{m}$	Available any time during orbit	Grating is rotated to produce $\lambda$ scan
Diffuser stability monitor	Sun	Spherical integrator with optical band-pass filtered detector	Full	$0.40 \mu\text{m} \leq \lambda \leq 2.20 \mu\text{m}$	Available once per orbit	Both high and low albedo levels

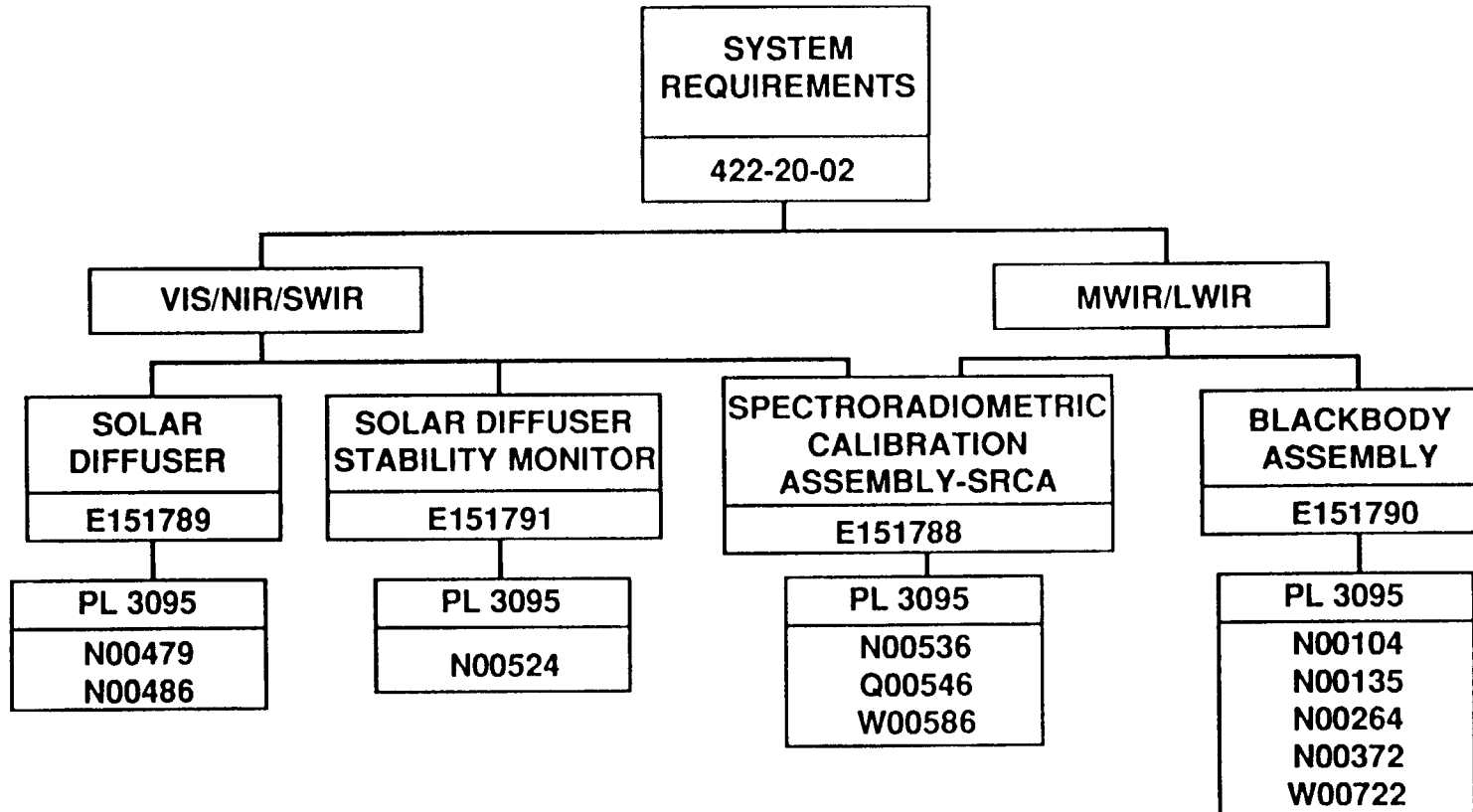
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# REQUIREMENT FLOW DOWN



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*needs etc available from N777*





# MAJOR MODIFICATION TO SRCA AND SDSM DESIGN APPROACHES



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## SRCA

DRIVERS: SOURCES AND SPECTRAL RANGE

MODIFICATION:

RIBBON FILAMENT → SIS - MULTIPLE LAMPS  
VIS/NIR → VIS/NIR/SWIR  
GRATING  
OUT OF PLANE → IN PLANE  
M = 1 → M = 1, 2, 3

## SDSM

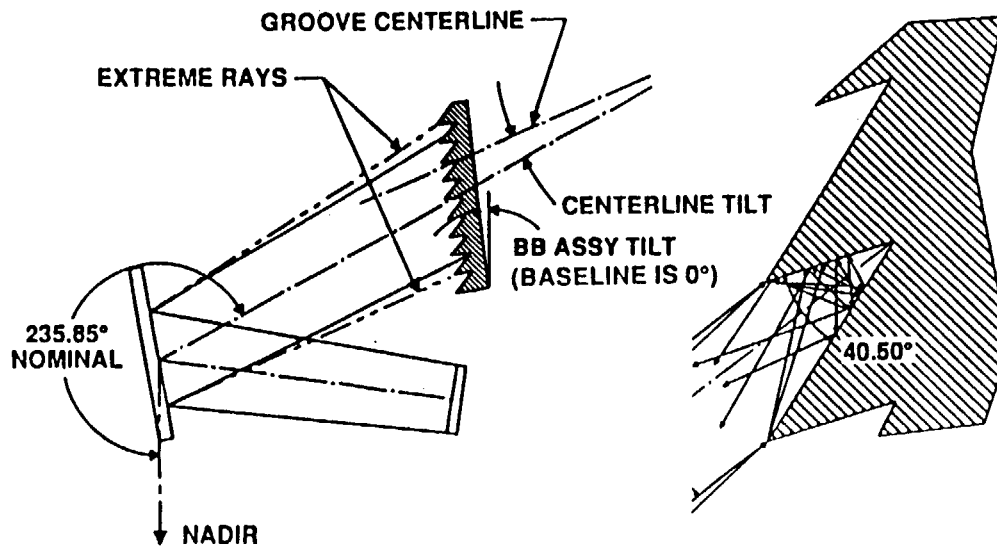
DRIVER: SPECTRAL RANGE CHANGE

f/6 AND f/100 EFFECT BREAD BOARDING

MODIFICATION:

VIS/NIR → VIS/NIR/SWIR  
SPECTROGRAPH → INTEGRATING CAVITY WITH  
FILTERED DETECTORS

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- FULL-APERTURE ILLUMINATION
- BLACKBODY SPATIAL AND TEMPERATURE UNIFORMITY
- EMISSIVITY
- CAVITY V-GROOVE INCLUDED ANGLE
- SPECULAR BLACK PAINT
- GROOVE TIP AND VALLEY AREA EFFECTS
- CALIBRATION ACCURACY
  - BAND 28 AND 29 SCAN MIRROR 1K TEMPERATURE EFFECTS
  - EARTH SHINE
  - I/F NOISE PC HgCdTe BANDS
  - BLACKBODY BREADBOARDING DETAILS GIVEN IN PL3095-W00722

0.1K  
 >0.992  
 40.6 DEG  
 <10%  
 0.7 - 0.2%  
 0.2%  
 ?  
 ?



