

THE MODIS-N RADIOMETRIC MATH MODEL Overview

Tom Pagan

Presented to

MODIS Science Team Calibration Working Group
NASA Goddard Space Flight Center

April 13 - 15, 1992



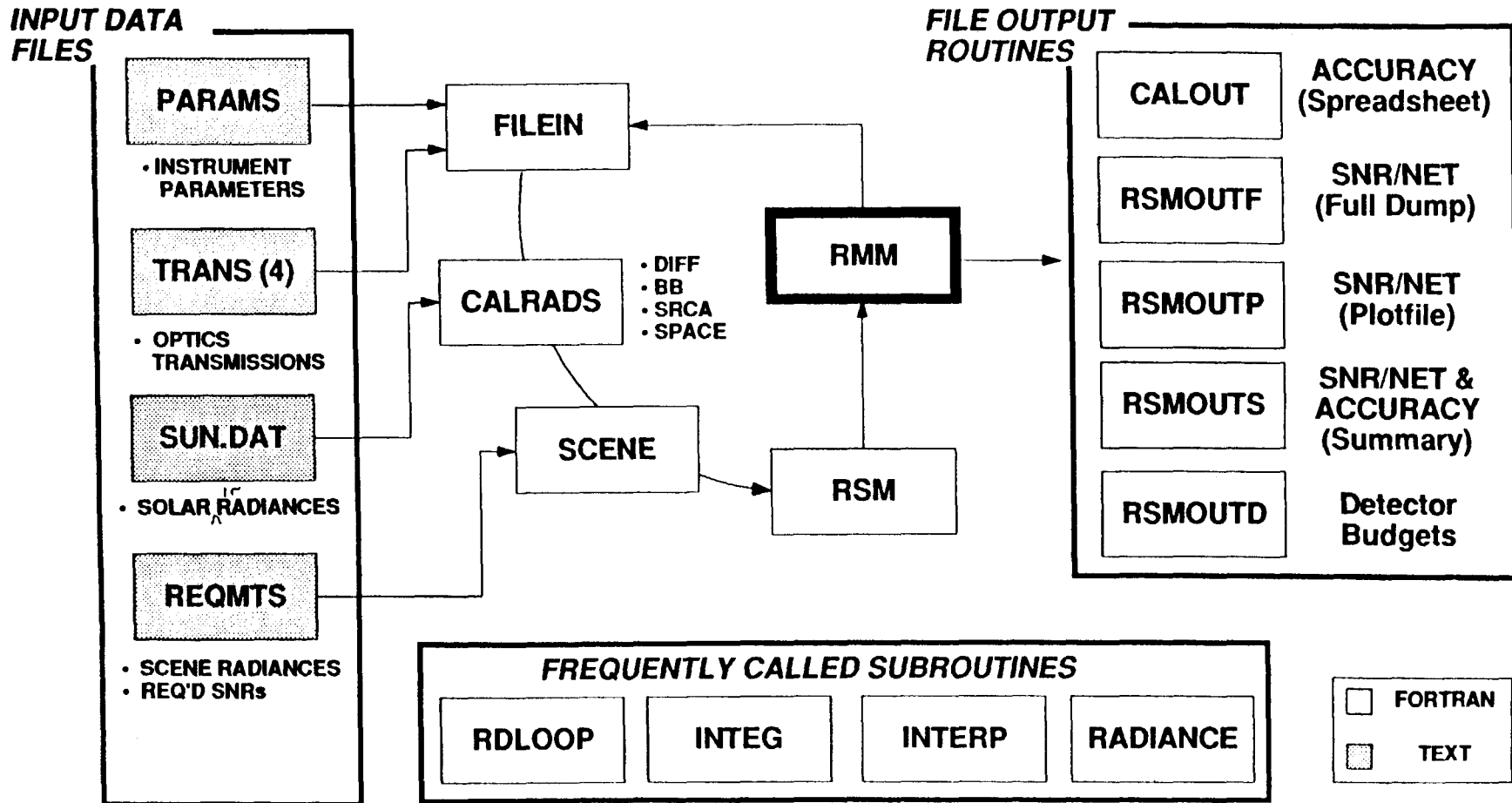
SANTA BARBARA RESEARCH CENTER
a subsidiary



RADIOMETRIC MATH MODEL COMPUTES SENSITIVITY AND ACCURACY



SANTA BARBARA RESEARCH CENTER
a subsidiary



**MODIS-N
AVERAGE OPTICAL TRANSMISSION
DATA SHEET**

5-Mar-92
 TITLE: Short-Wave / Mid-Wave IR
 BANDS: 5,6,7,20,21,22,23,24,25,26
 Min. Wvlgth. 1.23
 Max. Wvlgth. 4.59

