MODIS-N INSTRUMENT STATUS

TOM PAGANO AND JIM YOUNG

14 APRIL 1990

Attachment 1.7

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary
4/92
92-0257-1

PRESENTATION OUTLINE

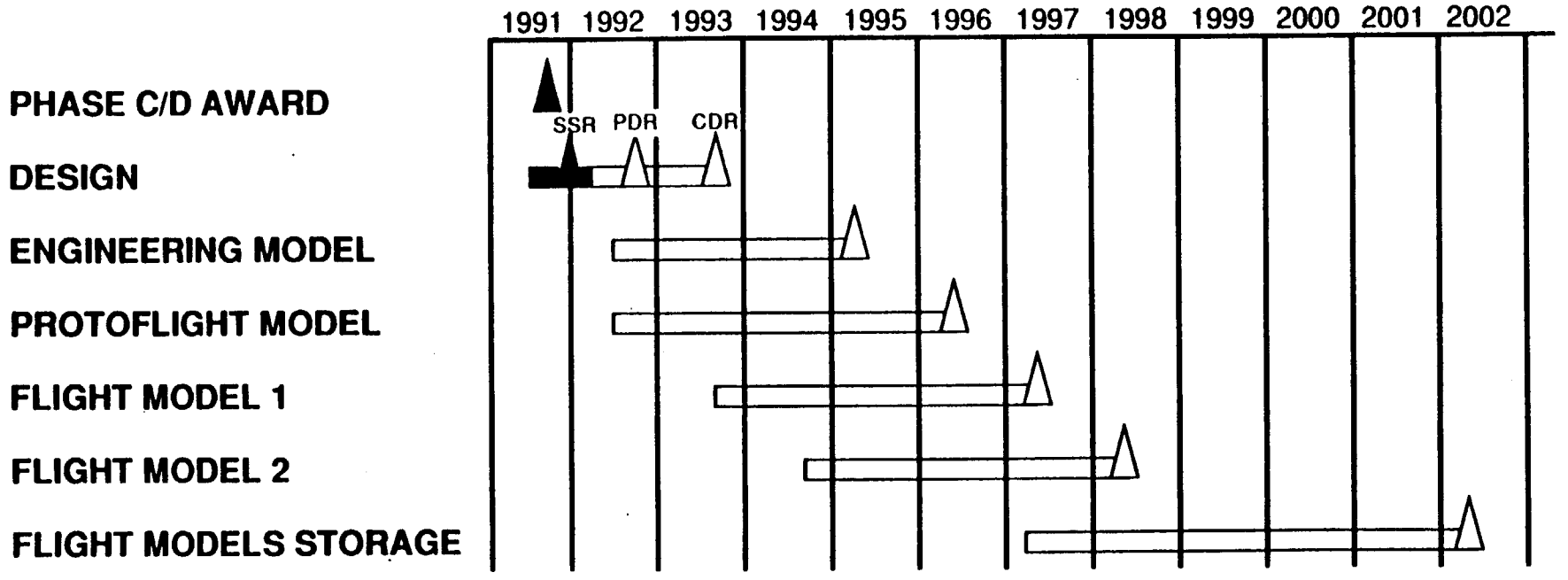
HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

- Introduction: MODIS-N Program
- Requirements Review
- System Overview
- Main Instrument Assemblies
- In-flight Calibration Assemblies
- System Performance Predictions
- Spacecraft and Data Interface Information
- Spectral Filter Discussion

MODIS-N SUMMARY SCHEDULE

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

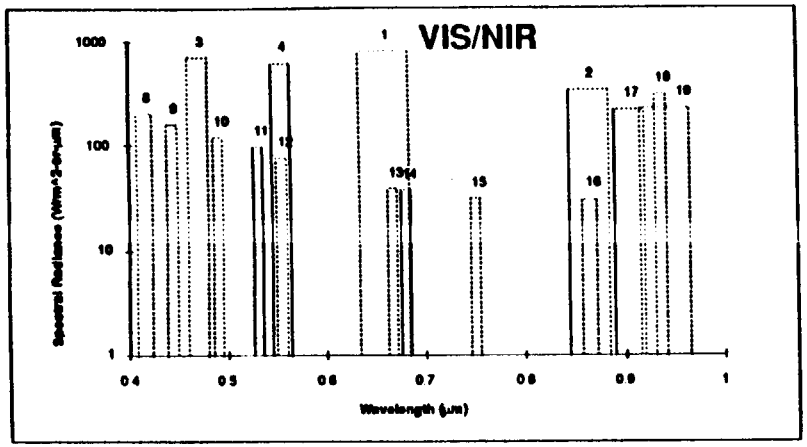


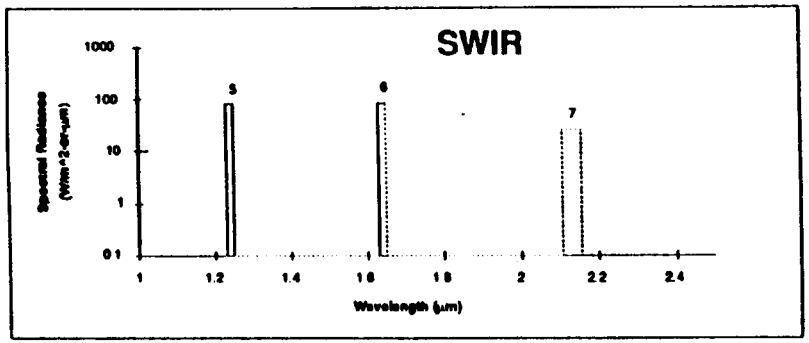
REQUIREMENTS REVIEW

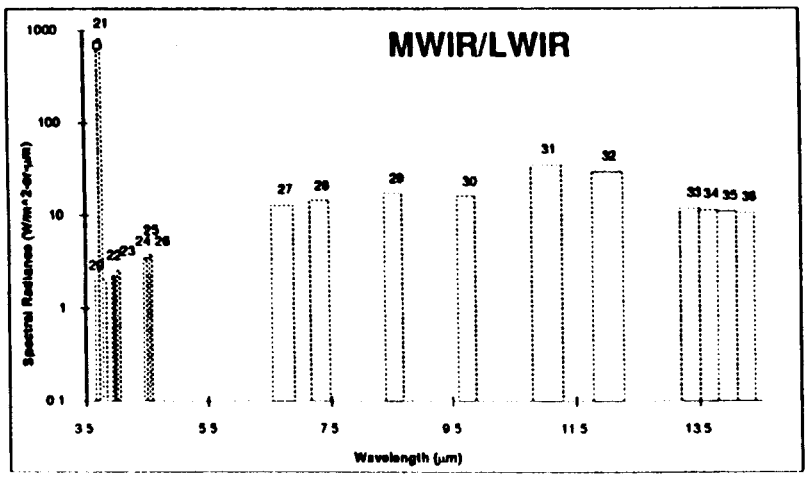
SYSTEM REQUIREMENTS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

• Spectral Coverage	0.407 μm - 14.385 μm, 36 Bands
• Spectral Resolution	10 nm ≤ Δλ ≤ 500 nm
• Spectral Stability	λ & Δλ stable to ≤ 2nm (VIS bands, desired for NIR bands)
	λ & Δλ stable to ≤ 1% (all other bands)
• Spatial Coverage	±55°, 2330 km swath length at 705km
	(contiguous scans at nadir at the equator)
• Spatial Resolution	250 m; 500 m; 1000 m at Nadir
	(375.7m; 751.4m; 1502.8m at ±45°)
	(501.5m; 1002.9m; 2005.8m at ±55°)
• Spatial Registration	≤0.1 IFOV
• IFOV	.354 mr, .709 mr, 1.418 mr (All ±6%)
• Radiometric Range	0.002% ≤ ρ ≤ 100%, 3K ≤ T ≤ 700K
• Dynamic Range	NEΔL to Lmax (requires 12 bits)
• Radiometric Performance	57 ≤ SNR ≤ 1087, 0.05 K ≤ NEΔT ≤ 5.0 K
• Polarization Insensitivity	≤2%, 0.43 μm ≤ λ ≤ 2.2 μm
• Calibration Accuracy	Absolute Calibration: ±1% λ > 3 μm; ±5% λ <3 μm;
	±2% Reflectance (λ <3 μm)







HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N MEETS WIDE RANGE OF SPECTRAL REQUIREMENTS

MODIS-N
GSFC SBRC

4/92
92-0257-2A

MODIS-N VIS/NIR/SWIR SPECTRAL BANDS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

BAND	λ	IFOV	Δλ	PURPOSE (EXAMPLES)
	LAND AND CLOUD BOUNDARIES BANDS			
1	659 nm	250m	50 nm	VEG CHLOROPHYLL ABS LAND COVER TRANS.
2	865 nm	250m	40 nm	CLOUD AND VEGETATION LAND COVER TRANSF.
	LAND AND CLOUD PROPERTIES BANDS			
3	470 nm	500m	20 nm	SOIL, VEGETATION DIFFERENCES
4	555 nm	500m	20 nm	GREEN VEGETATION
5	1240 nm	500m	20 nm	LEAF/CANOPY DIFFERENCES
6	1640 nm	500m	20 nm	SNOW/CLOUD DIFFERENCES
7	2130 nm	500m	50 nm	LAND AND CLOUD PROPERTIES
	OCEAN COLOR BANDS			
8	415 nm	1000m	15 nm	CHLOROPHYLL
9	443 nm	1000m	10 nm	CHLOROPHYLL
10	490 nm	1000m	10 nm	CHLOROPHYLL
11	531 nm	1000m	10 nm	CHLOROPHYLL
12	555 nm	1000m	10 nm	SEDIMENTS
13	667 nm	1000m	10 nm	SEDIMENTS, ATMOSPHERE
14	681 nm	1000m	10 nm	CHLOROPHYLL FLUORESCENCE
15	750 nm	1000m	10 nm	AEROSOL PROPERTIES
16	865 nm	1000m	15 nm	AEROSOL/ATMOSPHERIC PROPERTIES
	ATMOSPHERE/CLOUD BANDS			
17	905 nm	1000m	30 nm	CLOUD/ATMOSPHERIC PROPERTIES
18	936 nm	1000m	10 nm	CLOUD/ATMOSPHERIC PROPERTIES
19	940 nm	1000m	50 nm	CLOUD/ATMOSPHERIC PROPERTIES

4/92
92-0257-7

MODIS-N
MWIR/LWIR/SPECTRAL BANDS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

BAND	λ	IFOV	Δλ	PURPOSE (EXAMPLES)
	THERMAL BANDS			
20	3.75 μm	1000m	0.18 μm	SEA SURFACE TEMPERATURE
21	3.75 μm	1000m	0.05 μm	FOREST FIRES/VOLCANOES
22	3.96 μm	1000m	0.05 μm	CLOUD/SURFACE TEMPERATURE
23	4.05 μm	1000m	0.05 μm	CLOUD/SURFACE TEMPERATURE
24	4.47 μm	1000m	0.05 μm	TROPOSPHERIC TEMPERATURE/CLOUD FRACTION
25	4.52 μm	1000m	0.05 μm	TROPOSPHERIC TEMPERATURE/CLOUD FRACTION
26	4.57 μm	1000m	0.05 μm	TROPOSPHERIC TEMPERATURE/CLOUD FRACTION
27	6.72 μm	1000m	0.36 μm	MID-TROPOSPHERIC HUMIDITY
28	7.33 μm	1000m	0.30 μm	UPPER-TROPOSPHERIC HUMIDITY
29*	8.55 μm	1000m	0.30 μm	SURFACE TEMPERATURE
30	9.73 μm	1000m	0.30 μm	TOTAL OZONE
31	11.03 μm	1000m	0.50 μm	CLOUD/SURFACE TEMPERATURE
32	12.02 μm	1000m	0.50 μm	CLOUD HEIGHT & SURFACE TEMPERATURE
33	13.34 μm	1000m	0.30 μm	CLOUD HEIGHT & FRACTION
34	13.64 μm	1000m	0.30 μm	CLOUD HEIGHT & FRACTION
35	13.94 μm	1000m	0.30 μm	CLOUD HEIGHT & FRACTION
36	14.24 μm	1000m	0.30 μm	CLOUD HEIGHT & FRACTION

* DELETED 29 HI

4/92
92-0257-8

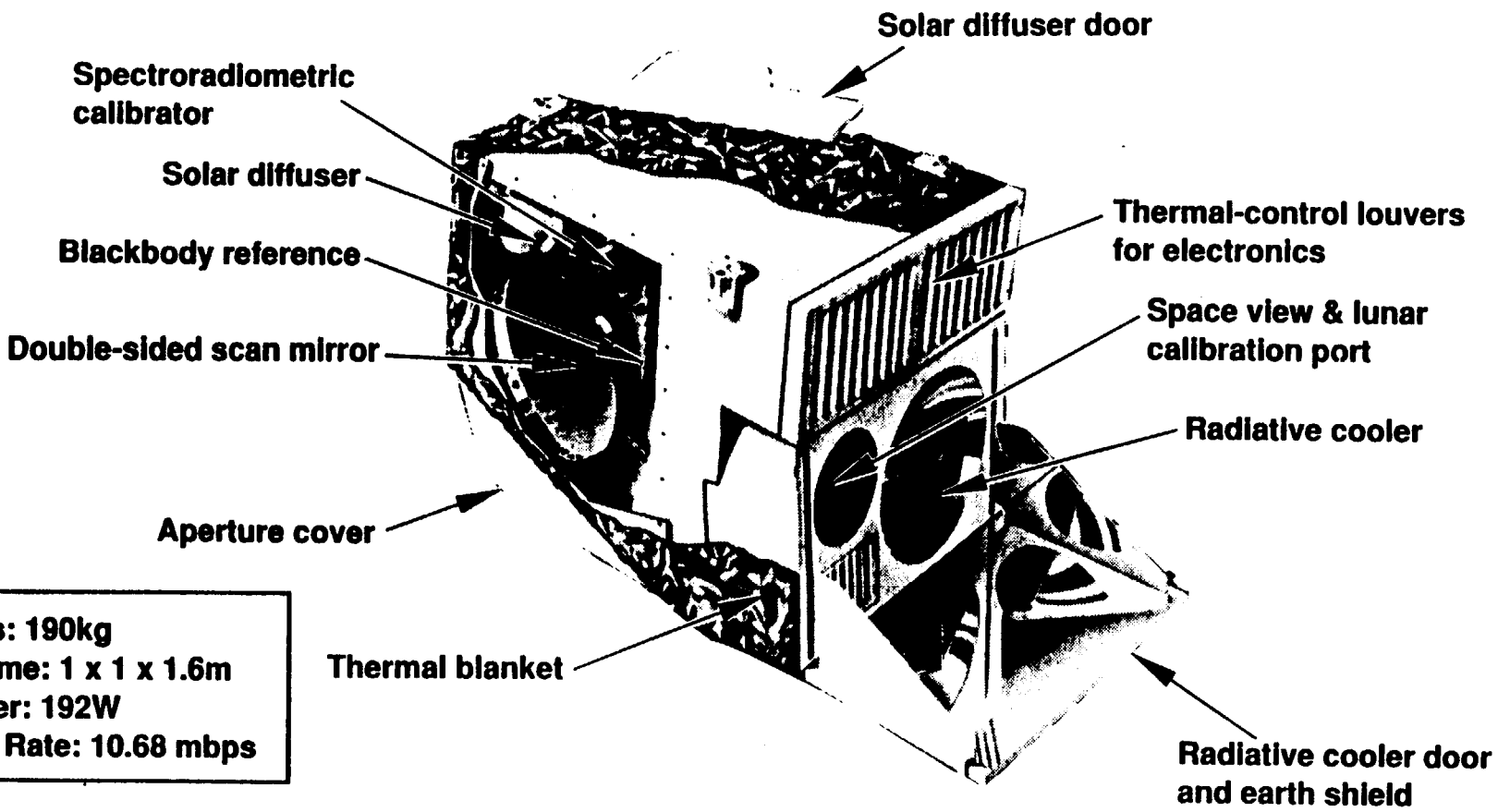
SYSTEM OVERVIEW

MODIS-N CUTAWAY SHOWS KEY SUBSYSTEMS

91-4-147

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



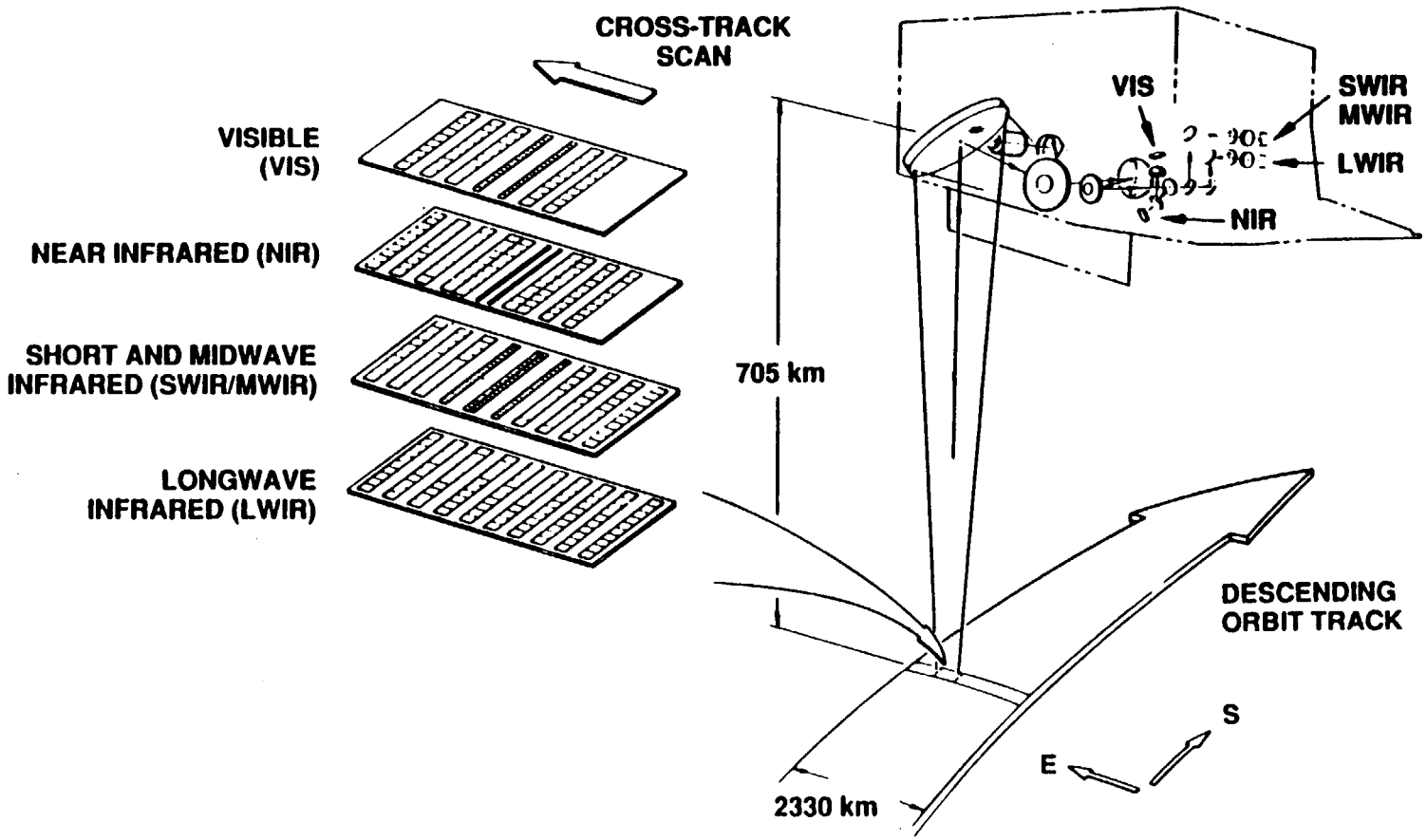
Mass: 190kg
Volume: 1 x 1 x 1.6m
Power: 192W
Data Rate: 10.68 mbps