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## HIGH EMISSIVITY AND CALIBRATION ACCURACY IS ATTAINABLE WITH V-GROOVE BLACKBODY DESIGN



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**FULL-APERTURE SOLAR DIFFUSER  
PROVIDES ACCURATE AND CORRECTABLE  
RADIOMETRIC CALIBRATION**



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- **FULL-APERTURE WITH FIXED POSITION DIFFUSER**
- **DIFFUSER BRDF (SR) 0.315**
- **SUN-DIFFUSER ANGLE (DEGREE) 62.8**
- **EFFECTIVE ALBEDO (%)**
  - DIFFUSER 46
  - DIFFUSER + SCREEN 4.6
- **SPECTRAL RANGE — VIS/NIR/SWIR BANDS 1-19**
- **DIFFUSER STABILITY — 15%**
  - CORRECTABLE WITH SDSM 1%
- **MATERIAL (POTENTIAL) HALON, YB71**
- **THREE CALIBRATION MODES AVAILABLE ALBEDO**
  - PRIMARY 46, 4.6
  - SECONDARY (DOOR FAILED, BACKUP SCREEN ACTUATOR) 46, 4.6
  - TERTIARY (SCREEN ACTUATOR FAILED) 4.6
- **DETAILED DESCRIPTION IN PL3095-N00479**



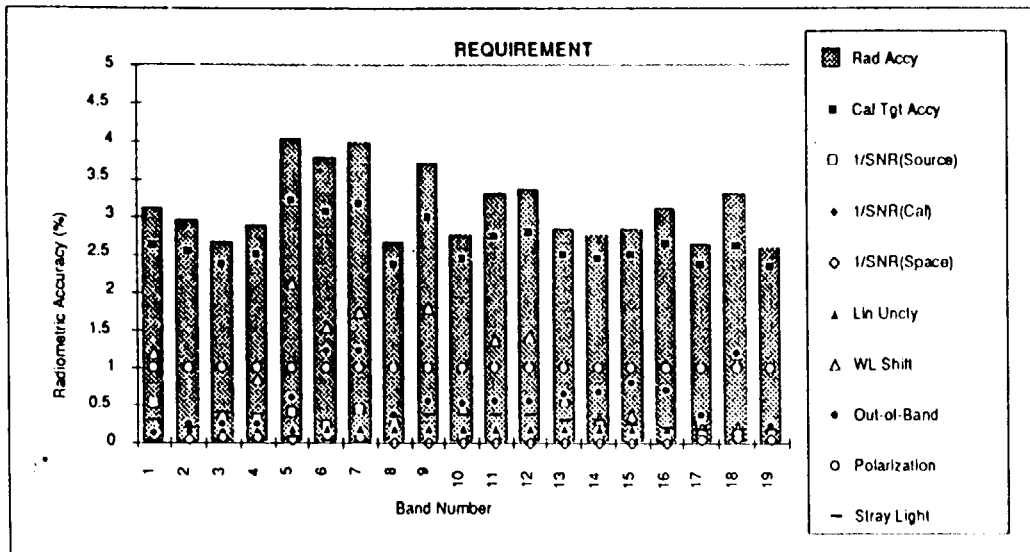
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# PREDICTED IN-FLIGHT RADIOMETRIC ACCURACY HAS ACCEPTABLE MARGIN IN 35 OF 36 BANDS

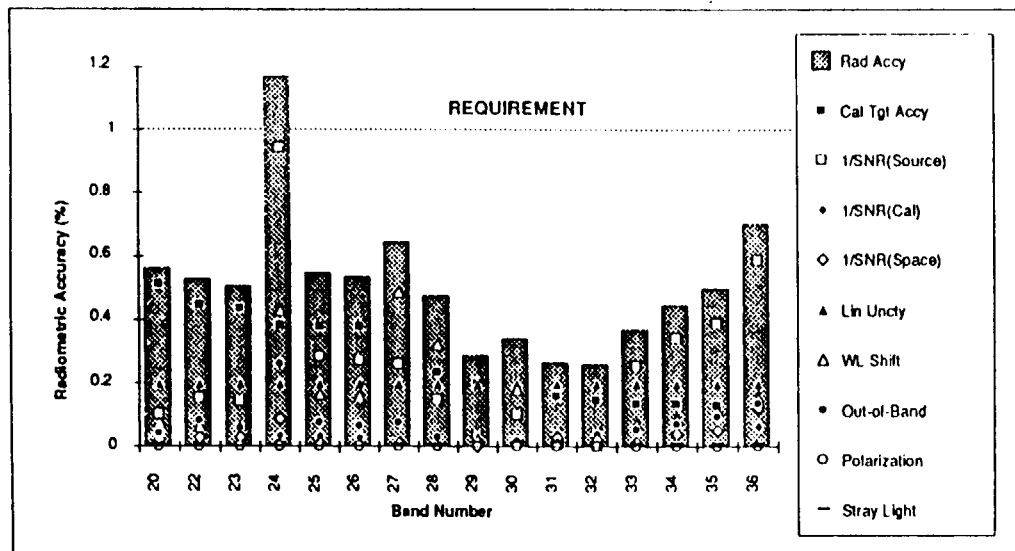
- BAND 24 LIMITED BY SNR AT Ltyp  
(100:1 SNR  $\approx$  1% ACCURACY)



## REFLECTIVE BANDS



## EMISSIVE BANDS

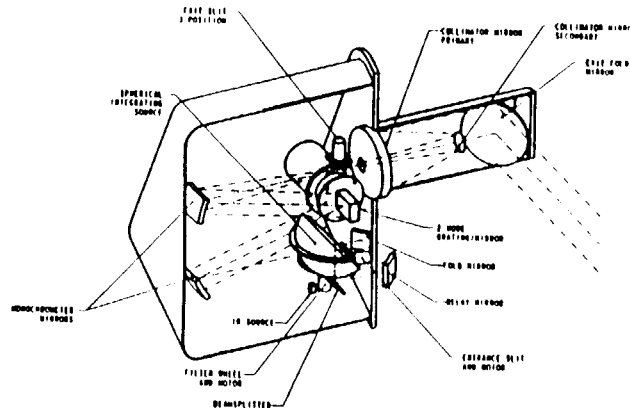




# SRCA DESIGN IS MATURING



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- **SOURCE MODULE — SPHERICAL INTEGRATING SOURCE**
  - 10 CM SPHERE, 1 CM<sup>2</sup> EXIT PORT
  - LAMPS: 1-1.6W; 1 TO 3-8W
  - IR SOURCE
  - OPTICAL RELAY — UNITY MAGNIFICATION
  
- **MONOCHROMATOR**
  - CZERNY TURNER MOUNT — IN PLANE
  - F/#
  - FOCAL LENGTH
  - GRATING
    - BLAZE WAVELENGTH
    - ORDERS
  
- **SPECIAL SLIT WIDTH (FWHM) (NM)**

TEMP: 2325K, 2900K  
390K

6  
210 MM  
150L/MM  
1.35 μm  
1, 2, 3

7.3, 3.7, 2.5

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## SPECTRORADIOMETRIC CALIBRATION ASSEMBLY (SRCA) (CONT)



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- **OUTPUT COLLIMATOR**
  - **CASSEGRAIN — 2 MIRROR**
  - **APERTURE DIAMETER** 89 MM
  - **EFFECTIVE FOCAL LENGTH** 530 MM
- **RADIOMETRIC CALIBRATION CHECK  
MODE FOR ALL VIS/NIR/SWIR** SNR > 500
- **SPECTRAL RESPONSE MODE FOR  
ALL VIS/NIR/SWIR** SNR > 200
- **DETAILED MODELLING DESCRIBED  
IN PL3095-N00536**

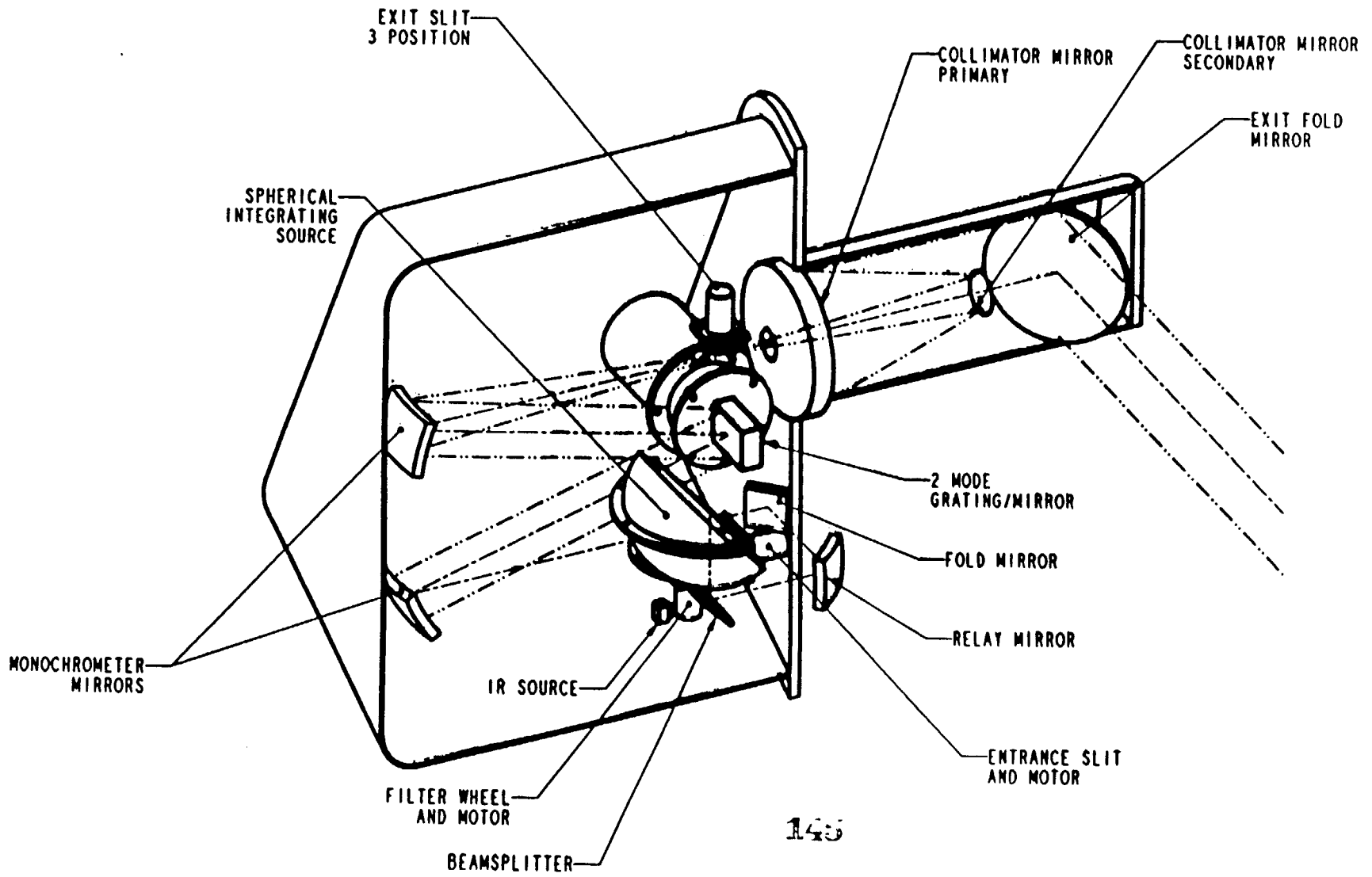




# SRCA CONCEPT HAS BEEN MODELED IN PRO-E



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FILTERED DETECTORS  
(9 Si, 2 Ge, 1 InAs)  
LOCATED IN  
CAVITY WALL