4/92
92-0257-10

DICHROIC BEAMSPLITTERS SEPARATE ENERGY TO FOUR COREGISTERED OBJECTIVES AND FOCAL PLANES

HUGHES

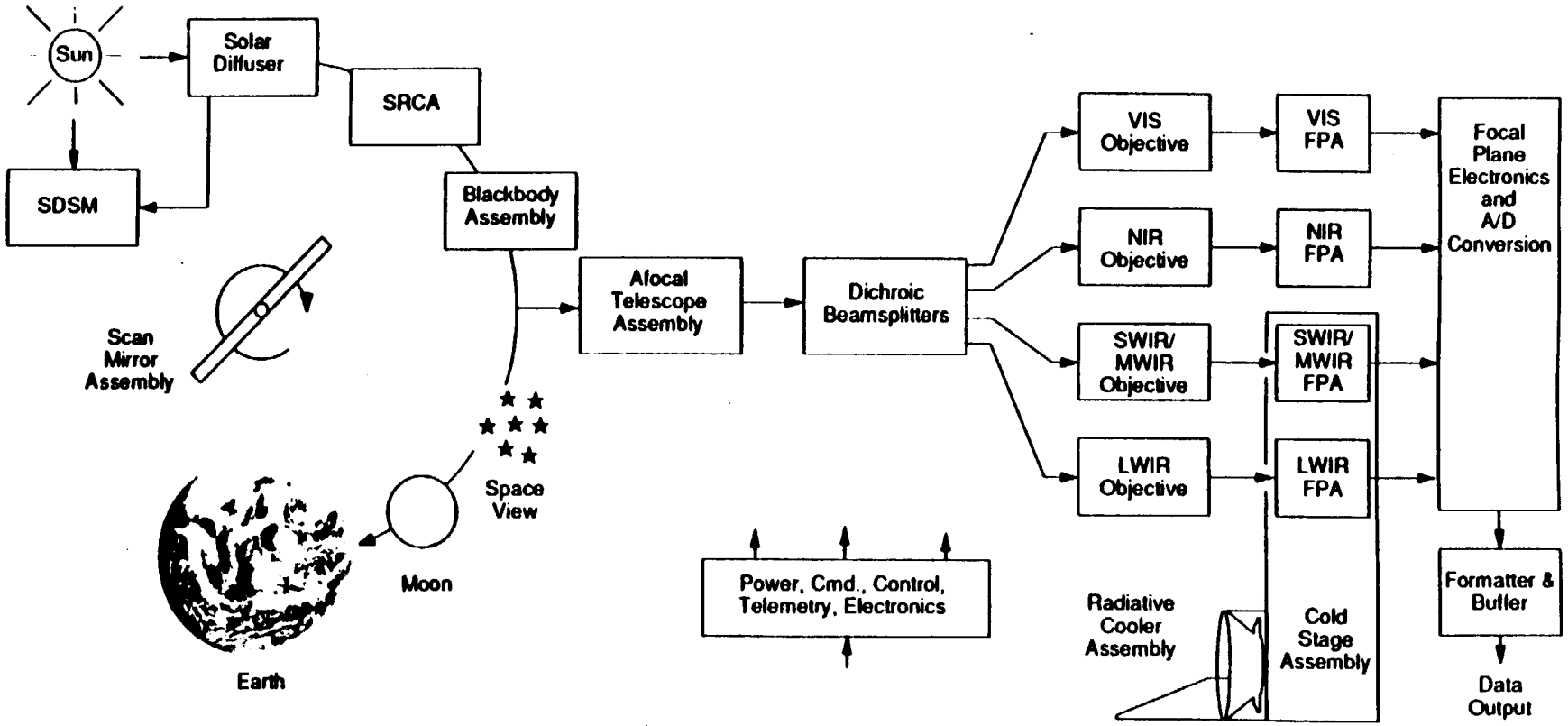
SANTA BARBARA RESEARCH CENTER
a subsidiary



4/92
92-0257-11

FROM PHOTONS TO DATA

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

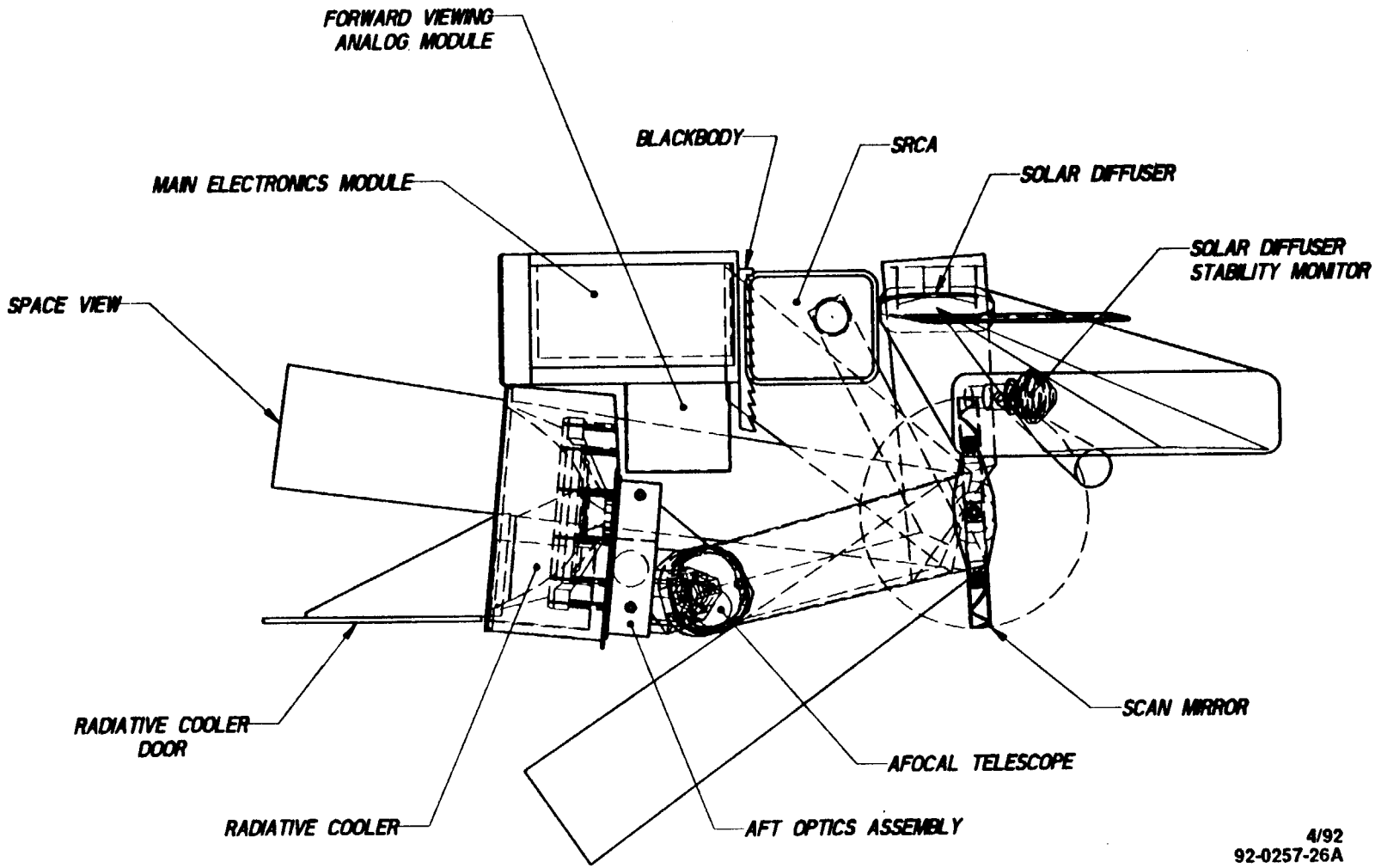


4/92
92-0257-12

SCAN AND CALIBRATION VIEWS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



4/92
92-0257-26A

MODIS-N BASELINE INSTRUMENT PARAMETERS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

ORBIT	705.3 km, 10:30 AM ASCENDING, 1:30 PM ASCENDING
SWATH	±55°, 10.0 km TRACK x 2330 km SCAN
SCANNING	360° SCAN, DOUBLE SIDED, 20.4 RPM, 0.450s ACTIVE SCAN TIME
IFOV	0.354 mr (0.25 km), 0.709 mr (0.50 km), 1.418 mr (1.0 km)
TELESCOPE	2-MIRROR OFF-AXIS GREGORIAN, EPD 17.8 CM, AFOCAL, 4X MAG
SPECTRAL BANDS	36 FROM 0.415 μm TO 14.3 μm
SPECTRAL SEPARATION	DICHROIC BEAMSPLITTERS AND SPECTRAL FILTERS
DWELL TIME	83.7 μs (0.25 km), 167.3 μs (0.50 km), 334.6 μs (1.0 km)
DETECTOR MATERIAL	SILICON ($0.4\ \mu m \leq \lambda \leq 0.95\ \mu m$), PV HgCdTe ($1\ \mu m \leq \lambda \leq 10\ \mu m$), PC HgCdTe ($\lambda > 10\ \mu m$)
DETECTOR READOUT	CAPACITIVE TRANSIMPEDANCE AMPLIFIERS (CTIA)
IR DETECTOR COOLING	THEMATIC MAPPER-DERIVATIVE, PASSIVE RADIATIVE COOLER, 85K
CALIBRATION	LABORATORY, GROUND TRUTH, ON-BOARD BLACKBODY, SOLAR DIFFUSER, SRCA, SDSM
DATA RATE	10.10 MBPS (DAY MODE), 2.71 MBPS (NIGHT MODE)
SIZE, WEIGHT, POWER	0.97m x 1.59m x 0.99m, 223.0 kg, 225W

4/92
92-0257-14

MAIN INSTRUMENT ASSEMBLIES

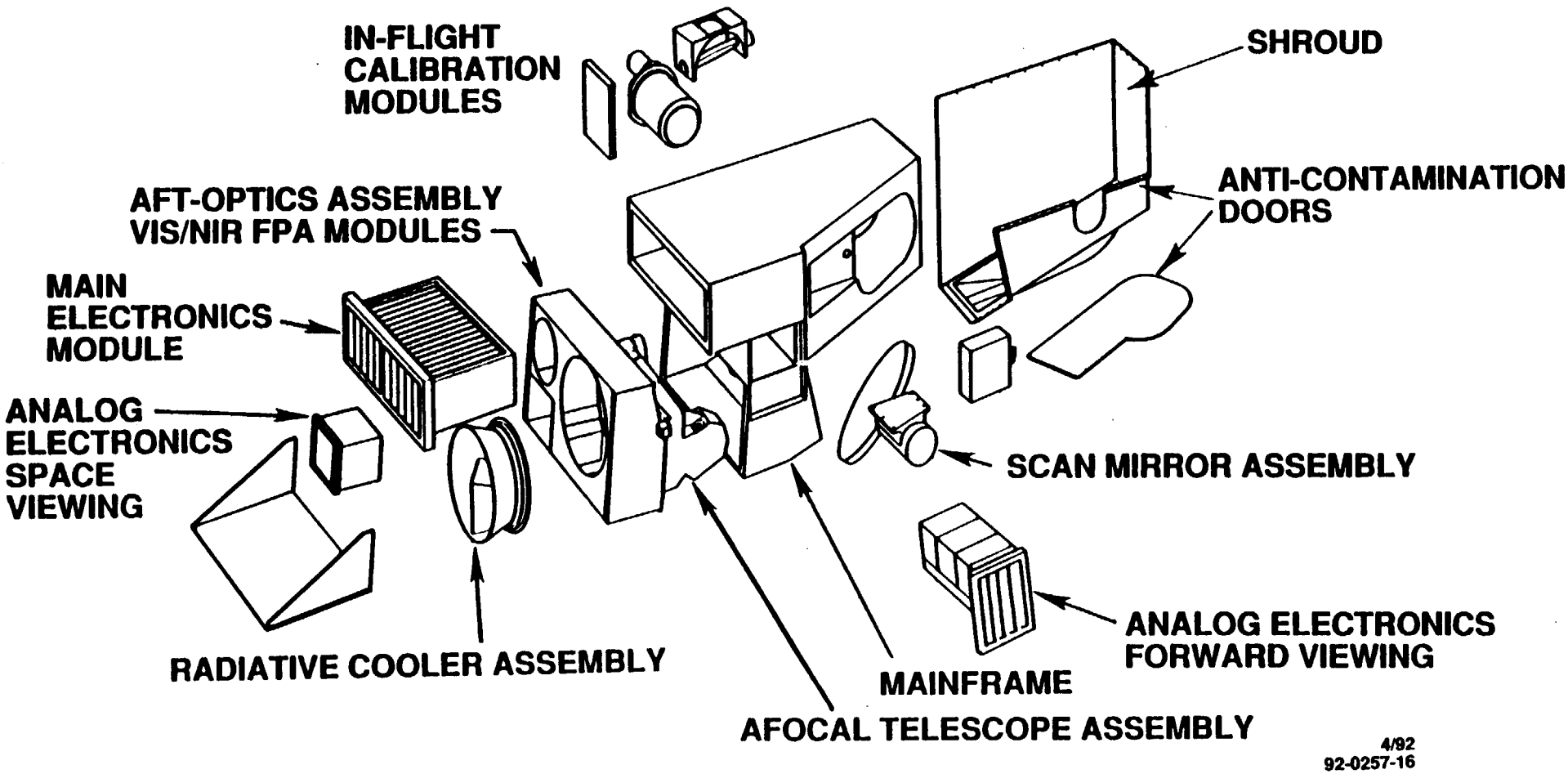
4/92
92-0257-15

MODULAR DESIGN FACILITATES ASSEMBLY, INTEGRATION AND TEST

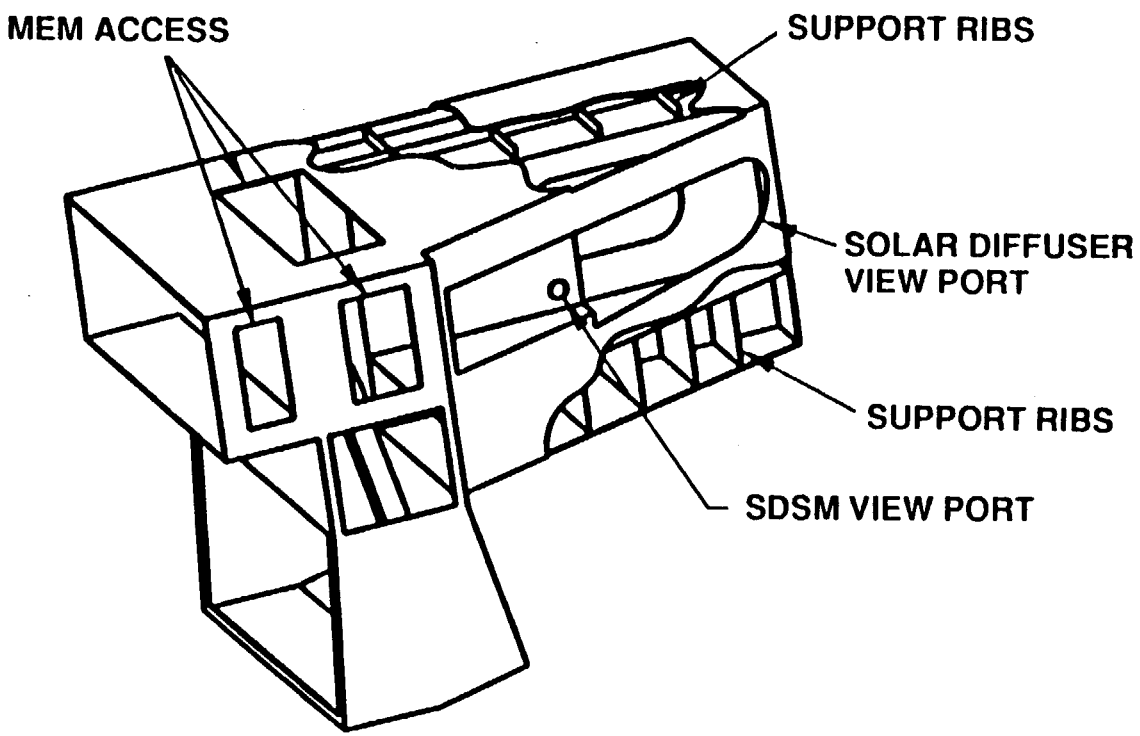
91-9-255A

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



4/92
92-0257-16



HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

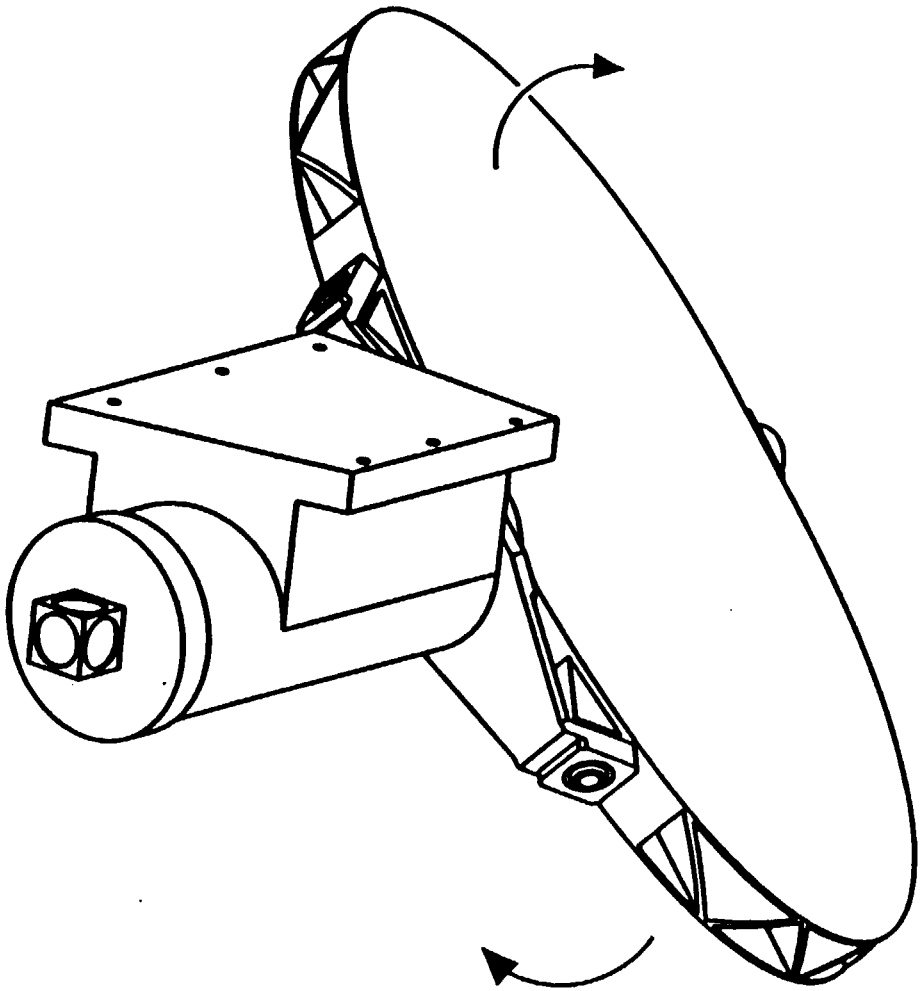
MODIS-N MAINFRAME SUPPORTS MAJOR SUBASSEMBLIES

4/92
92-0257-17

MODIS-N EMPLOYS 2-SIDED SCAN MIRROR

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



DESIGN REQUIREMENTS:

SIZE: 57.15 x 14.13x 5.08 cm

SCAN RATE: 20.44 RPM

SCAN PERIOD: 2.935±0.001s

VELOCITY: 2.1405±0.0017 rad/s

OPERATING LIFE: 1E8 revs

POSITION KNOWLEDGE: 30 arc sec

ANGLE IF INCIDENCE; 38±27.5°

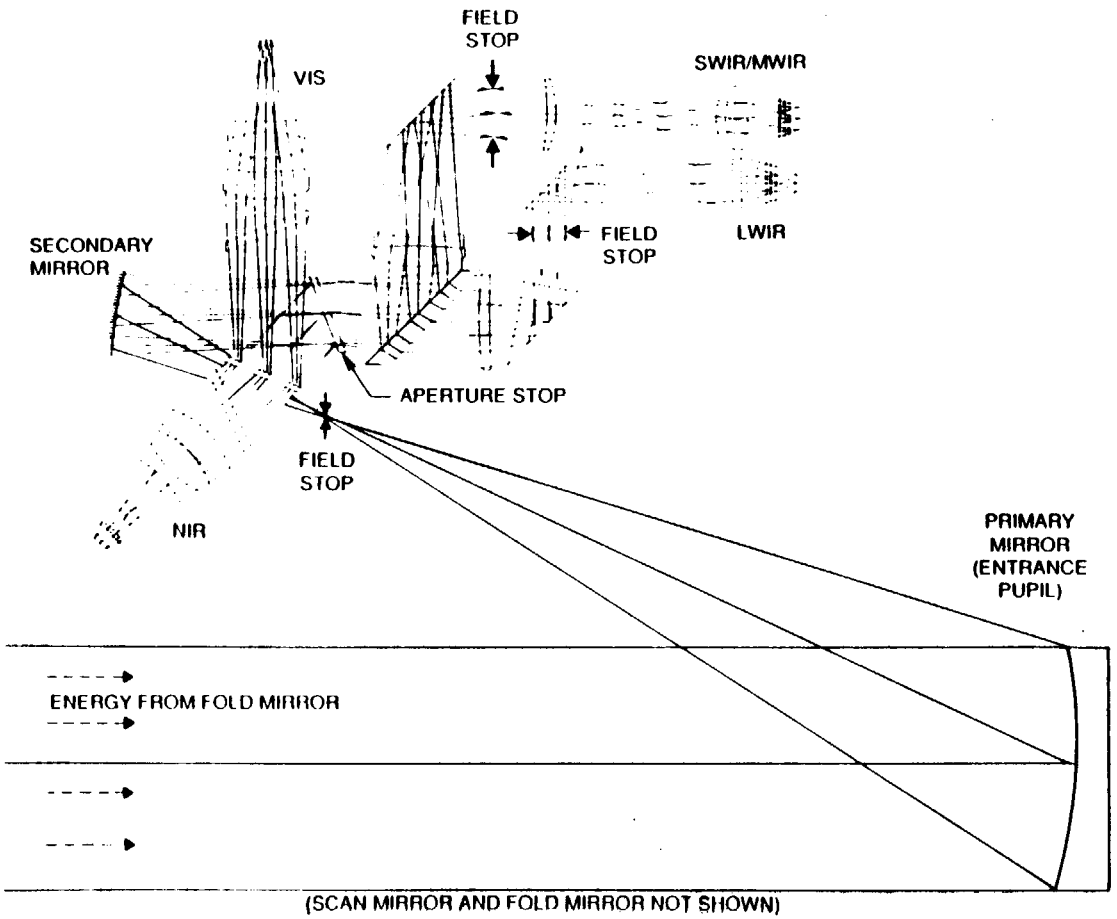
LOW POLARIZATION: ENHANCED SILVER COATINGS