SPHERICAL  
INTEGRATOR

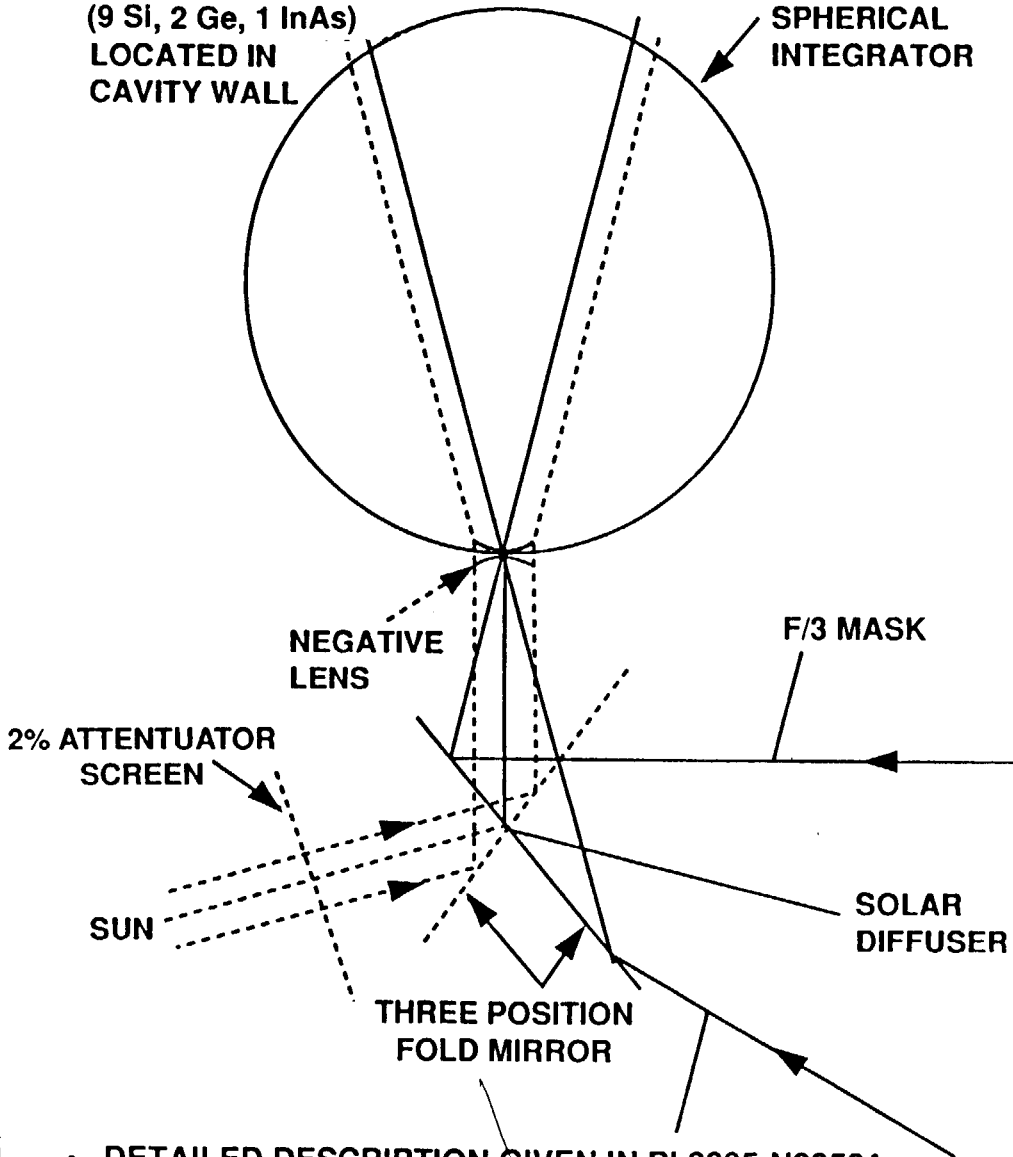


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# IMPROVED SOLAR DIFFUSER STABILITY MONITOR DATA USED TO CORRECT SOLAR DIFFUSER CALIBRATION



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• DETAILED DESCRIPTION GIVEN IN PL3095-N00524