4/92
92-0257-18

OPTICAL DESIGN UTILIZES REFLECTIVE AFOCAL TELESCOPE WITH FOUR REFRACTIVE OBJECTIVE ASEMBLIES

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

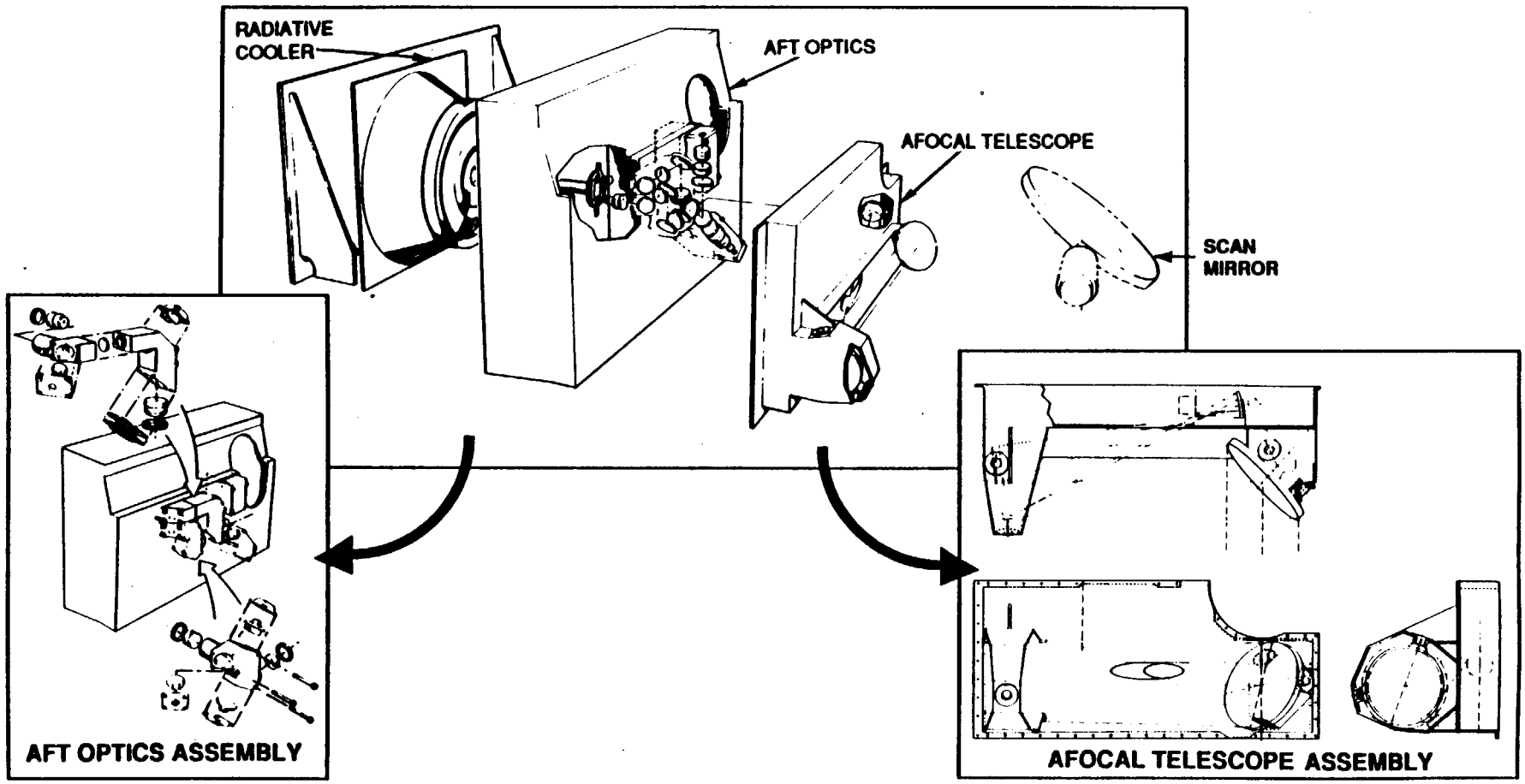


4/92
92-0257-19

MODIS-N TELESCOPE AND AFT-OPTICS ASSEMBLY

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

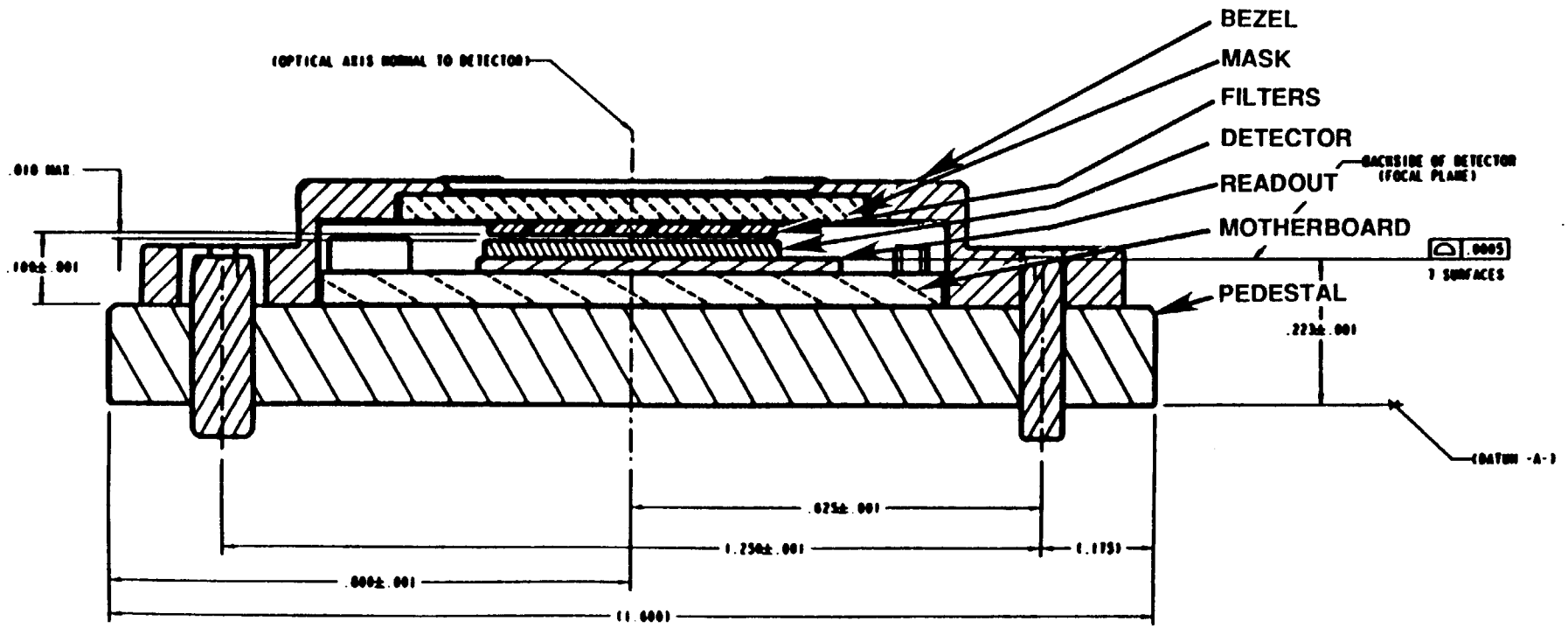


4/92
92-0257-20

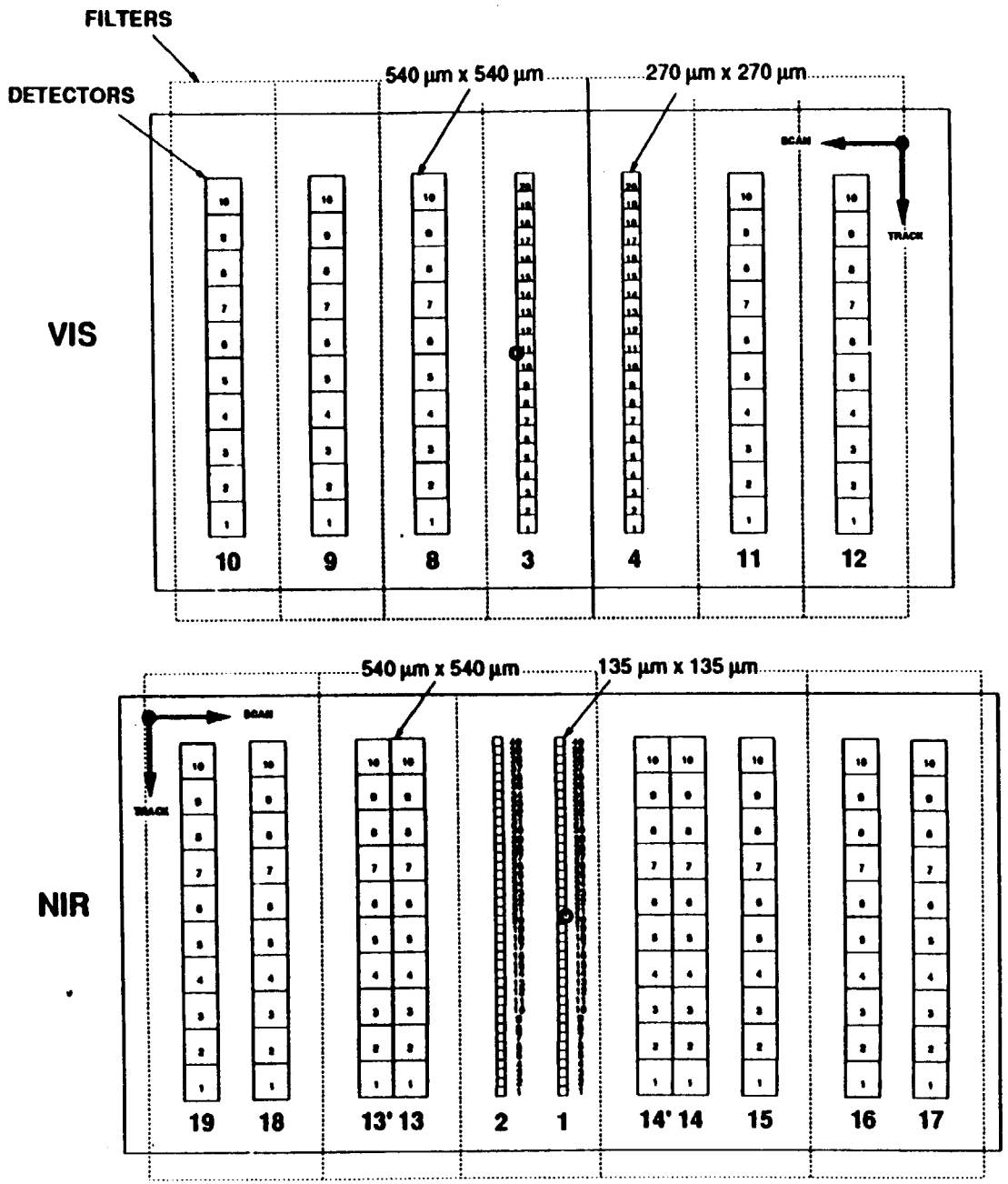
SPECTRAL FILTERS MOUNTED CLOSE TO DETECTORS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



4/92
92-0257-21



HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

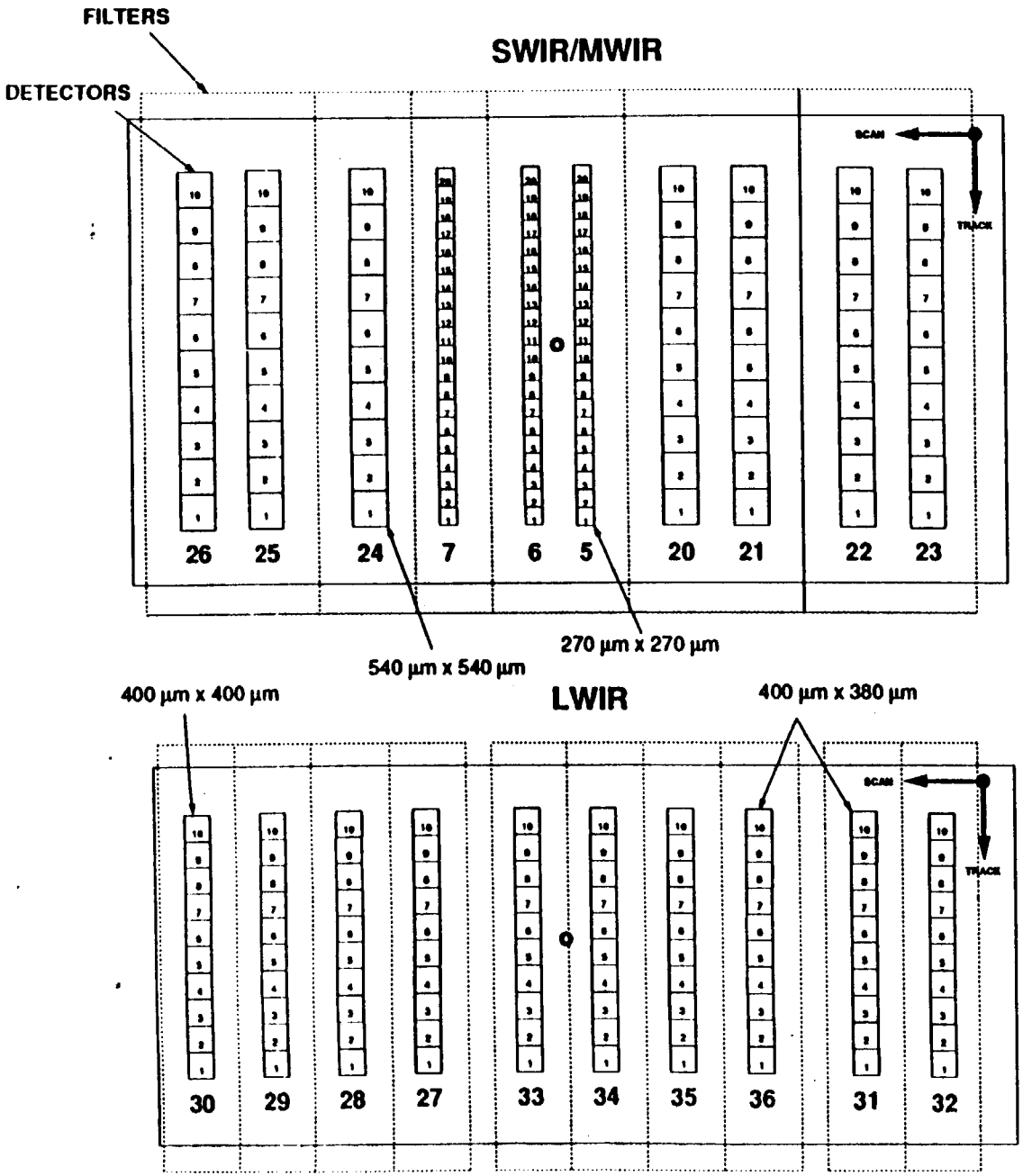
MODIS-N FOCAL PLANE LAYOUTS MINIMIZE EFFECTS OF OPTICAL DISTORTION

FIGURE SHOWS:

- PIXEL LOCATIONS
- PIXEL ID NUMBERS
- FILTER SUBSTRATES
- SCAN AND TRACK
- OPTICAL AXIS

MODIS-N

4/92
92-0257-22



HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

SMALLER PIXELS IN LWIR (≈400 µm Sq.) MINIMIZE DETECTOR NOISE

FIGURE SHOWS:

- **PIXEL LOCATIONS**
- **PIXEL ID NUMBERS**
- **FILTER SUBSTRATES**
- **SCAN AND TRACK**
- **OPTICAL AXIS**

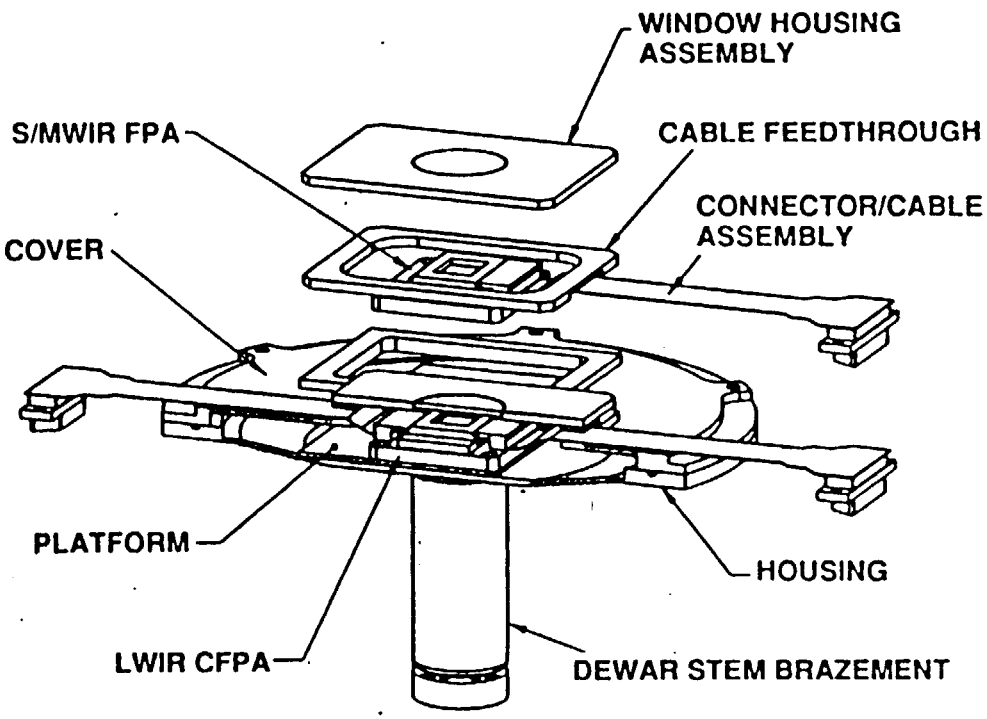
MODIS-N

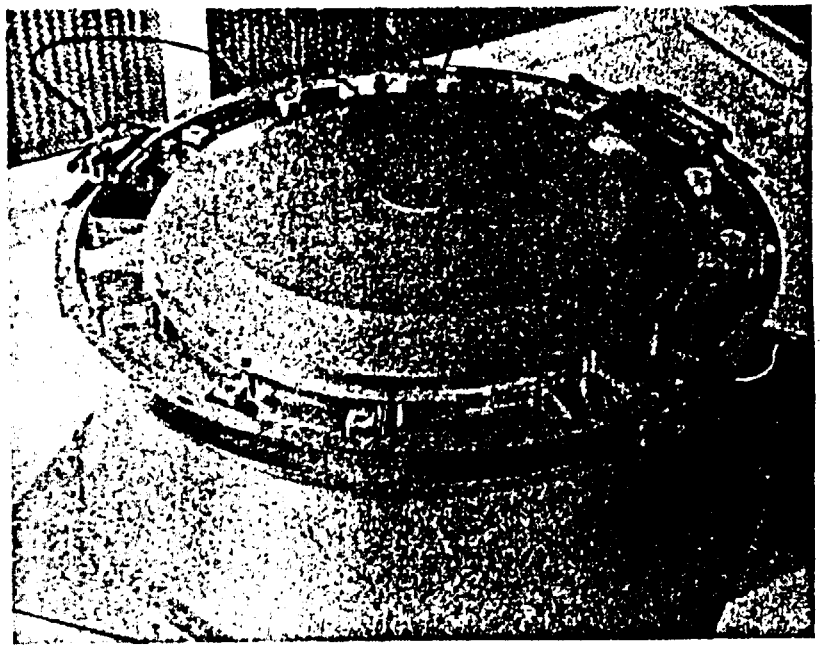
4/92
92-0257-23

RADIATIVE COOLER ASSEMBLY IS ENHANCED THEMATIC MAPPER (ETM) DERIVATIVE

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



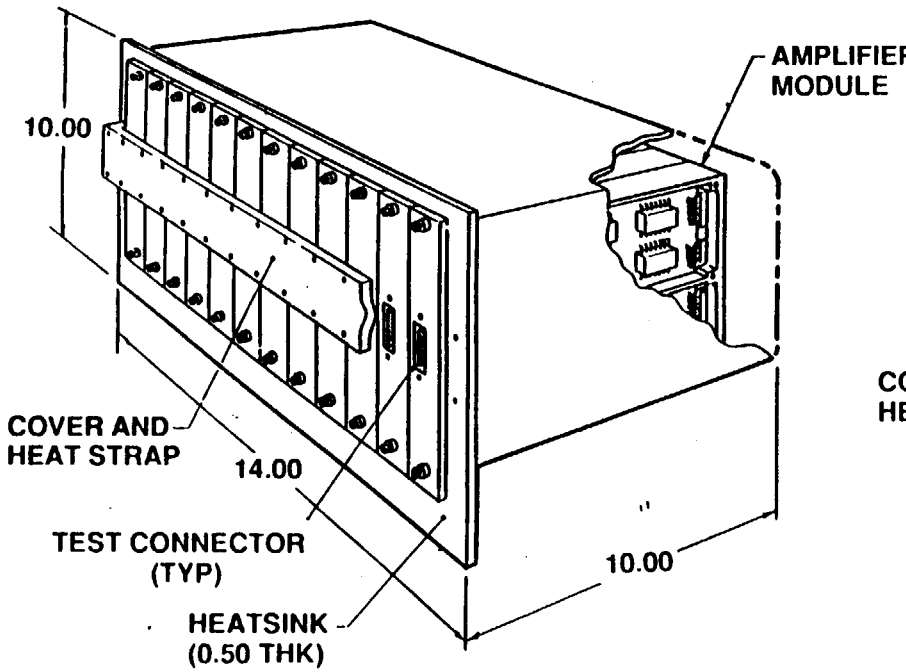


ETM COOLER

COLD STAGE ASSEMBLY
- 85K COLD STAGE TEMPERATURE

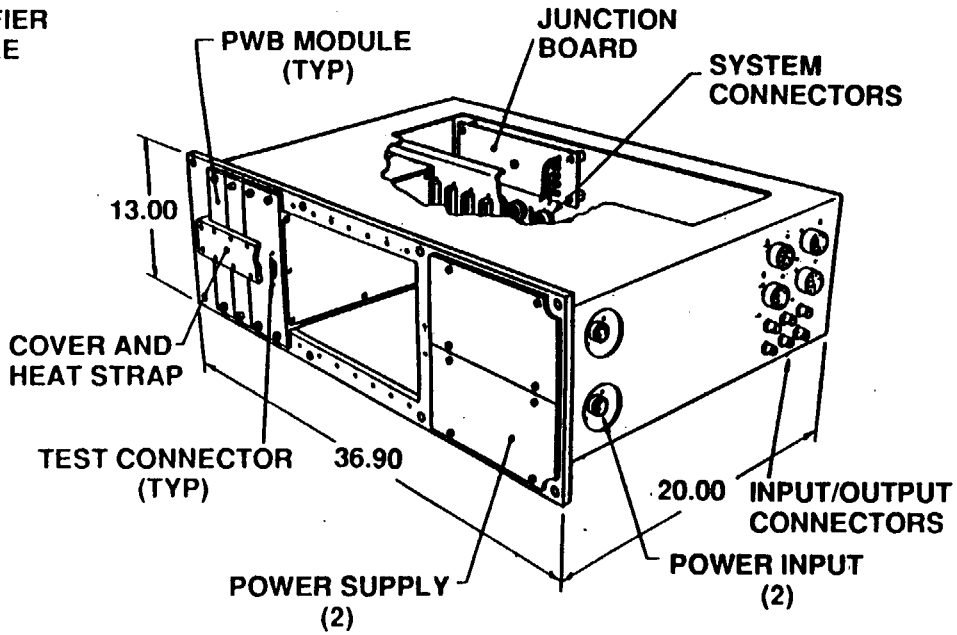
ELECTRONICS HOUSED IN TWO MODULES

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary



ANALOG ELECTRONICS MODULE SPACE VIEWING

- Analog processing (FPAs)
- A/D conversion
- Isolates sensitive analog signals
- AEM - forward viewing not shown