*Handwritten notes:*  
Incl. detector -  
PL 16370

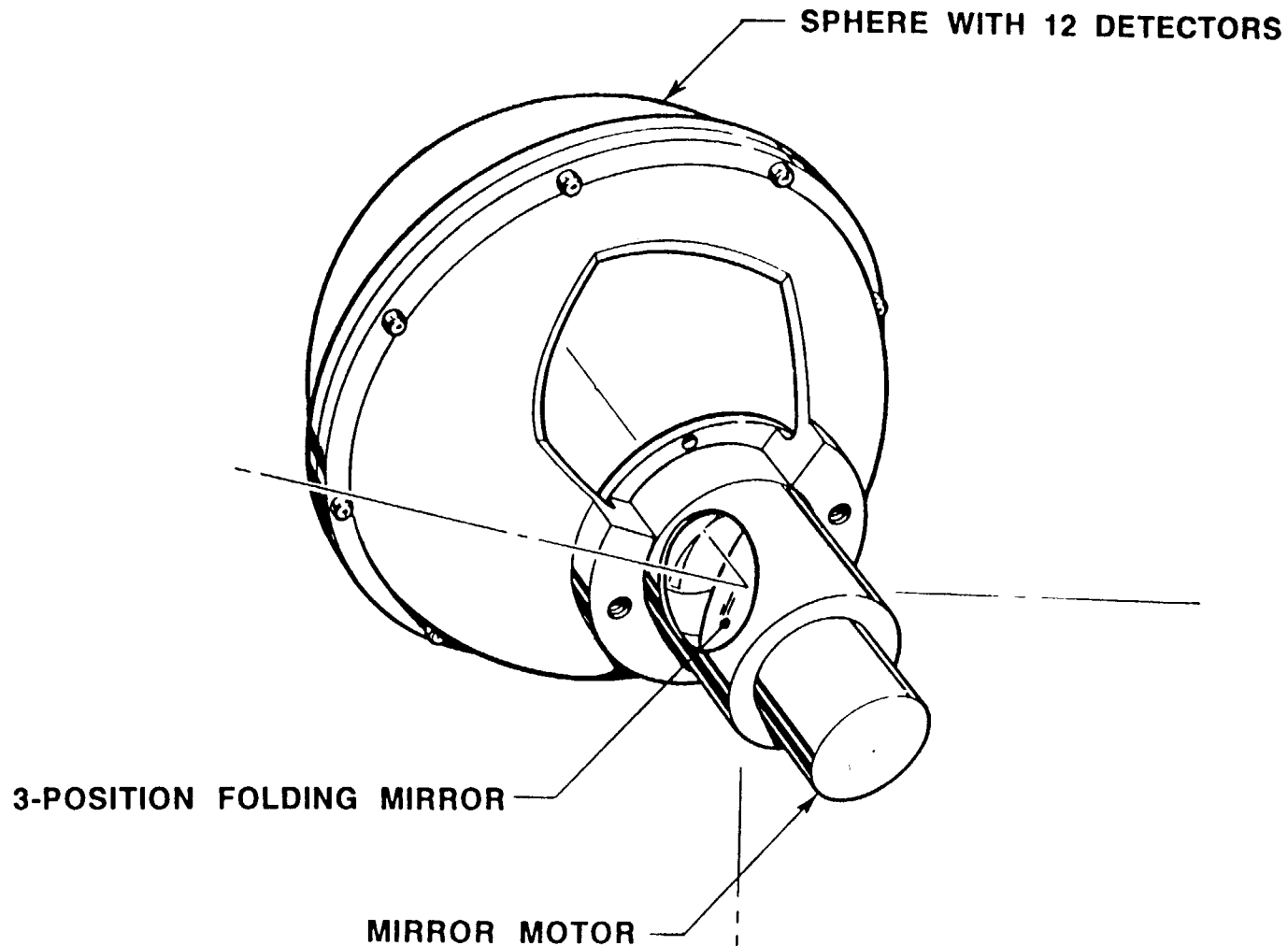




# ARTIST'S RENDERING OF NEW SDSM CONCEPT

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# CONTAMINATION EFFECTS ON CROSSTRACK CALIBRATION

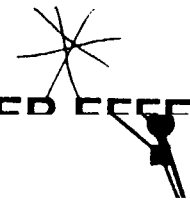


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## • ASSUMPTIONS:

- CONTAMINATION LEVEL (5 YEAR) GSFC MODEL 55-77A THICKNESS
- CONTAMINANT SPECIES: CARBON AND SILICON OXIDE
- DEPOSITED AS CONTINUOUS THIN FILM
- SBRC MODELING DOCUMENTED IN "MODIS-N CROSSTRACK RADIOMETRIC CALIBRATION VARIATION AS A FUNCTION OF SCAN MIRROR CONTAMINATION" PL3095-N-00360
- CARBON CONTAMINANT HAS MUCH GREATER EFFECT THAN SILICON

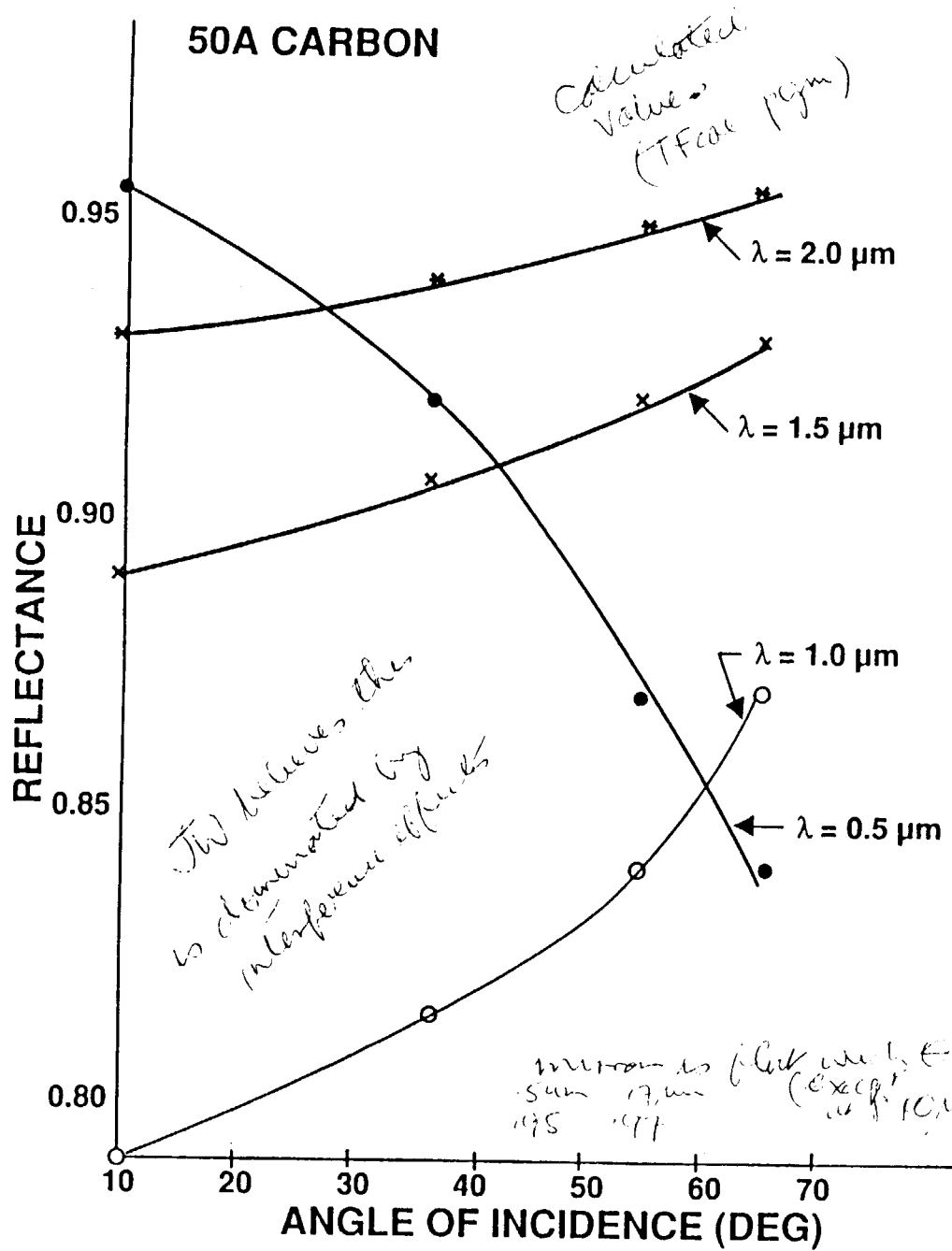
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• "IF" GSFC AND SBRC MODELING IS CORRECT, CONTAMINATION IS A MAJOR PROBLEM FOR RADIOMETRIC CALIBRATION