MAIN ELECTRONICS MODULE

- Power, command, control
- Data formatting
- 15 Mb FIFO memory

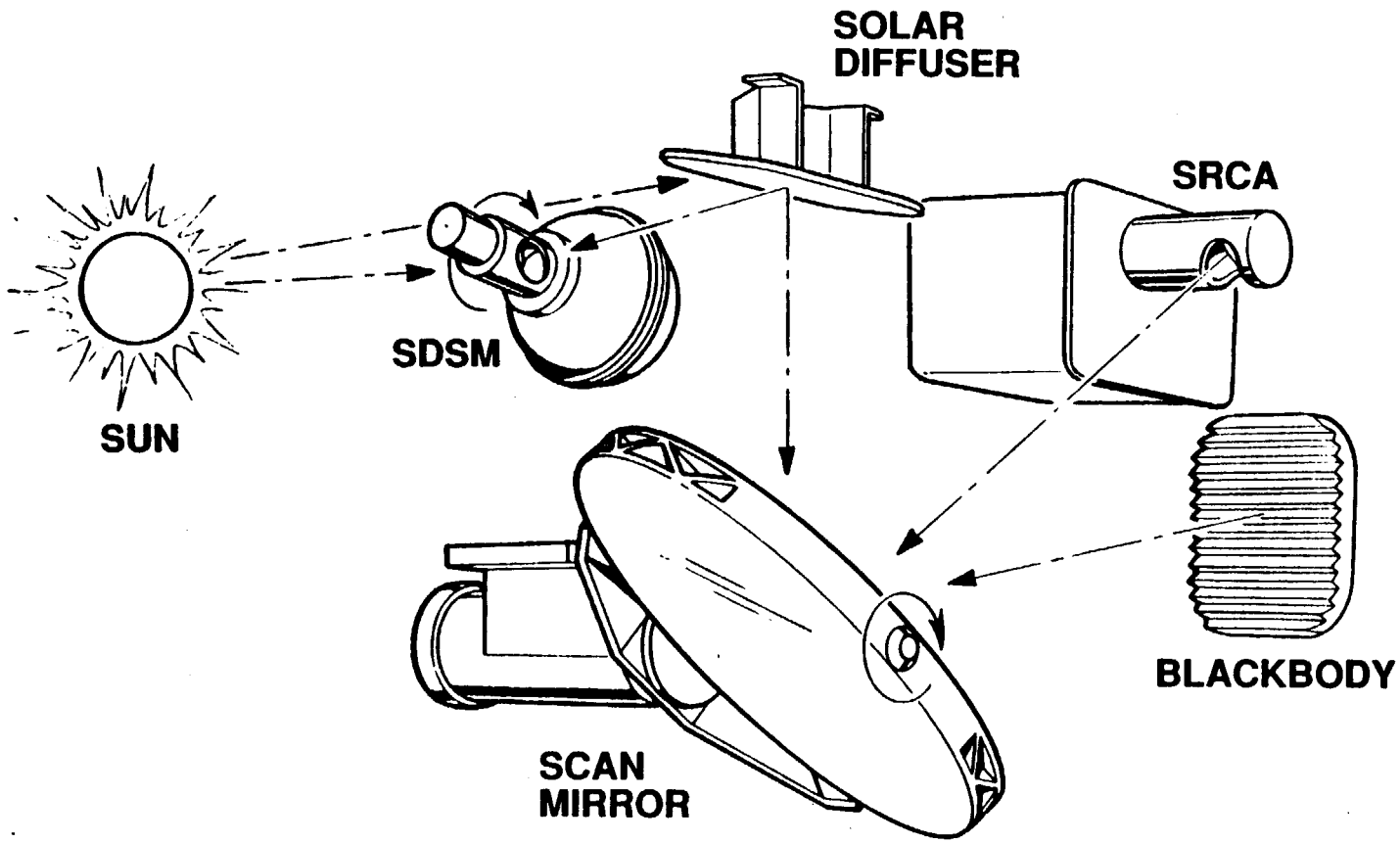
4/92
92-0257-25

IN-FLIGHT CALIBRATION ASSEMBLIES

4/92
92-0257-26

MODIS-N IN-FLIGHT CALIBRATORS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

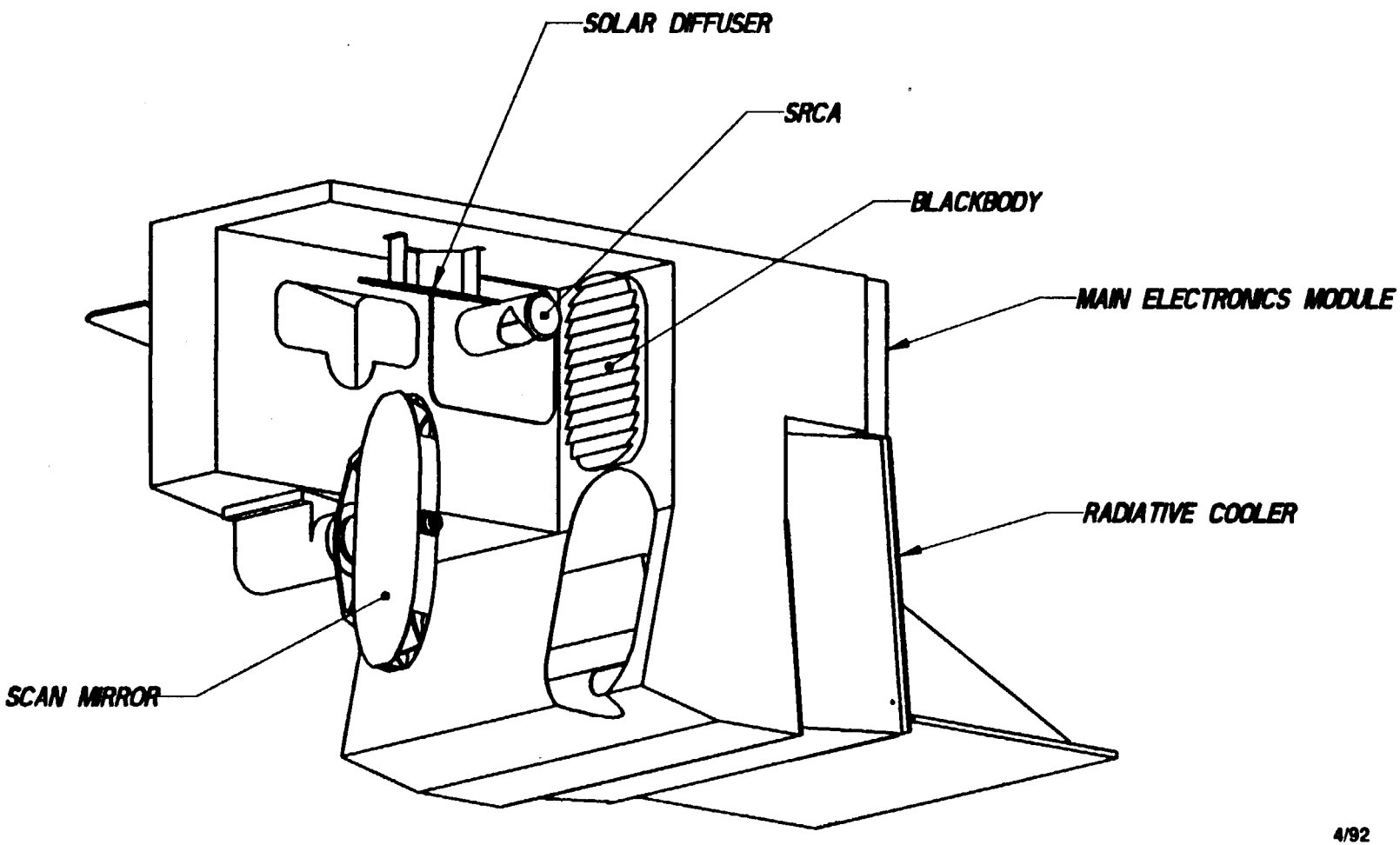


4/92
92-0257-27

MODIS-N INTERIOR VIEW

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



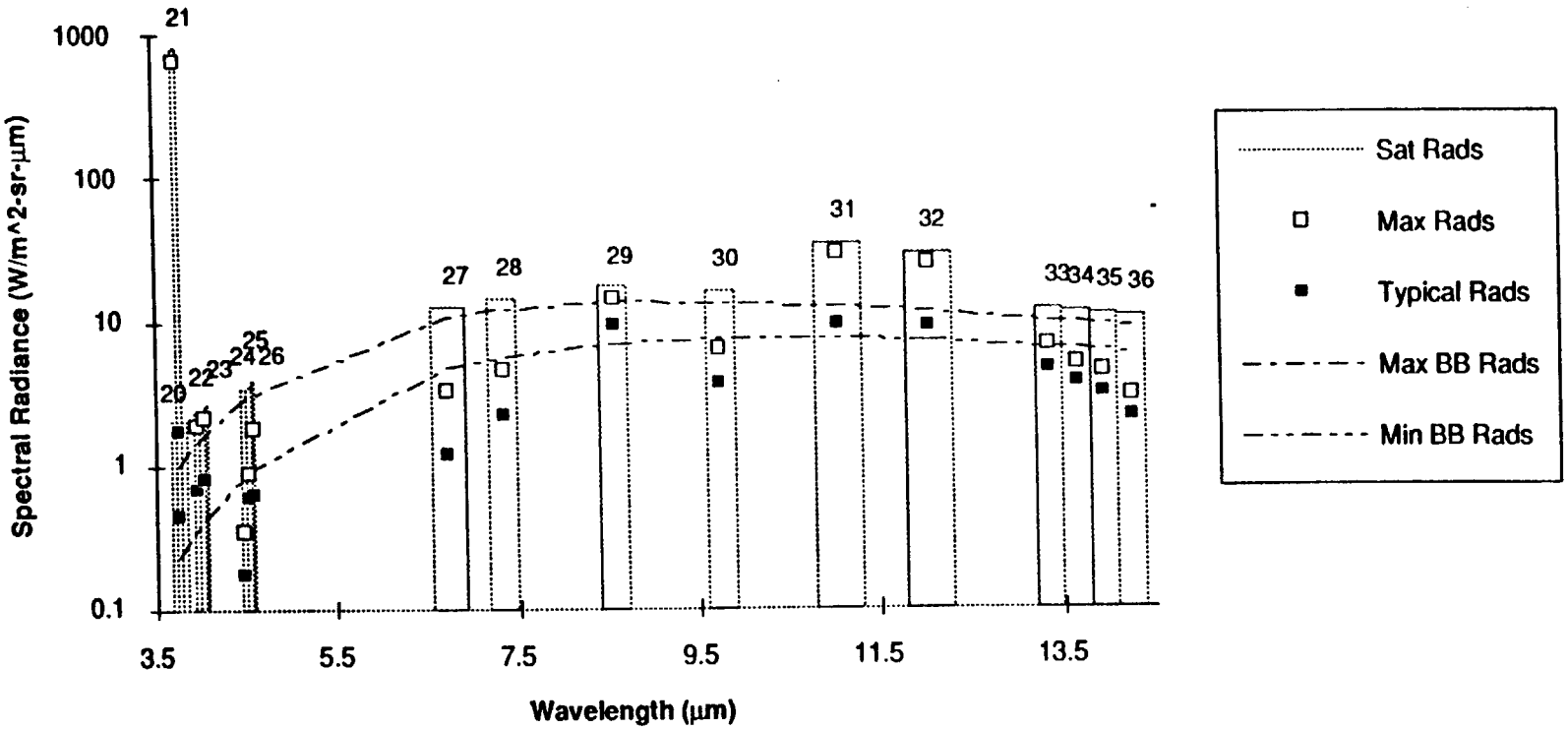
4/92
92-0257-13A

EMISSIVE BANDS ACCOMMODATE FULL RANGE OF SIGNAL LEVELS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N

Typical, Saturation and Blackbody Radiances



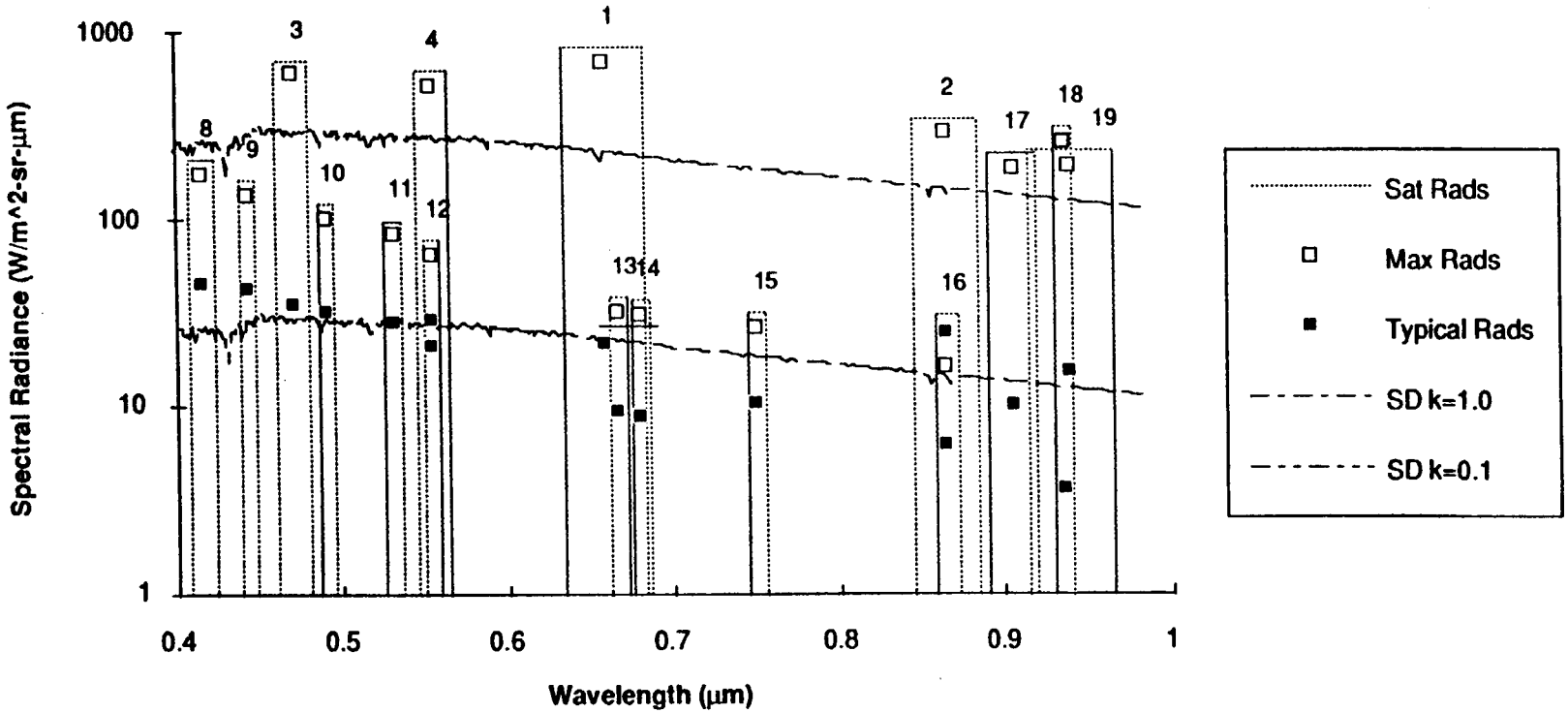
REFLECTIVE BANDS COVER WIDE SIGNAL RANGE

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N

Typical, Saturation and Diffuser Radiances

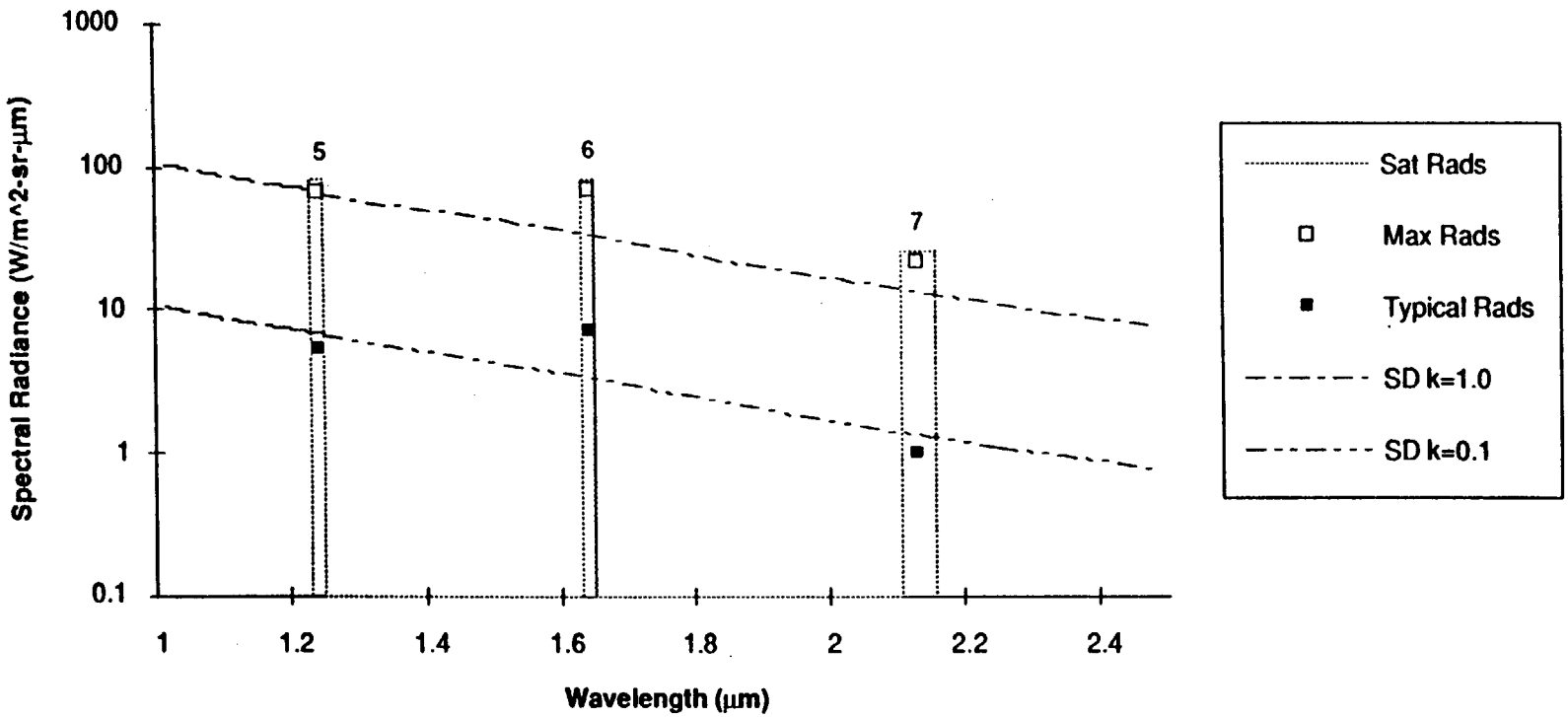


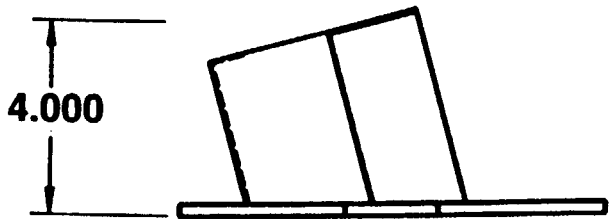
SIGNAL LEVELS FOR SWIR BANDS

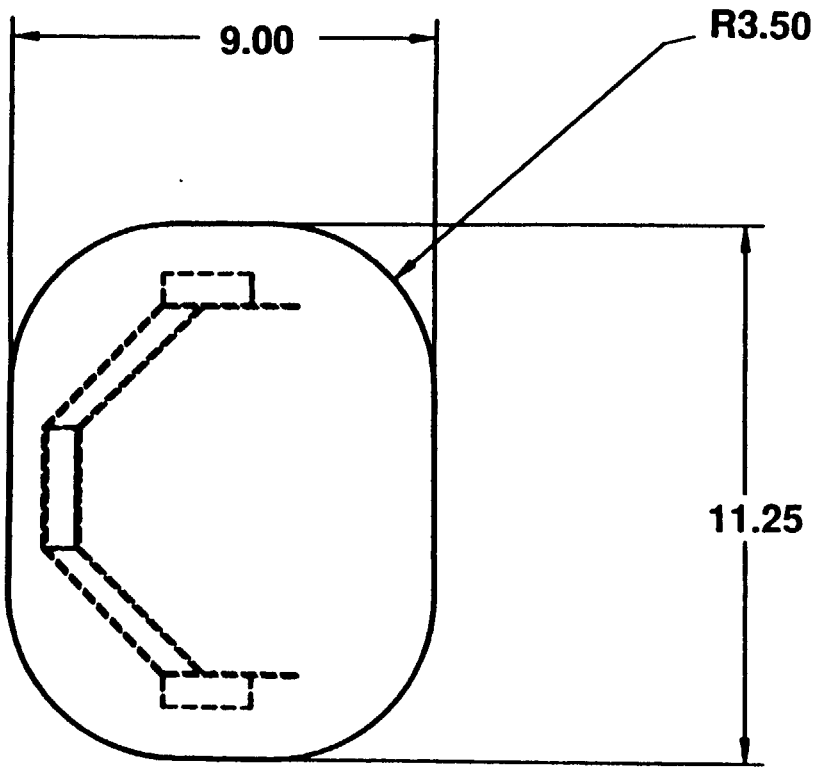
HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N

Typical, Saturation and Diffuser Radiances







- BRDF: 0.18/sr
- EFFECTIVE ALBEDO: 46%
- ALSO USED WITH 10% SCREEN

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

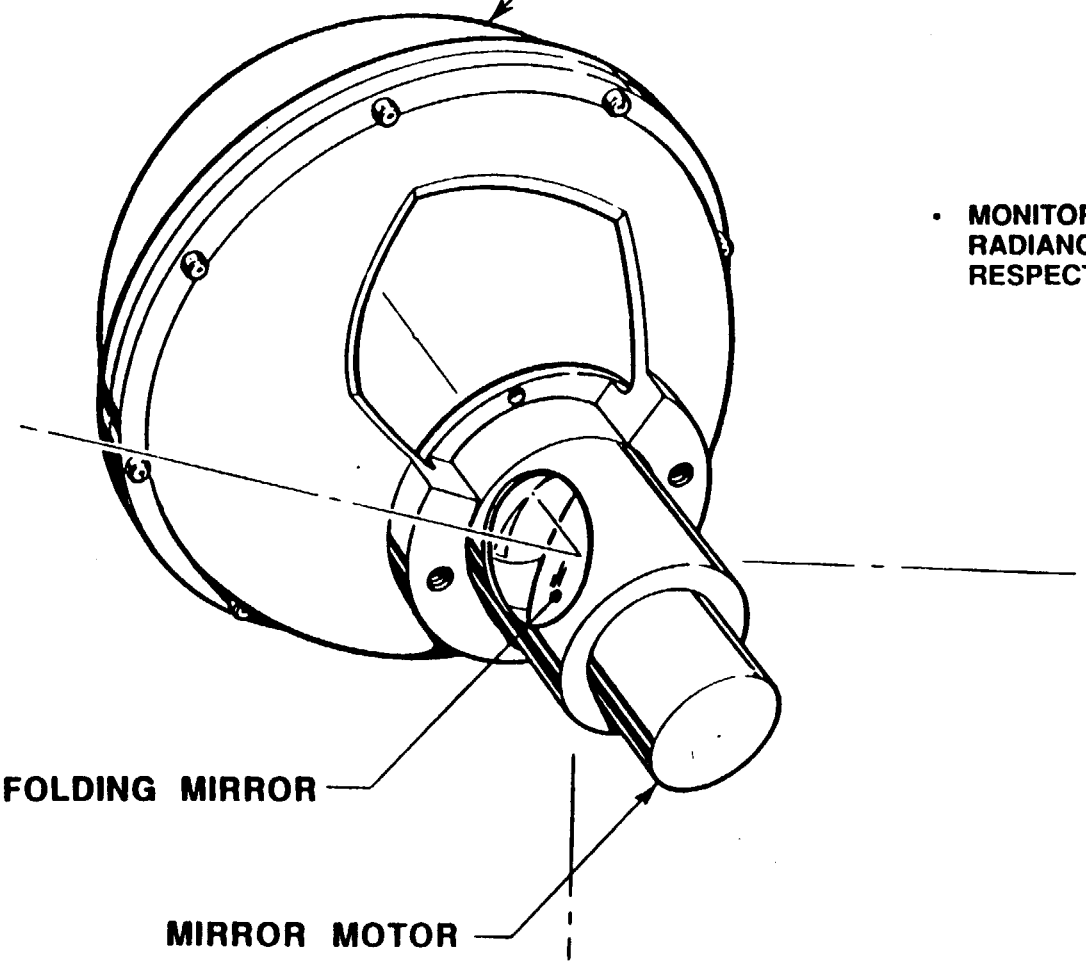
FULL APERTURE SOLAR DIFFUSER PROVIDES ACCURATE AND STABLE RADIOMETRIC CALIBRATION

4/92
92-0257-29

NEW SDSM DESIGN USES INTEGRATING SPHERE

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



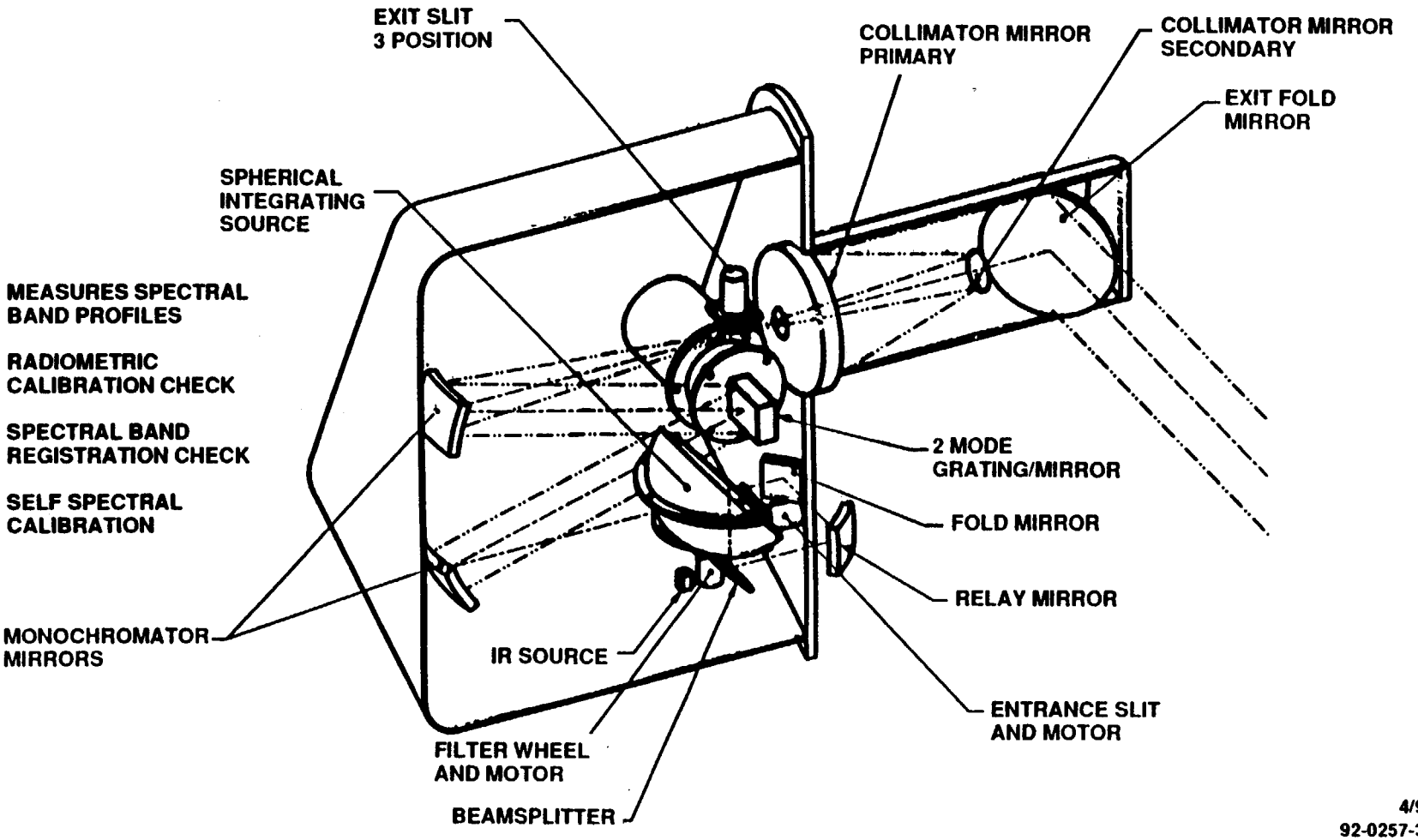
- MONITORS SOLAR DIFFUSER RADIANCE DIRECTLY WITH RESPECT TO SOLAR RADIANCE

4/92
92-0257-30

SRCA PROVIDES EXTENSIVE IN-FLIGHT CALIBRATION

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

- MEASURES SPECTRAL BAND PROFILES
- RADIOMETRIC CALIBRATION CHECK
- SPECTRAL BAND REGISTRATION CHECK
- SELF SPECTRAL CALIBRATION

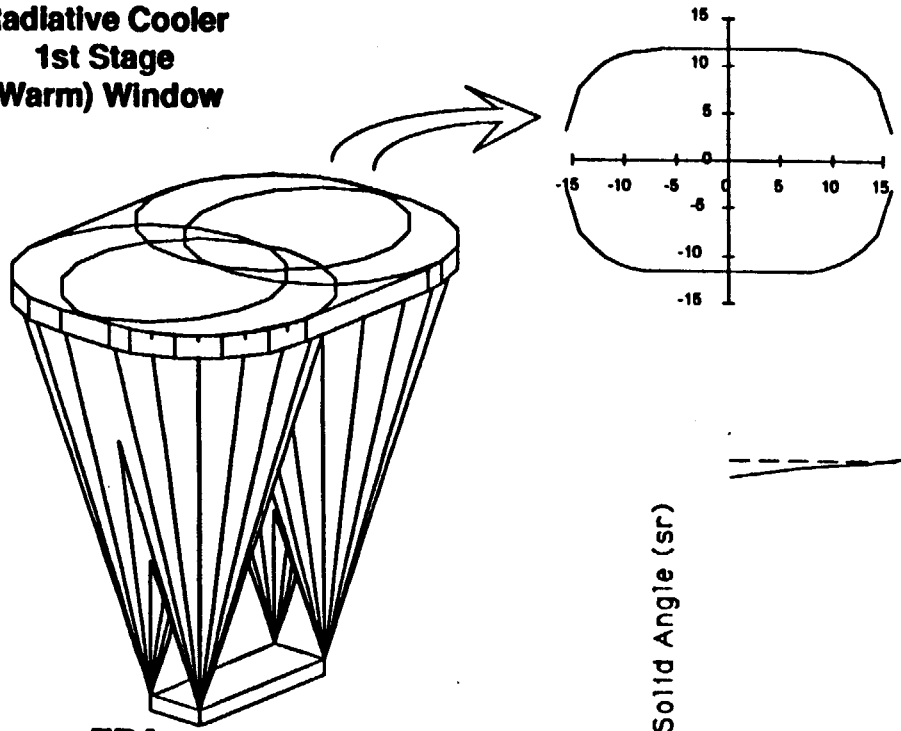


4/92
92-0257-31

SOLID ANGLE MODEL USED TO COMPUTE BACKGROUND CAN BE INCORPORATED INTO RMM

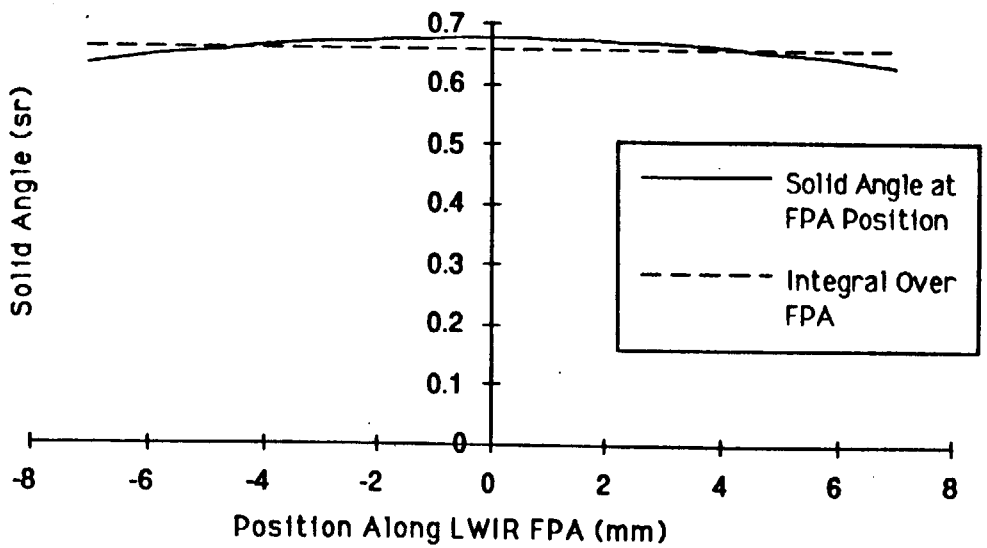
HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

Radiative Cooler
1st Stage
(Warm) Window



F-CONE Defines
Window Geometry

- MODEL INTEGRATES OVER TARGET AND RECEIVER SURFACES
- COMPUTES AΩ PRODUCT
- CAN BE USED TO COMPUTE Ω's OF SCATTERED/STRAY LIGHT ON CAL TARGETS IN RMM



SYSTEM PERFORMANCE PREDICTIONS

RADIOMETRIC SENSITIVITY REMAINS HIGH FOR MODIS-N

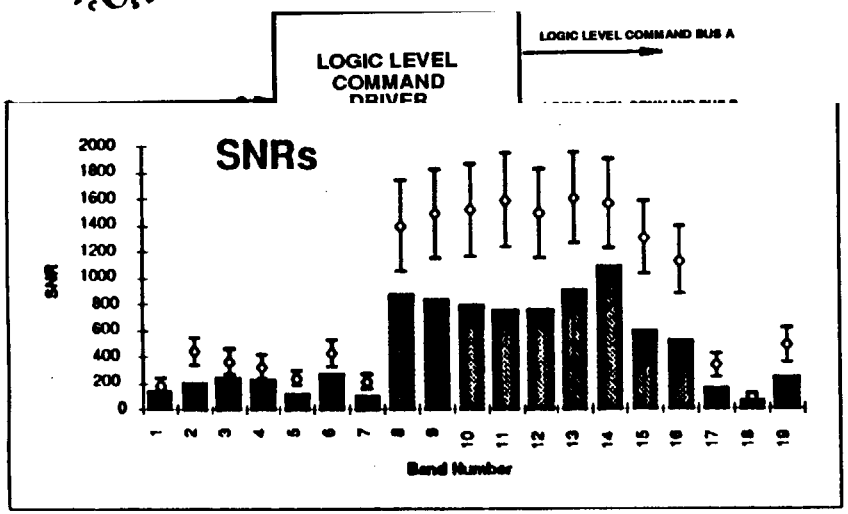
HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

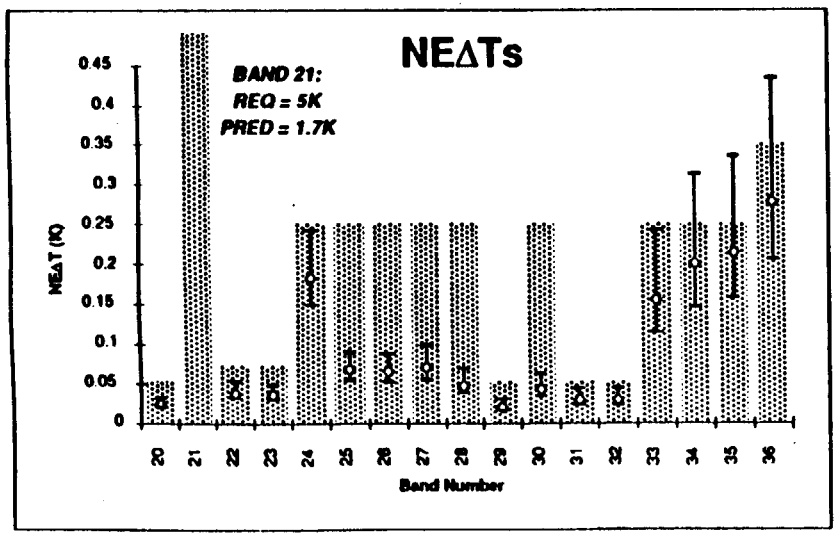
- ALL 36 BANDS MEET REQUIREMENTS
- 33 BANDS HAVE GREATER THAN 36% MARGIN (GOAL)
- CHANGES SINCE SSR THAT AFFECT PERFORMANCE
  - HIGHER TRANSMISSIONS IN ALL BUT LWIR > 11 μm
  - INCREASED DYNAMIC RANGE
  - INCREASED BACKGROUNDS BASED ON LATEST WINDOW GEOMETRY
  - UPDATE OF PC DETECTOR PERFORMANCE

MARGINS EXCEED SPECS IN ALL BANDS

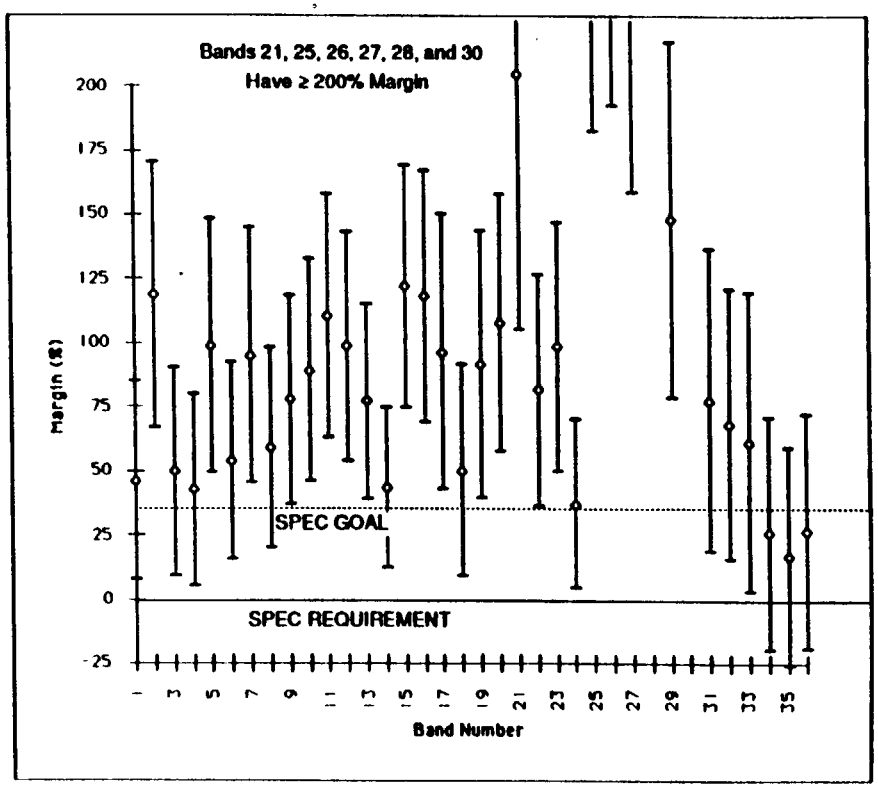
HUGHES

SANTA BARBARA RESEARCH CENTER





MARGINS



• ERROR BARS REPRESENT 3 SIGMA UNCERTAINTY

4/92
92-0257-34

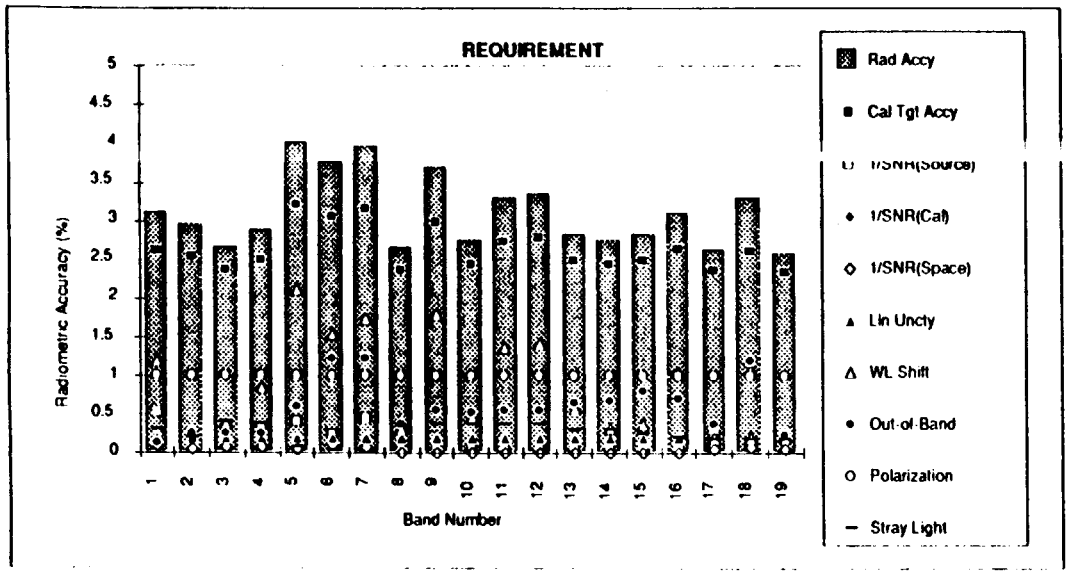
RADIOMETRIC ACCURACY MODEL INCLUDES ALL KEY FACTORS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