NO EVIDENCE OF LANDSAT DEGRADATION DUE TO CONTAMINATION

NOTE



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*smooth thin film*

# EFFECT OF 50A CARBON CONTAMINATION ON SCAN MIRROR REFLECTANCE IN VIS/NIR/SWIR REGIONS



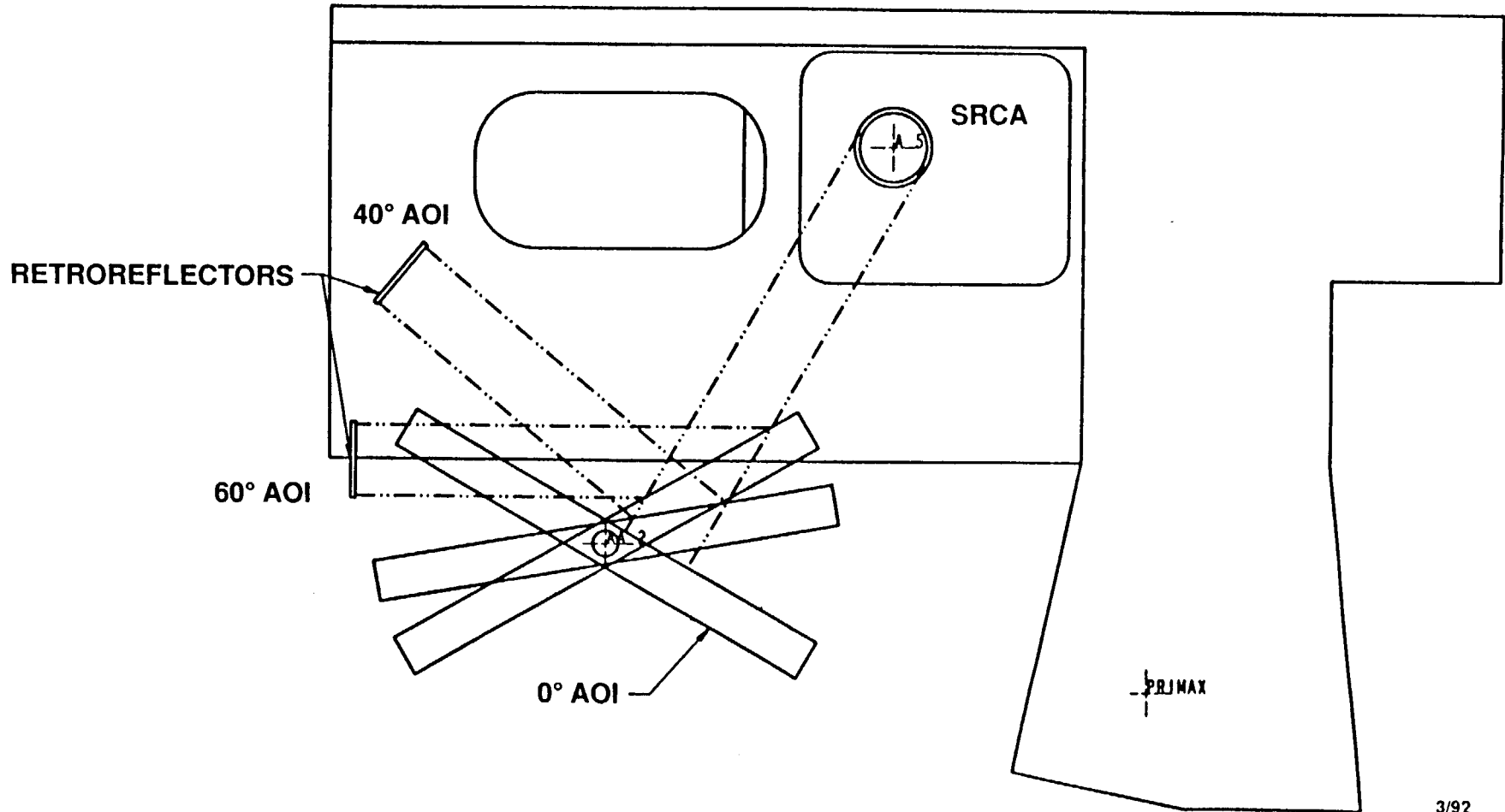
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# MODIFIED SRCA CAN BE USED TO MEASURE SCAN MIRROR REFLECTANCE AT MULTIPLE ANGLES



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FUNCTIONAL/  
PERFORMANCE PARAMETER

	Ambient	Vacuum	MODIS-N Calibrator	Reticles	Sik source	Grating Monochromator	Payload Stimulus Control Console	Spherical Integrator Source	Blackbody FAIRS	Large-Aperture IR Source LAIRS	DC Heatsore Source	Alignment Test Set	Bench Cooler	Space Background Simulator	Payload Interface Control Console	Computer	High Data Rate Recorder	TEST PHASE*
Command and Power																		
Command Verification	X	X													X	X		1, 2, 4, 5, 6
Power Profile	X	X													X	X		
Turn On Transients	X	X													X	X		
Operational Transients	X	X													X	X		
Power Supply Transients	X	X													X	X		
Power Supply Ripple	X	X													X	X		
Spectral Coverage																		
In-Band Shape	X	X	X			X				X		X	X	X	X	X		1, 2, 3, 4, 5
Out of Band	X	X	X			X				X		X	X	X	X	X		
Spatial Coverage (IFOV)																		
Cross Track	X		X	X	X					X				X	X	X		1, 2, 3
Along Track	X		X	X	X					X				X	X	X		
Far Field Spurious	X		X					X	X	X	X	X		X	X	X		4
Radiometric Performance																		
Gain	X	X	X				X	X	X	X		X	X	X	X	X	X	3, 4, 5, 6
Offset	X	X	X				X	X	X	X		X	X	X	X	X	X	
Signal Versus Radiance	X	X	X				X	X	X	X		X	X	X	X	X	X	
Linearity	X	X	X				X	X	X	X		X	X	X	X	X	X	
SNR	X	X	X				X	X	X	X		X	X	X	X	X	X	
On Board Calibrator	X	X	X				X	X	X	X		X	X	X	X	X	X	
Spectral Matching			X	X						X		X	X	X	X	X	X	
Coherent Noise	X	X	X				X	X	X	X		X	X	X	X	X	X	
Scan Modulation	X	X					X	X	X	X		X	X	X	X	X	X	
Band-to-Band Stability	X	X		X			X	X	X	X		X	X	X	X	X	X	
MTF (Sine Wave)																		
Along Track	X	X	X	X			X			X		X	X	X	X	X		1, 2, 3, 4, 5, 6
Cross Track	X	X	X	X			X			X		X	X	X	X	X		
Transient Response																		
Rise Time	X	X	X	X			X			X		X		X	X	X		1, 4
Overshoot/Undershoot	X	X	X	X			X			X		X		X	X	X		
Polarization Sensitivity	X					X				X		X		X				1, 3
Spectral Band Registration																		
Along Track	X	X	X	X			X			X		X	X	X	X	X	X	3, 4, 5
Crosstrack	X	X	X	X			X			X		X	X	X	X	X	X	
Alignment Reference	X										X							3, 6

- \*Test Phase
1. Subsystem checkout
  2. Subsystem integration
  3. Optical alignment and performance (performed during subsystem integration and prior to Phase 4.)
  4. Ambient environmental bench tests
  5. Thermal vacuum environmental tests
  6. Instrument/spacecraft integration tests



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# PERFORMANCE VERIFICATION MATRIX