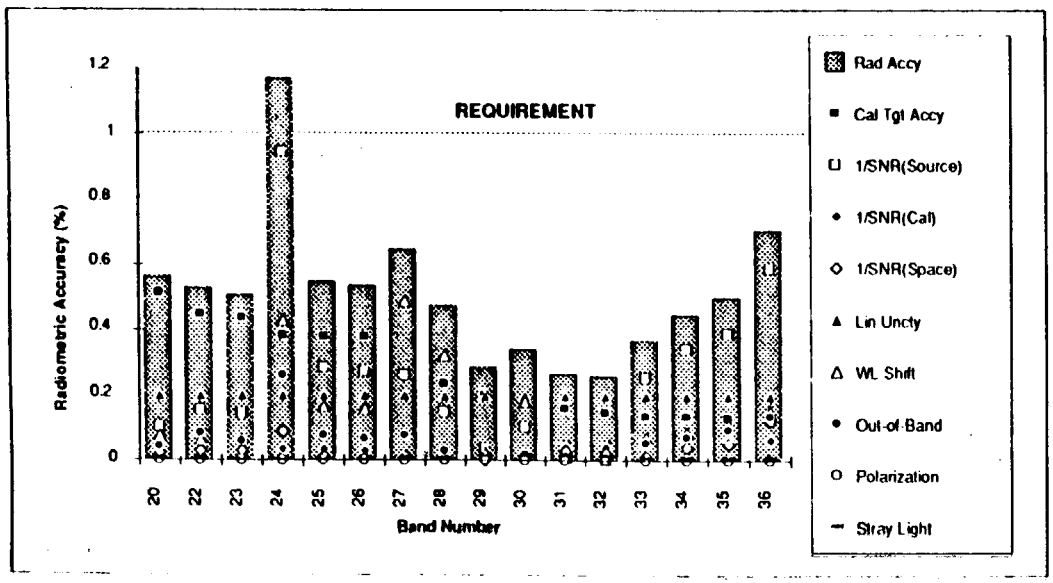
- $\lambda \leq 3\ \mu m$ **REQMT = 5% (1 sigma)**
- $\lambda \geq 3\ \mu m$ **REQMT = 1% (1 sigma)**
- **REFLECTANCE CALIBRATION REQMT = 2% (Not Calculated Yet)**

- **NUMEROUS CONTRIBUTORS INCLUDED**
  - CAL TARGET RADIANCE UNCERTAINTIES
  - SNR AT Ltyp
  - SNR OF CALIBRATORS
  - NOISE IN SPACE PORT
  - UNCERTAINTY IN RESPONSE PROFILE (Linearity)
  - POLARIZATION (2% INSTRUMENT, 50% SCENE)
  - WAVELENGTH SHIFTS
  - SCATTERED LIGHT FROM SCAN MIRROR

REFLECTIVE BANDS



EMISSIVE BANDS



HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

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

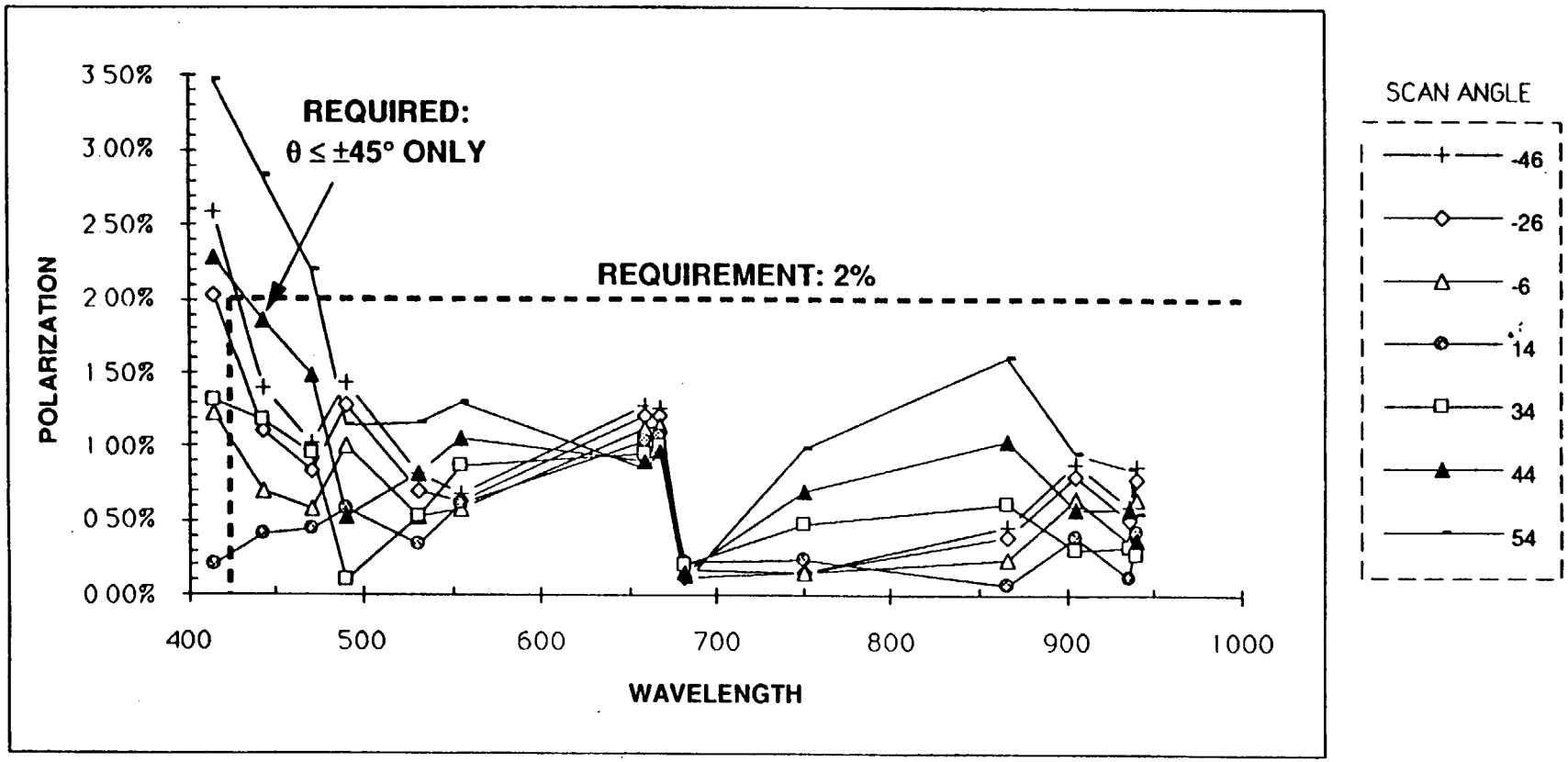
- **BAND 24 LIMITED BY SNR AT L_{TYP} (100:1 = 1% ACCURACY)**

MODIS-N
GSFC SBRC

4/92
92-0257-36

POLARIZATION SENSITIVITY FOR MODIS-N MEETS REQUIREMENTS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary



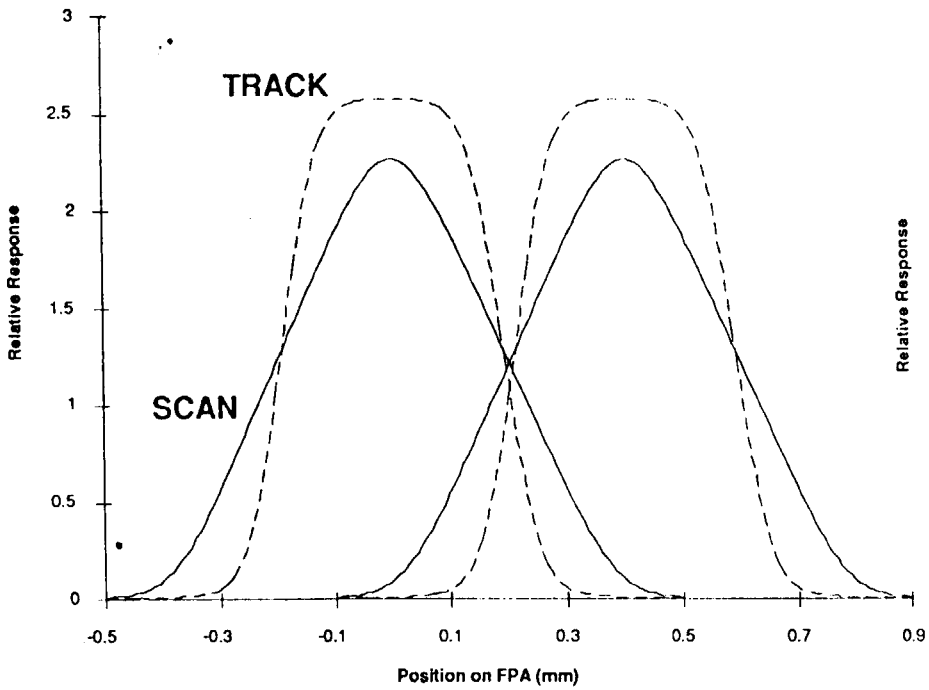
4/92
92-0257-37A

SPATIAL EFFECTS NOT CONSIDERED IN RADIOMETRIC MATH MODEL DUE TO SCENE DEPENDENCE

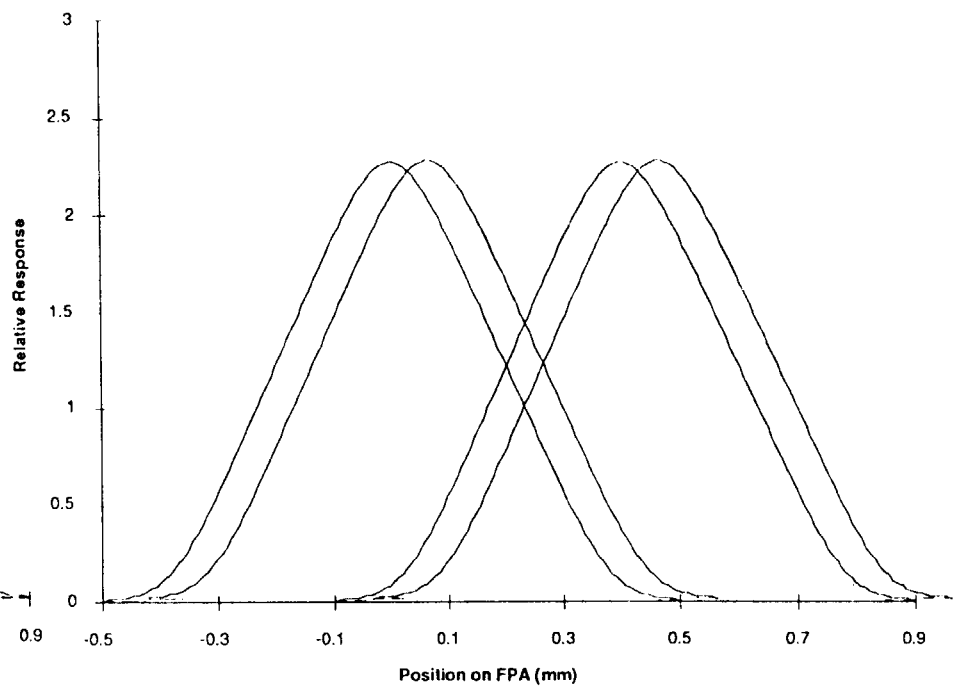
HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

- SIGNAL IS INTEGRAL OF PRODUCT OF LINE SPREAD FUNCTION AND SCENE DISTRIBUTION

NON-UNIFORM LINE SPREAD FUNCTIONS



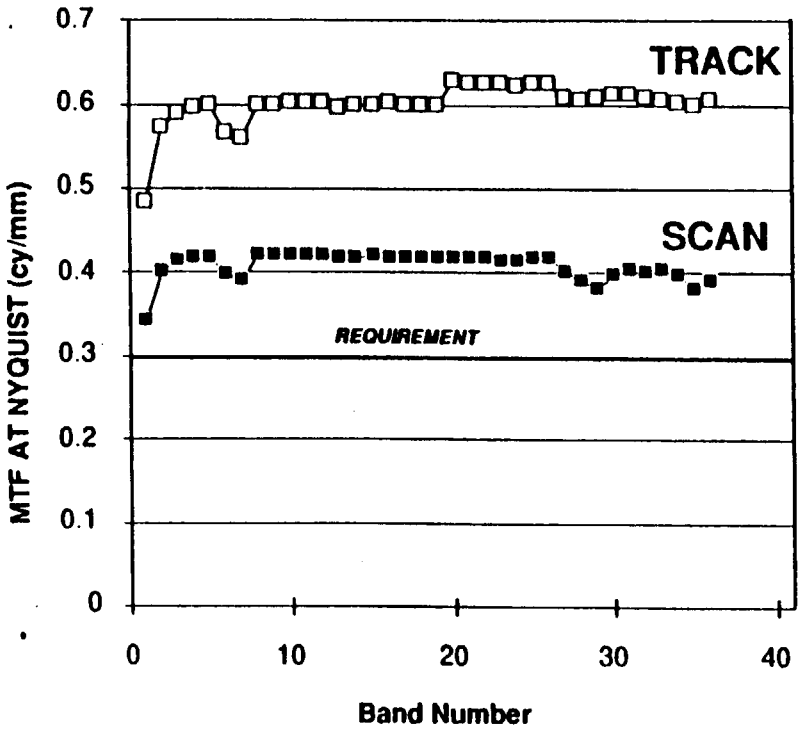
MISREGISTRATION



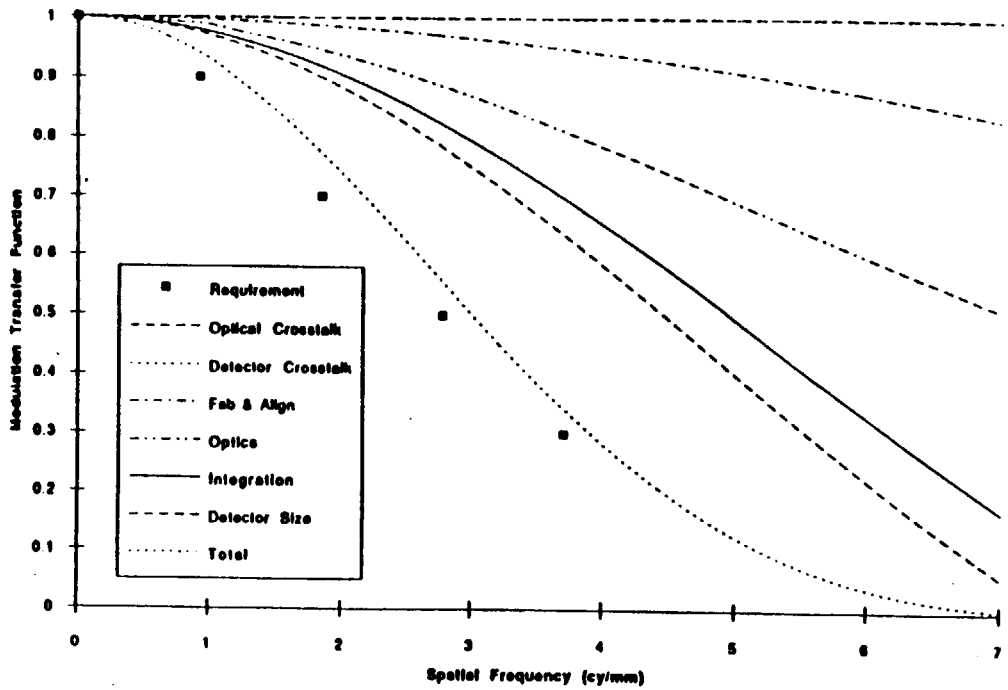
MTFs MEET REQUIREMENTS IN ALL BANDS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

MTFs AT NYQUIST



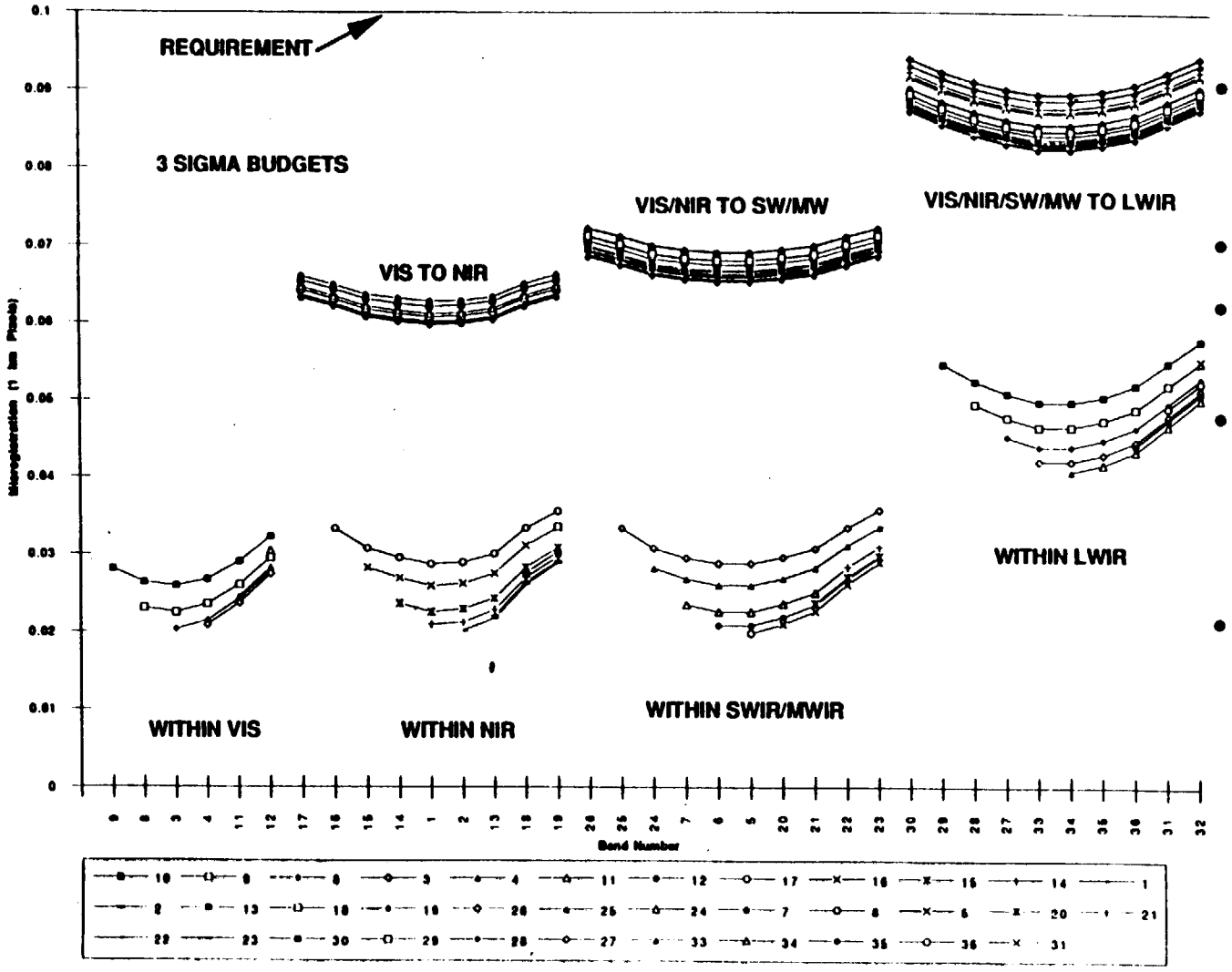
BAND 1 CONTRIBUTORS (WORST CASE: SCAN)



4/92
92-0257-38

SPECTRAL BAND REGISTRATION MEETS REQUIREMENTS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary



- OPTICAL DISTORTION REMOVED
- TOP OF BAND
- OTHERS COMPARABLE
- EVERY POSSIBLE COMBINATION OF BANDS IS PLOTTED
- WORST-CASE SCAN DIRECTION PLOTTED: TRACK IS BETTER

MODIS-N POINTING BUDGET

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

CONTRIBUTOR (1 Sigma)	SCAN (Arcsec)	TRACK (Arcsec)
• ALIGNMENT CUBE TO SCAN MIRROR	9	9
• SCAN TIMING AND ENCODER	10	--
• TRACK DYNAMIC MIRROR DEVIATION	--	4
• PIXEL-TO-OPT AXIS	3	3
• THERMAL	27	28
• RSS BUDGET (REQUIREMENT)	30	30