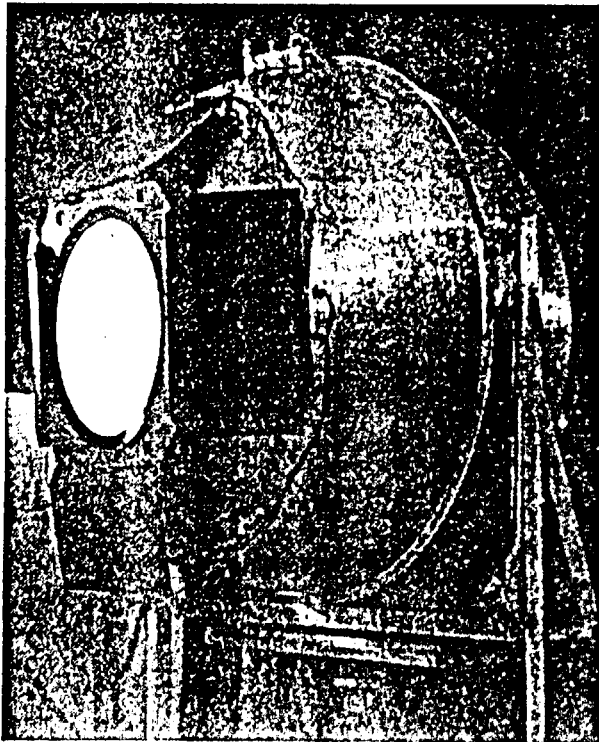
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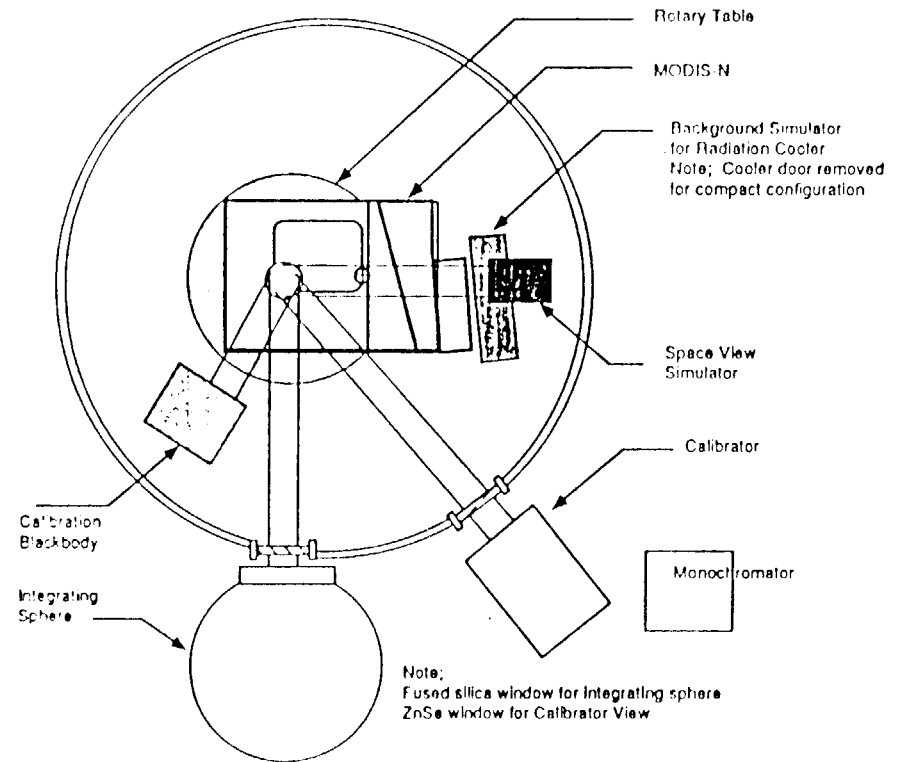
# MODIS-N PRE-FLIGHT CALIBRATION HARDWARE AND TEST EXPERIENCE BASED ON TM



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- INTEGRATING SPHERE FOR VIS/NIR/SWIR RADIOMETRIC CALIBRATION



- THERMAL VACUUM CHAMBER TEST CONFIGURATION

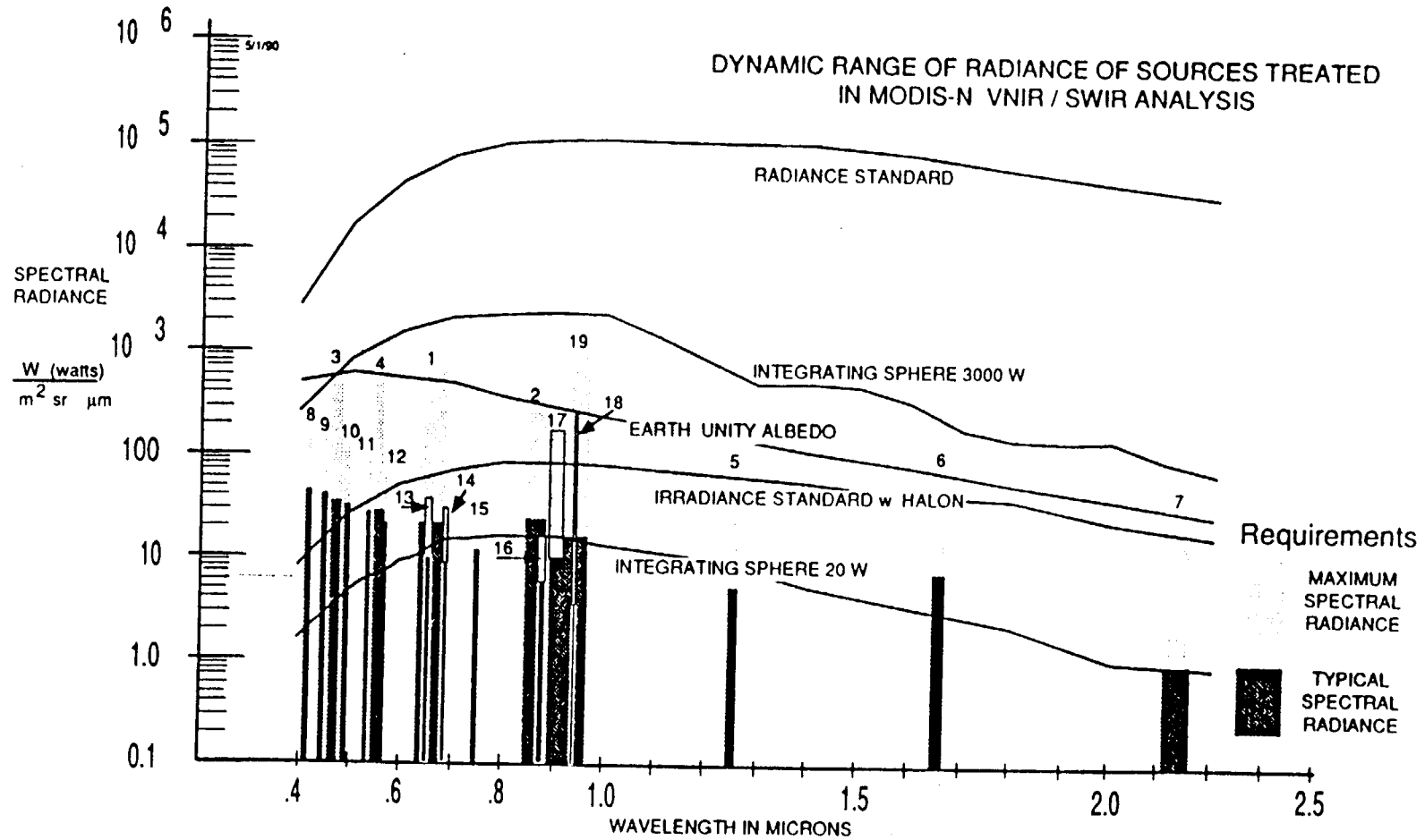
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# RADIANCE LEVELS OF SPHERICAL INTEGRATING SOURCE VS. REQUIREMENTS