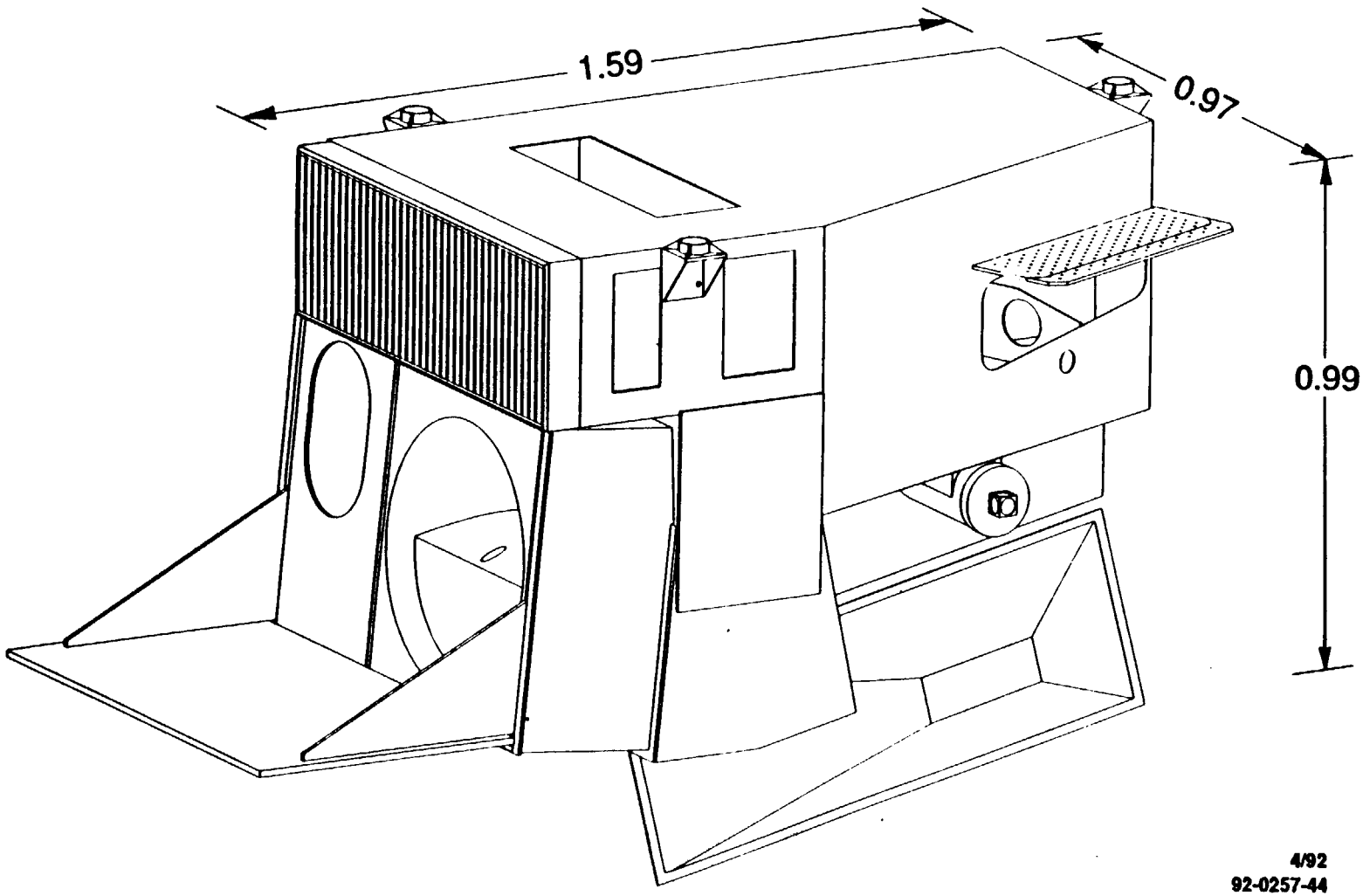
SPACECRAFT AND DATA INTERFACE INFORMATION

4/92
92-0257-43

CURRENT ENVELOPE MEETS REQUIREMENTS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



4/92
92-0257-44

MASS ESTIMATES AND BUDGETS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

FUNCTIONAL AREA	SSR	BUDGET	PREDICTION
OPTICAL SUBSYSTEMS	**45.0 kg**	**45.0 kg**	**45.1 kg**
A. SCAN MIRROR	14.3	14.3	14.3
B. AFOCAL TELESCOPE	11.6	11.6	11.6
C. AFT OPTICS PLATFORM	11.1	11.1	11.1
D. RADIATIVE COOLER	8.0	8.0	8.1
ON-BOARD CALIBRATORS	**17.5**	**17.5**	**21.3**
A. BLACKBODY	2.2	2.2	6.0
B. SRCA	8.4	8.4	8.4
C. SOLAR DIFFUSER	3.2	3.2	3.2
D. SOLAR DIFFUSER MONITOR	3.7	3.7	3.7
STRUCTURES AND MECHANISMS	**63.3**	**65.6**	**69.8**
A. MAINFRAME	40.8	43.1	47.3
B. DOORS AND ACTUATORS	8.4	8.4	8.4
C. THERMAL CONTROLS	6.8	6.8	6.8
D. MISCELLANEOUS	7.3	7.3	7.3
ELECTRONICS	**73.8**	**89.2**	**86.8**
A. MAIN ELECTRONICS MODULE	60.8	65.5	63.1
B. AEM-FORWARD VIEWING	7.6	10.8	8.9
C. AEM-SPACEVIEWING	5.4	9.2	11.1
D. CABLES	0.0	3.7	3.7
TOTALS	**199.6 kg**	**217.3 kg**	**223.0 kg**

4/92
92-0257-45

MODIS-N POWER SUMMARY

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

Subsystem	Pk Pwr (W)	Duty Cycle	Avg Pwr (W)	Avg Pwr Δ This Rpt	Day/Night (W)	Calibration (W)
Main Electronics Module						
Formatter	22.4	1	22.4		22.4	
FIFO	33.6	1	33.6		33.6	
T & C Processor	12.6	1	12.6		12.6	
Scan Mtr Drvr	5.9	1	5.9		5.9	
Cal SRCA Cntl	5.0	0.75	3.8			3.8
Timing Generator	3.4	1	3.4		3.4	
Analog Tlmy	3.7	1	3.7		3.7	
FDDI Fmt & Output Drvr	4.5	1	4.5		4.5	
subtotal	91.1		89.9		86.1	
AEM Space Viewing						
VIS/NIR/PV LWIR	30.3	1	30.3	-2.0	30.3	
AEM Forward Viewing						
SWIR/MWIR/PC LWIR	21.2	1	21.2		21.2	
Scan Motor	3.0	1	3.0		3.0	
SRCA	29.2	0.75	21.9			21.9
Contingency Reserve	26.5	1	26.5	-2.0	26.5	
PS Load Totals	201.3	-	192.8	0.4	167.1	25.7
PS Disp @ 0.8 Efficiency	50.3	-	48.2	0.1	41.8	6.4
Per Orbit Input Pwr	251.6	-	241.0	0.4	208.9	32.1
Two Orbit Avg Pwr, Cal in 1 orbit			224.9	0.4	208.9	16.0

- POWER CONTINGENCY CURRENTLY 12 %

4/92
92-0257-46

MODIS-N POWER ASSUMPTIONS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

- EQUAL POWER CONSUMPTION DAY AND NIGHT
- DUTY CYCLE REFLECTS PER ORBIT USE (USUALLY 100%)
- PEAK POWER NOT SHOWN FOR TRANSIENT DEVICES

  (EVENT DURATION: ≤ 1S; EVENT MAGNITUDE: ≤ 4.5W)
- WORST CASE SCENARIO: SRCA SPECTRAL CALIBRATION
  - SRCA USED DURING ONE OF TWO ORBITS
  - USED FOR 75% OF ACTIVE ORBIT
  - ANTICIPATE ONLY ONCE PER MONTH USE

MODIS-N DATA RATE

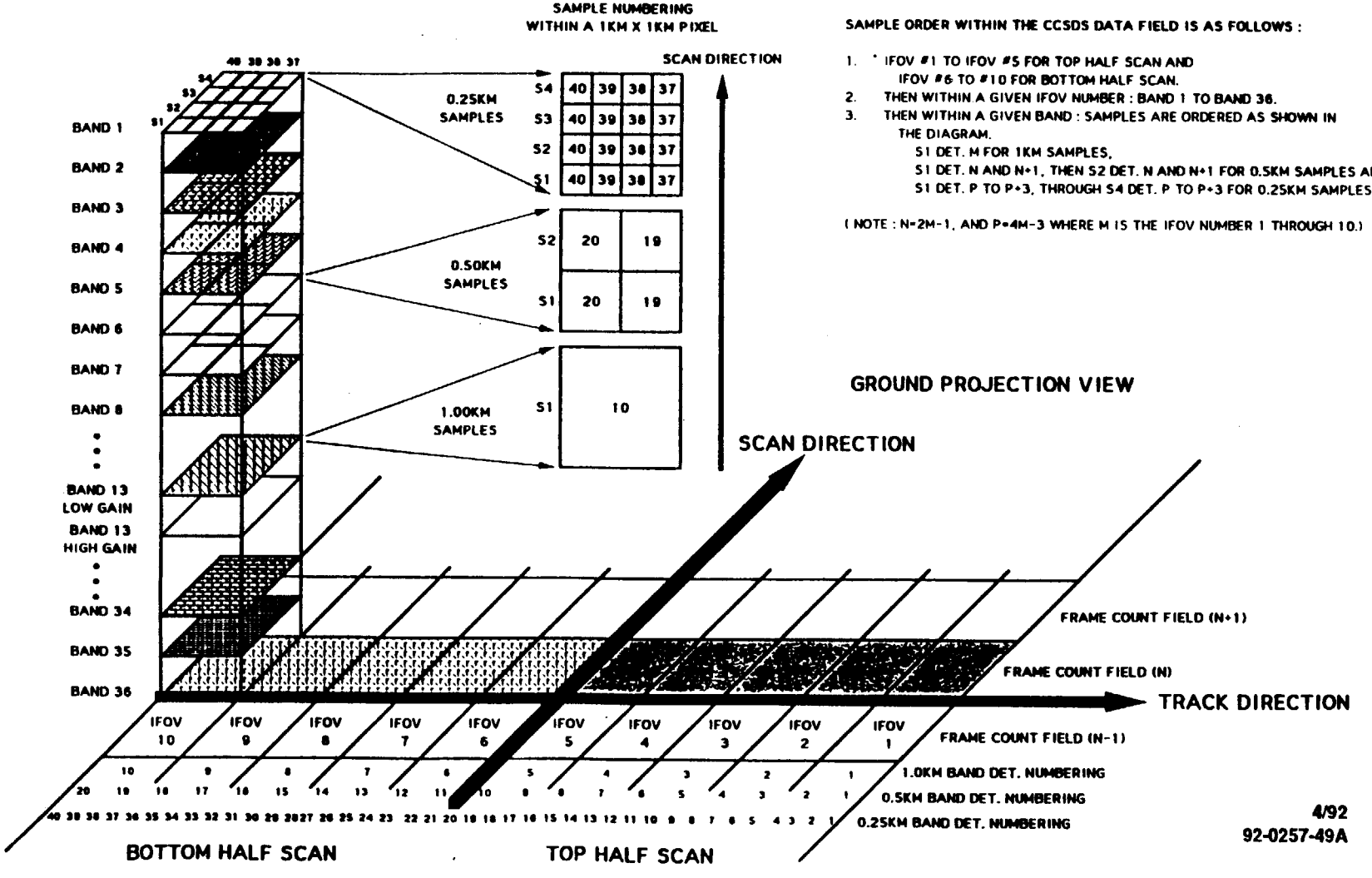
HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

• Day Mode	
• Earth Scan, 1354 FD * 2 Segments each	13,908,288 bits
• Solar Diffuser, 31 FD * 2 Segments each	318,432
• SRCA, 5 FD * 2 Segments each	51,360
• BB, 31 FD * 2 Segments each	318,432
• Space View, 30 Segments each	308,160
• Engineering Data, 2 Segments	10,272
• Sub-total (normal operation)	14,914,944 bits/scan
• Data Rate averaged over 1.47717 sec/scan	10,096,995 bits/second
• Memory Dump, unsegmented packet (when scheduled)	5,136 bits
• Total	14,920,080 bits/scan
• Data Rate averaged over 1.47717 sec/scan	10,100,449 bits/second
• Night Mode	
• Earth Scan, 1354 FD * 1 Segment each	2,989,632 bits
• Solar Diffuser, 31 FD * 2 Segments each	318,432
• SRCA, 5 FD * 2 Segments each	51,360
• BB, 31 FD * 2 Segments each	318,432
• Space View, 30 Segments each	308,160
• Engineering Data, 2 Segments	10,272
• Sub-total (normal operation)	3,996,288 bits/scan
• Data Rate averaged over 1.47717 sec/scan	2,705,374 bits/second
• Memory Dump, unsegmented packet (when scheduled)	5,136 bits
• Total	4,001,424 bits/scan
• Data Rate averaged over 1.47717 sec/scan	2,708,845 bits/second

DATA FIELD SAMPLE ORDER

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



SAMPLE ORDER WITHIN THE CCSDS DATA FIELD IS AS FOLLOWS :

1. IFOV #1 TO IFOV #5 FOR TOP HALF SCAN AND
   IFOV #6 TO #10 FOR BOTTOM HALF SCAN.
2. THEN WITHIN A GIVEN IFOV NUMBER : BAND 1 TO BAND 36.
3. THEN WITHIN A GIVEN BAND : SAMPLES ARE ORDERED AS SHOWN IN THE DIAGRAM.
   S1 DET. M FOR 1KM SAMPLES,
   S1 DET. N AND N+1, THEN S2 DET. N AND N+1 FOR 0.5KM SAMPLES AND
   S1 DET. P TO P+3, THROUGH S4 DET. P TO P+3 FOR 0.25KM SAMPLES.

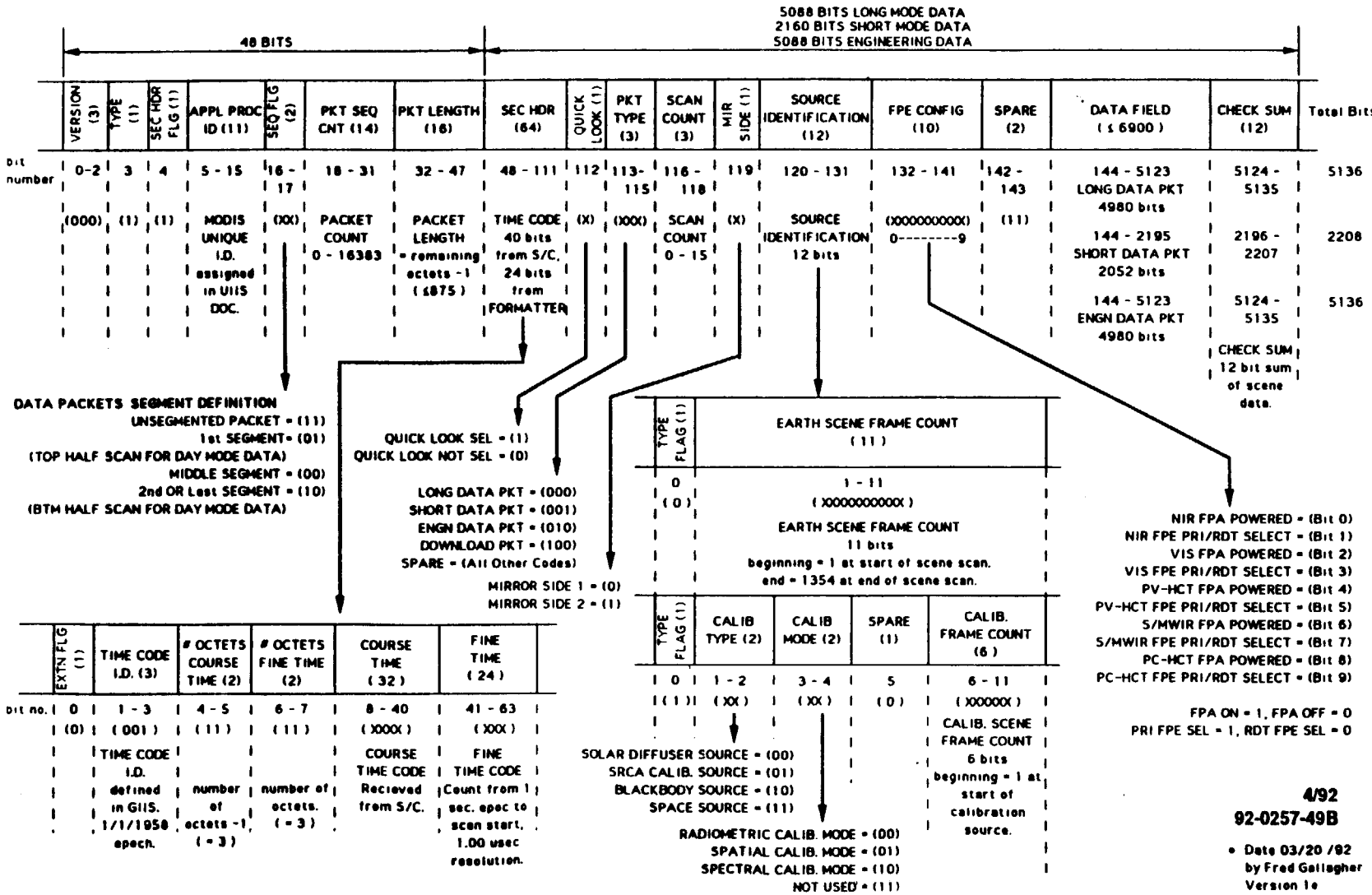
(NOTE : N=2M-1, AND P=4M-3 WHERE M IS THE IFOV NUMBER 1 THROUGH 10.)

4/92
92-0257-49A

CCSDS PACKET DATA FORMAT

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary



4/92
92-0257-49B

- Date 03/20 /92 by Fred Gallagher Version 1e

SUMMARY

HUGHES

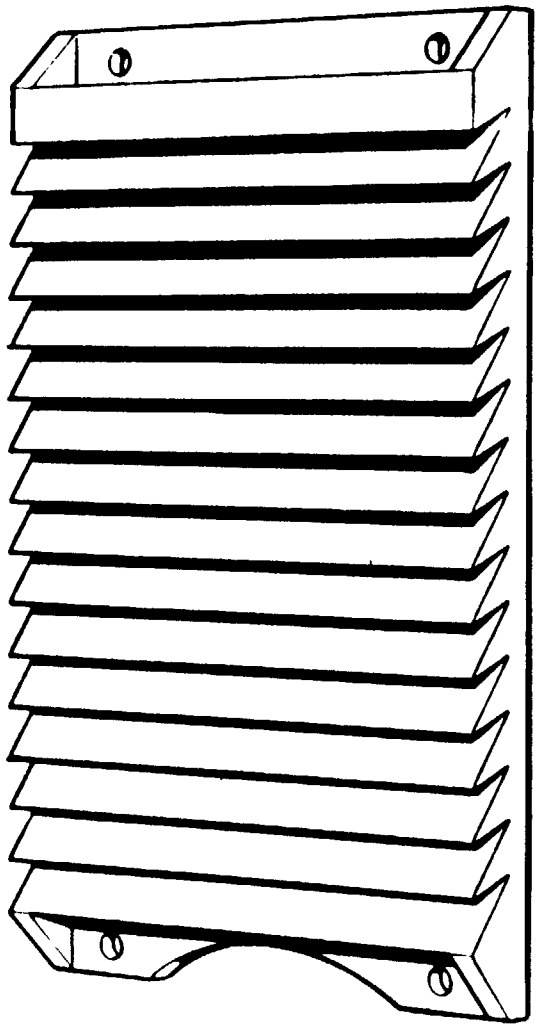
SANTA BARBARA RESEARCH CENTER
a subsidiary

- MODIS-N HARDWARE DEVELOPMENT IS ON SCHEDULE
- COMPLETED SYSTEM STUDY REVIEW (SSR)
- DESIGN SPECIFICATIONS HAVE BEEN INITIATED
- DETAILED DESIGN AND ANALYSIS HAS BEGUN
- PROCUREMENT OF LONG-LEAD ITEMS HAS BEGUN
- DESIGN MEETS MAJORITY OF PERFORMANCE REQUIREMENTS
- PERFORMANCE GOALS ARE BEING MET IN MOST CASES
- OVERALL PROGRAM ON-TRACK

CALIBRATOR AND VIEWPORT LOCATIONS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

POSITION	SCAN START ANGLE, DEG	SCAN STOP ANGLE, DEG	NOMINAL ANGLE, DEG
EARTH VIEW	-55/305	+55	0
SOLAR DIFFUSER	182.250	184.750	183.500
SRCA	206.551	206.957	206.754
BLACKBODY	229.600	232.100	230.850
SPACE VIEW	260.157	262.657	261.407



- 40.6° V-GROOVE INCLUDED ANGLE
- ALUMINUM STRUCTURE
- AMBIENT TEMPERATURE
- EMISSIVITY ≥ 0.992

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

V-GROOVE BLACKBODY DESIGN OFFERS HIGH EMISSIVITY

MODIS-N

GSFC SBRC

4/92
92-0257-28

SPECTRAL BANDPASS FILTERS

4/92
92-0257-62

PRESENTATION OBJECTIVES

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

- Sensitize the MODIS-N Science Team to the high degree of difficulty of the Spectral Filter Requirements
- Propose changes to the requirements which will ease the design and fabrication complexities
- Solicit Science Team support in reducing program risks without compromising the science objectives

SPECTRAL FILTER REQUIREMENTS OVERVIEW

(See Following Illustration)

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

- Tolerance on Center Wavelength λc: ± 1 nm (VIS & NIR) to ± 71 nm (band 36)
  (± 1nm is $\pm 0.1\%$ for band 19 @ 940 nm.)
- Bandwidth: 10 nm (VIS & NIR) to 500 nm (LWIR)
  (10 nm is 1.04% of λc for band 18 @ 936 nm.)
- Tolerance on Bandwidth of $\pm .25\%$ of λc (bands 8-16) and $\pm .5\%$ of λc for all others:
  ($\pm$ 0.25% = ± 1.04 nm ($\pm 6.9\%$ of BW) for band 8 @ 415 nm.)
  ($\pm$ 0.5% = $\pm$ 3.3 nm ($\pm 6.6\%$ of BW) for band 1 @ 659 nm.)
- Out of Band Response: OOB response $\leq$ 5% of integrated response.
  1% response points within 1.5 x BW from band edge.
- Edge Range (5% to 80%) $\leq$ 50% of BW.