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# DESIGN PARAMETERS SPHERICAL INTEGRATING SOURCE



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- RADIOMETRIC CALIBRATION SOURCE FOR VIS/NIR/SWIR
  
- INTEGRATING SPHERE SIZE
  - SPHERE DIAMETER 100 cm
  - EXIT PORT DIAMETER 46 cm
  - REMOVABLE PORT DIAMETER 30 cm
  
- INTERIOR WALL PAINT BaSO<sub>4</sub>
  
- QUARTZ HALOGEN LAMPS 37
  - 18-200W, 9-45W,
  - 10 - 4.8W
  
- SOURCE MONITORING
  - LAMP CURRENT 0.02%
  - EFFECTIVE ALBEDO RANGE 1.0 TO 0.001
  - PROJECTED CALIBRATION ACCURACY 3%

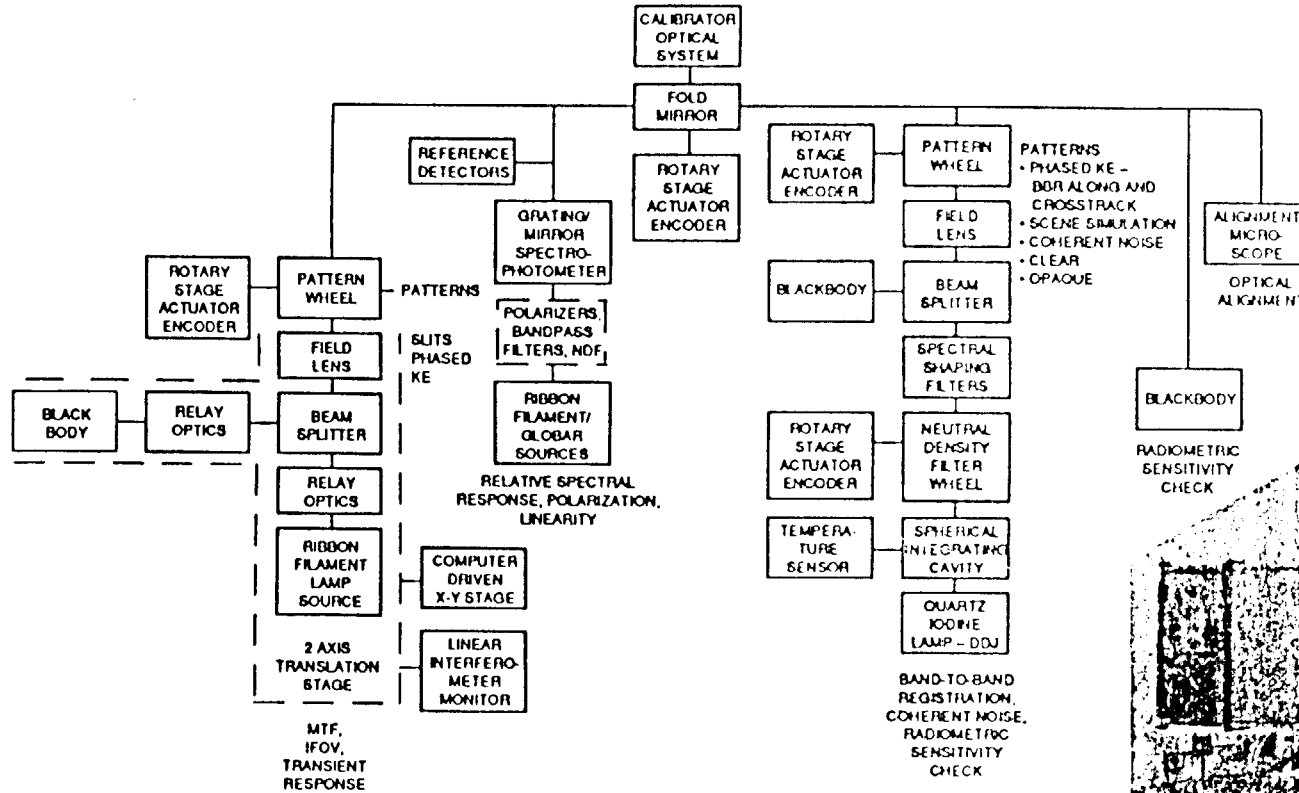




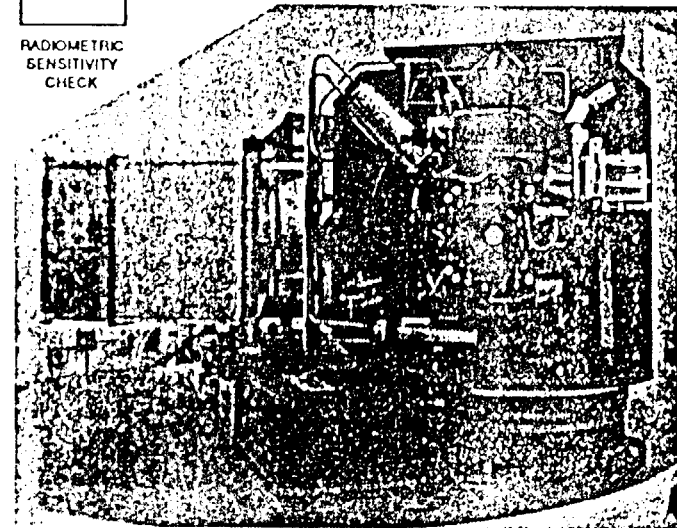
# MODIS-N CALIBRATOR WILL BE USED TO CONDUCT A BATTERY OF TESTS



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TM CALIBRATOR



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