SPECTRAL FILTER REQUIREMENTS OVERVIEW

(See Following Illustration)

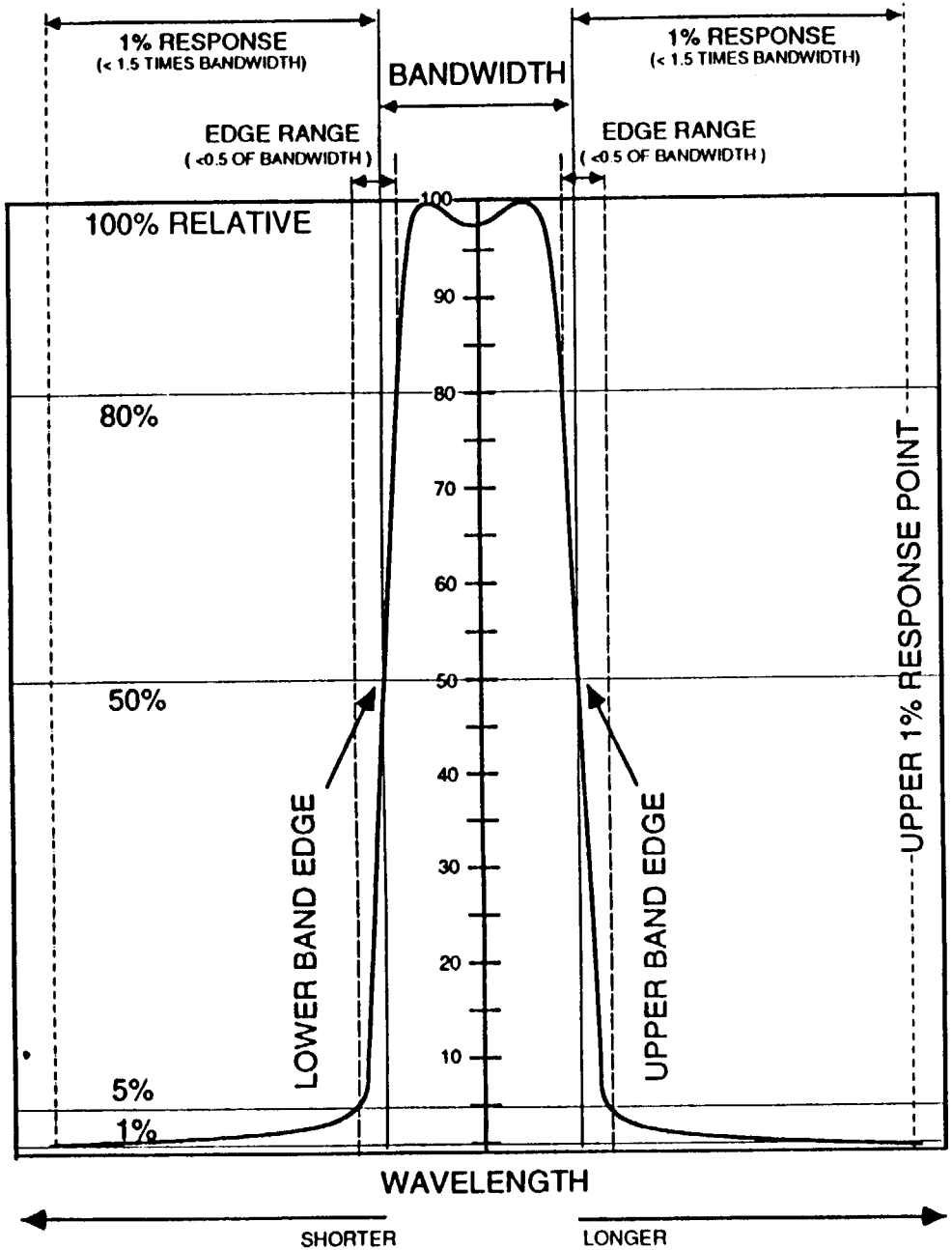
HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

- **Ripple:**
  The response between the 80% points shall always exceed 80%

- **Wavelength Stability: ≤ 2nm for VIS bands; ≤ 1% of λc for all others.**

  (2nm is 0.36% of λc for bands 4 and 12 @ 555 nm.)



HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

BANDPASS FILTER SPECTRAL DEFINITIONS AND SPECIFICATIONS

MODIS-N
GSFC SBRC

4/92
92-0257-66

SOME OF THE REQUIREMENTS ARE EXTREMELY CHALLENGING

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

- The most difficult requirements are where:

  The Bandwidth (BW) is $\leq$ 1.5% of λc.

  The tolerance on the BW is $\leq$ 20% of BW.

  The required BW tolerances are stated as 0.25 or 0.5% of λc.
  This results in BW tolerances of as small as 6.6% of the BW.

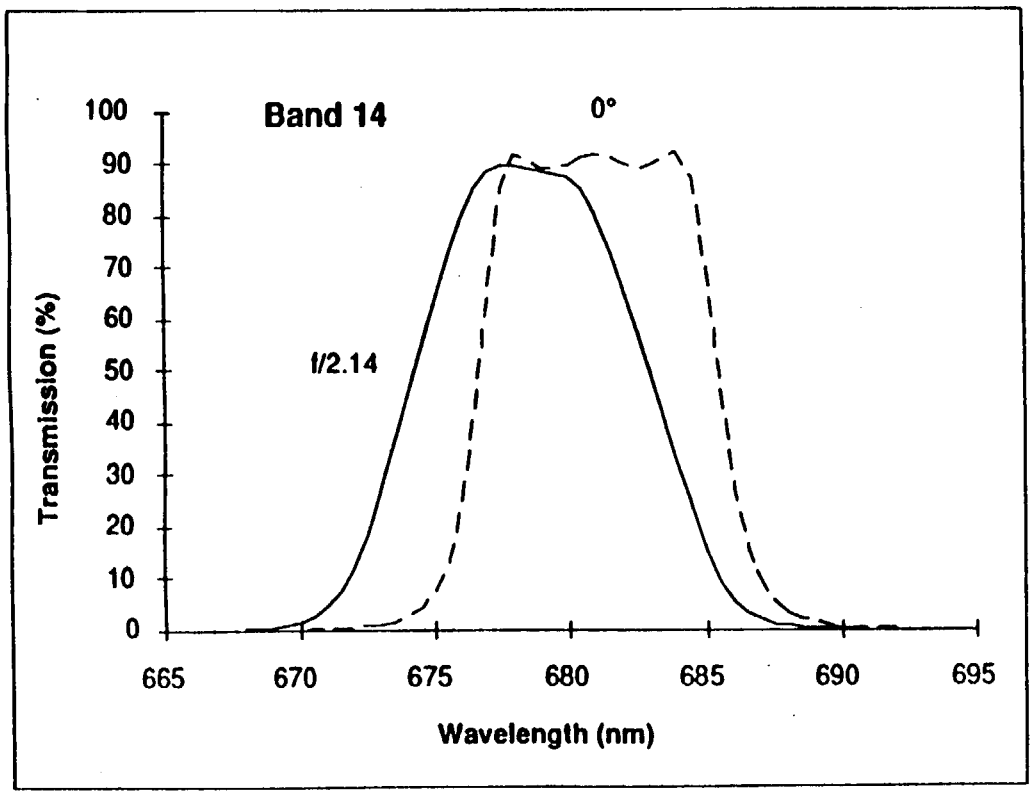
  The tolerance on λc is $\leq$ 0.25%.

And,

- The Edge Range requirement of $\leq$ 50% of the BW may be impossible to meet, on some of the very narrow band filters, when f-cone effects are considered.

EXAMPLE OF F-CONE EFFECTS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary



Center Wavelength (nm)
Normal 681.057
Shifted 678.612
Difference -2.44495

Bandwidth (nm)
Normal 8.92285
Shifted 9.30481
Ratio (Shifted/Normal) 1.04281

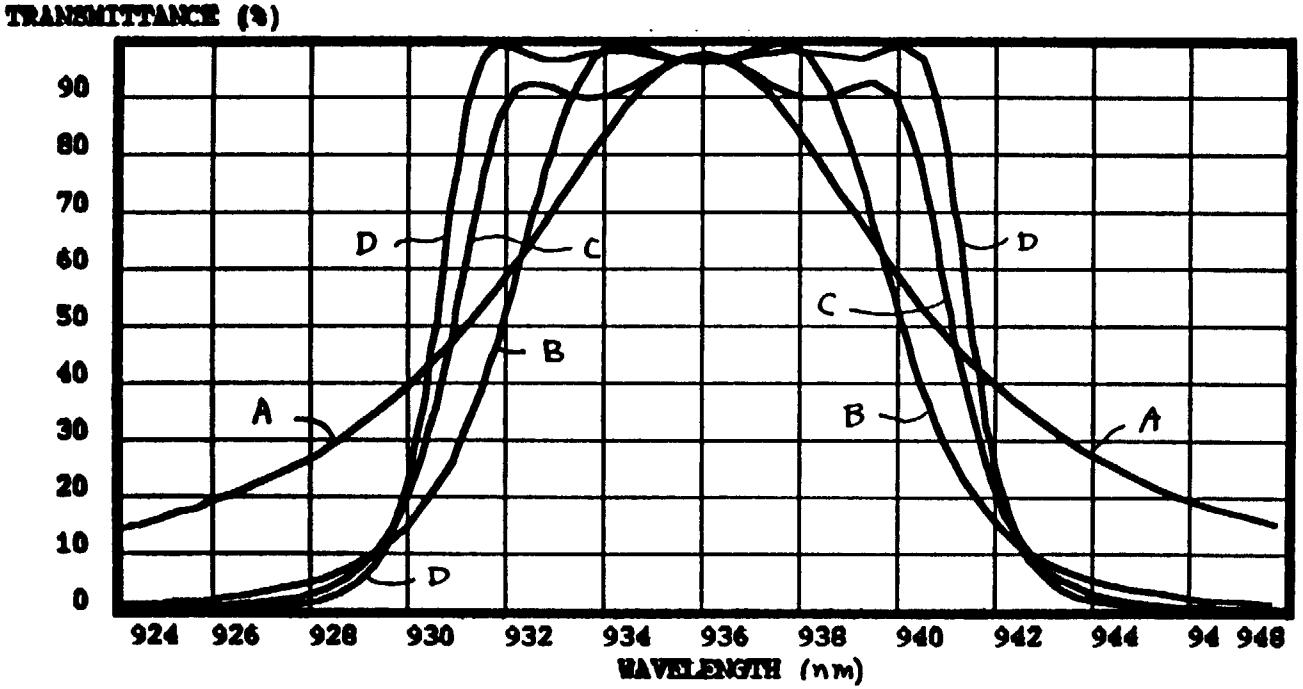
Upper Edge Range (nm)
Normal 2.76392
Shifted 4.52612
Shifted Percent of BW 48.6428

Lower Edge Range (nm)
Normal 2.66199
Shifted 4.55457
Shifted Percent of BW 48.9485

Transmission (%)
Normal 85.4351
Shifted 76.1605
Ratio (Shifted/Normal) 0.891442

DESIRED PROFILES REQUIRE INCREASINGLY COMPLEX DESIGNS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary



Bandpass Coatings (No Blocking Stacks)

A	14 Layers	One - 3rd Order Half Wave Cavity
B	28 Layers	Two - 3rd Order Half Wave cavities
C	42 Layers	One - 1st Order + Two 3rd Order Half Wave Cavities
D	56 Layers	Two - 1st Order + Two 3rd Order Half Wave Cavities

DETAILED SUMMARY OF REQUIREMENTS
(Most Difficult are Highlighted)

PRESENT SPECTRAL REQUIREMENTS
(Highlight Indicates Areas of Concern)

BAND	IFOV (m)	Center Wavelength (nm)	Wavelength Tolerance (nm)	Wavelength Tolerance (%)	BANDWIDTH (nm)	% Bandwidth (of Wavelength)	Bandwidth Tolerance (nm)	Bandwidth Tolerance (% of Bandwidth)
8	1000	415	±2	0.5%	15	3.6%	1.04	6.9%
9	1000	443	±1	0.2%	10	2.3%	1.11	11.1%
3	500	470	±5	1.1%	20	4.3%	2.35	11.8%
10	1000	490	±1	0.2%	10	2.0%	1.23	12.3%
11	1000	531	±2	0.4%	10	1.9%	1.33	13.3%
4	500	555	±5	0.9%	20	3.6%	2.78	13.9%
12	1000	555	±5	0.9%	10	1.8%	1.39	13.9%
1	250	659	±5	0.8%	50	7.6%	3.30	6.6%
13	1000	667	+1,-2	0.2%	10	1.5%	1.67	16.7%
14	1000	681	±1	0.1%	10	1.5%	1.70	17.0%
15	1000	750	±2	0.3%	10	1.3%	1.88	18.8%
2	250	865	±5	0.6%	40	4.6%	4.33	10.8%
16	1000	865	±5	0.6%	15	1.7%	2.16	14.4%
17	1000	905	±1	0.1%	30	3.3%	4.53	15.1%
18	1000	936	±1	0.1%	10 (12.5)	1.1%	4.68	46.8%
19	1000	940	±1	0.1%	50	5.3%	4.70	9.4%
5	500	1240	±6	0.5%	20	1.6%	6.20	31.0%
6	500	1640	±8	0.5%	20	1.2%	8.20	41.0%
7	500	2130	±10	0.5%	50	2.3%	10.65	21.3%
20	1000	3750	±19	0.5%	180	4.8%	18.75	10.4%
21	1000	3750	±19	0.5%	50	1.3%	18.75	37.5%
22	1000	3959	±20	0.5%	50	1.3%	19.80	39.6%
23	1000	4050	±20	0.5%	50	1.2%	20.25	40.5%
24	1000	4465	±22	0.5%	50	1.1%	22.33	44.7%
25	1000	4515	±22	0.5%	50	1.1%	22.58	45.2%
26	1000	4565	±23	0.5%	50	1.1%	22.83	45.7%
27	1000	6715	±34	0.5%	360	5.4%	33.58	9.3%
28	1000	7325	±37	0.5%	300	4.1%	36.63	12.2%
29	1000	8550	±43	0.5%	300	3.5%	42.75	14.3%
30	1000	9730	±49	0.5%	500	5.1%	48.65	9.7%
31	1000	11030	±55	0.5%	500	4.5%	55.15	11.0%
32	1000	12020	±60	0.5%	500	4.2%	60.10	12.0%
33	1000	13335	±67	0.5%	300	2.2%	66.68	22.2%
34	1000	13635	±68	0.5%	300	2.2%	68.18	22.7%
35	1000	13935	±70	0.5%	300	2.2%	69.68	23.2%
36	1000	14235	±71	0.5%	300	2.1%	71.18	23.7%

≤0.2% ≤15% < 20%

CHANGES THAT WOULD SIGNIFICANTLY EASE THE REQUIREMENTS

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

- Center Wavelength tolerances > 0.25% of λc X 2-3
- Bandwidth ~~tolerances~~ > 1.5% of λc.
- Bandwidth tolerances > 20% of BW.
- Edge Range ≤ 70% of BW.
- Details on next page (Suggested changes are highlighted).

RECOMMENDED SPECTRAL REQUIREMENTS

(Highlights indicate changes required to improve design and fabrication with attendant reductions in risk and cost.)

BAND	IFOV (m)	Center Wavelength (nm)	Wavelength Tolerance (nm)	Wavelength Tolerance (%)	BANDWIDTH (nm)	% Bandwidth (of Wavelength)	Bandwidth Tolerance (nm)	Bandwidth Tolerance (% of Bandwidth)
8	1000	415	±2	0.48%	15	3.6%	3.00	20.0%
9	1000	443	±1.1	0.25%	10	2.3%	2.00	20.0%
3	500	470	±5	1.06%	20	4.3%	4.00	20.0%
10	1000	490	±1.22	0.25%	10	2.0%	2.00	20.0%
11	1000	531	±2	0.38%	10	1.9%	2.00	20.0%
4	500	555	±5	0.90%	20	3.6%	4.00	20.0%
12	1000	555	±5	0.90%	10	1.8%	2.00	20.0%
1	250	659	±5	0.76%	50	7.6%	10.00	20.0%
13	1000	667	±1.7	0.25%	10	1.5%	2.00	20.0%
14	1000	681	±1.7	0.25%	10	1.5%	2.00	20.0%
15	1000	750	±2	0.27%	11.5	1.5%	2.30	20.0%
2	250	865	±5	0.58%	40	4.6%	8.00	20.0%
16	1000	865	±5	0.58%	15	1.7%	3.00	20.0%
17	1000	905	±2.3	0.25%	30	3.3%	6.00	20.0%
18	1000	936	±2.3	0.25%	(14) 12.5	1.5%	2.80	20.0%
19	1000	940	±2.4	0.26%	50	5.3%	10.00	20.0%
5	500	1240	±6	0.48%	20	1.6%	6.20	31.0%
6	500	1640	±8	0.49%	25	1.5%	8.20	32.8%
7	500	2130	±10	0.47%	50	2.3%	10.65	21.3%
20	1000	3750	±19	0.51%	180	4.8%	36.00	20.0%
21	1000	3750	±19	0.51%	58	1.5%	18.75	32.3%
22	1000	3959	±20	0.51%	60	1.5%	19.80	33.0%
23	1000	4050	±20	0.49%	62	1.5%	20.25	32.7%
24	1000	4465	±22	0.49%	65	1.5%	22.33	34.3%
25	1000	4515	±22	0.49%	67	1.5%	22.58	33.7%
26	1000	4565	±23	0.50%	70	1.5%	22.83	32.6%
27	1000	6715	±34	0.51%	360	5.4%	72.00	20.0%
28	1000	7325	±37	0.51%	300	4.1%	60.00	20.0%
29	1000	8550	±43	0.50%	300	3.5%	60.00	20.0%
30	1000	9730	±49	0.50%	500	5.1%	100.00	20.0%
31	1000	11030	±55	0.50%	500	4.5%	100.00	20.0%
32	1000	12020	±60	0.50%	500	4.2%	100.00	20.0%
33	1000	13335	±67	0.50%	300	2.2%	66.68	22.2%
34	1000	13635	±68	0.50%	300	2.2%	68.18	22.7%
35	1000	13935	±70	0.50%	300	2.2%	69.68	23.2%
36	1000	14235	±71	0.50%	300	2.1%	71.18	23.7%

JANUARY 1992 REQUIREMENTS CHANGE RECOMMENDATIONS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

- In January SBRC submitted a list of recommended changes to GSFC in memorandum #PL3095-Q00581.

  The recommended changes applied to 18 of the 36 spectral bands.

  The recommended changes apply to Center Wavelength tolerances, Bandwidths, and Bandwidth tolerances.

  A complete listing of the changes recommended in January follows.

- The previous chart suggests changes to 30 of the 36 bands.

4/92
0257-75

MODIS-N SPECTRAL FILTER
REQUIREMENT CHANGE RECOMMENDATIONS
(Numbers in **BOLD** indicate current spec value and recommended change)

	BAND	CENTER WVLN	CWL TOL	BW	BW TOL
GSFC Specification:	18	936nm	**1nm**	**10nm**	4.7nm
Recommended Change:			**2nm**	**15nm**	
GSFC Specification:	13	667nm	**+1/-2nm**	10nm	**1.7nm**
Recommended Change:			**±1.5nm**		**2.0nm**
GSFC Specification:	14	681nm	**1nm**	10nm	**1.7nm**
Recommended Change:			**1.5nm**		**2.0nm**
GSFC Specification:	15	750nm	**2nm**	**10nm**	**1.9nm**
Recommended Change:			**2.3nm**	**15nm**	**3.0nm**
GSFC Specification:	17	905nm	**1nm**	30nm	**4.5nm**
Recommended Change:			**2.3nm**		**6.0nm**
GSFC Specification:	10	490nm	**1nm**	10nm	**1.2nm**
Recommended Change:			**1.2nm**		**2.0nm**
GSFC Specification:	9	443nm	**1nm**	10nm	**1.1nm**
Recommended Change:			**1.3nm**		**2.0nm**
GSFC Specification:	24	4465nm	22nm	**50nm**	22.3nm
Recommended Change:				**67nm**	
GSFC Specification:	25	4515nm	23nm	**50nm**	22.6nm
Recommended Change:				**68nm**	
GSFC Specification:	26	4565nm	23nm	**50nm**	22.8nm
Recommended Change:				**68nm**	
GSFC Specification:	6	1640nm	8nm	**20nm**	8.2nm
Recommended Change:				**25nm**	

MODIS-N SPECTRAL FILTER
REQUIREMENT CHANGE RECOMMENDATIONS (CONT'D)

(Numbers in **BOLD** indicate current spec value and recommended change)

4/92
92-0257-76

	BAND	CENTER WVLN	CWL TOL	BW	BW TOL
GSFC Specification:	19	940nm	**1nm**	50nm	**4.7nm**
Recommended Change:			**2.4nm**		**10.0nm**
GSFC Specification:	23	4050nm	20nm	**50nm**	20.3
Recommended Change:				**61nm**	
GSFC Specification:	33	13335nm	67nm	300nm	**66.7nm**
Recommended Change:					**150nm**
GSFC Specification:	34	13636nm	68nm	300nm	**68.2nm**
Recommended Change:					**150nm**
GSFC Specification:	35	13935nm	70nm	300nm	**69.7nm**
Recommended Change:					**150nm**
GSFC Specification:	36	14235nm	71nm	300nm	**71.2nm**
Recommended Change:					**150nm**

COMMENTS FROM POTENTIAL SUPPLIERS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

- "....the most ambitious filter specification this author has seen in his 27 years of designing and manufacturing filters for space infrared applications."

- "The bandpass filters and beamsplitters for MODIS-N incorporate a variety of stringent requirements that present (a) formidable design and manufacturing challenge."

- "The center wavelength and bandwidth tolerances are much too critical to rely solely on test coupons and witnesses."

IN SUMMARY

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary

- The filter requirements are very difficult.
- The proposed costs are somewhat higher than anticipated.
- The suppliers still say that they can be achieved, however, they have probably not examined the designs to the extent we have at this point in time.
- Meeting all of the MODIS-N requirements remains a High Risk proposition.
- We can say with a reasonably high degree of confidence that some Waivers will be needed.
- A timely response to waivers will be necessary to avoid costly schedule delays.