Band		5	6	7	20	21	22	23	24	25	26
Center Wvlgth.		1.24	1.64	2.13	3.75	3.75	3.959	4.05	4.465	4.515	4.565
Min. Wvlgth.		1.23	1.63	2.105	3.66	3.725	3.934	4.025	4.44	4.49	4.54
Max. Wvlgth.		1.25	1.65	2.155	3.84	3.775	3.984	4.075	4.49	4.54	4.59
	Temp										
Scan_Mirror	290.0	0.9752	0.9836	0.9871	0.9893	0.9893	0.9896	0.9898	0.9896	0.9896	0.9896
Fold_1	290.0	0.9752	0.9836	0.9871	0.9893	0.9893	0.9896	0.9898	0.9896	0.9896	0.9896
Primary	290.0	0.9717	0.9822	0.9867	0.9896	0.9896	0.9900	0.9901	0.9900	0.9900	0.9900
Secondary	290.0	0.9717	0.9822	0.9867	0.9896	0.9896	0.9900	0.9901	0.9900	0.9900	0.9900
Dichroic_1_(ZnSe)	290.0	0.8124	0.9550	0.9033	0.9770	0.9770	0.9820	0.9697	0.8770	0.8737	0.8714
Dichroic_3_(Mirror)	290.0	0.9890	0.9887	0.9956	0.9983	0.9983	0.9986	0.9987	0.9937	0.9899	0.9846
MW_Lens_1_(ZnSe)	290.0	0.9585	0.9585	0.9585	0.9585	0.9585	0.9585	0.9585	0.9585	0.9585	0.9585
MW_Lens_2_(CdTe)	290.0	0.9545	0.9545	0.9545	0.9545	0.9545	0.9545	0.9545	0.9545	0.9545	0.9545
Fold_2	290.0	0.9850	0.9850	0.9850	0.9850	0.9850	0.9850	0.9850	0.9850	0.9850	0.9850
MW_Lens_3_(ZnSe)	290.0	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595
Roof_Mirror	290.0	0.9702	0.9702	0.9702	0.9702	0.9702	0.9702	0.9702	0.9702	0.9702	0.9702
MW_Lens_4_(ZnSe)	290.0	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595	0.9595
MW_Lens_5_(ZnSe)	290.0	0.9592	0.9592	0.9592	0.9592	0.9592	0.9592	0.9592	0.9592	0.9592	0.9592
MW_Window_1_(Saph)	290.0	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.8930	0.8930	0.8930
MW_Window_2_(Saph)	140.0	0.8900	0.8900	0.8900	0.8900	0.8900	0.8900	0.8900	0.8366	0.8366	0.8366
MW_Window_3_(Saph)	85.0	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.9500	0.8930	0.8930	0.8930
Band_Pass_Filter	85.0	0.7000	0.7000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
Transmission		0.3132	0.3825	0.4233	0.4638	0.4638	0.4669	0.4614	0.3447	0.3421	0.3394

Notes:

- 1) Silver mirror reflectance data is a design estimate by S. Pellicori
- 2) Transmission coefficient of dichroic 1 and 3 are design estimates from S. Pellicori.
- 3) Band pass filter performance are from SBRC Specification # E85146

4) Assumed window material is Sapphire

5) SWIR/MWIR lens ARC assumed performance (from S. Pellicori): 98% per surface

6) Aft optics mirrors are assumed to be gold coated (R=98.5%) with 2 reflections in the roof mirror

7) Intermediate window performance is a preliminary estimates from S. Pellicori.

8) Bands 24-26 have 4% internal absorption for sapphire.

Created on 3/4/92

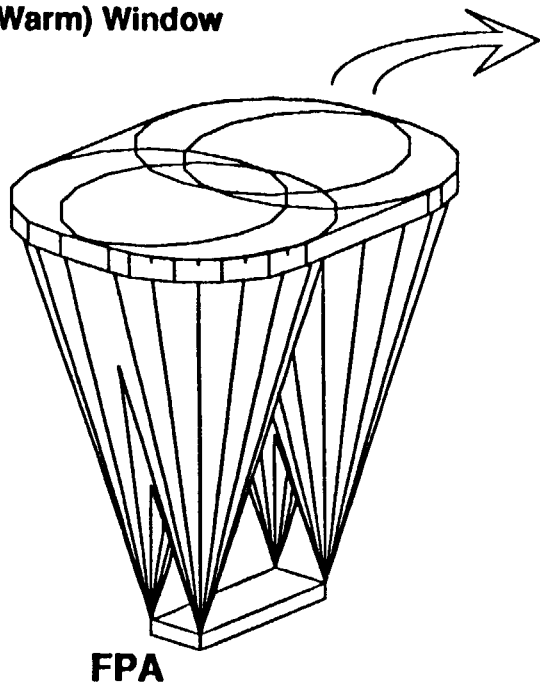


SOLID ANGLE MODEL USED TO COMPUTE BACKGROUND CAN BE INCORPORATED INTO RMM



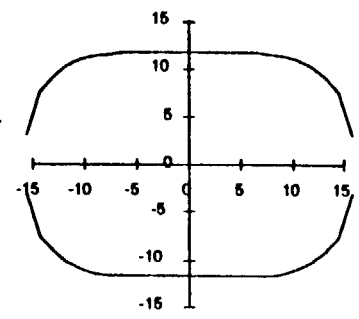
SANTA BARBARA RESEARCH CENTER
a subsidiary

Radiative Cooler
1st Stage
(Warm) Window

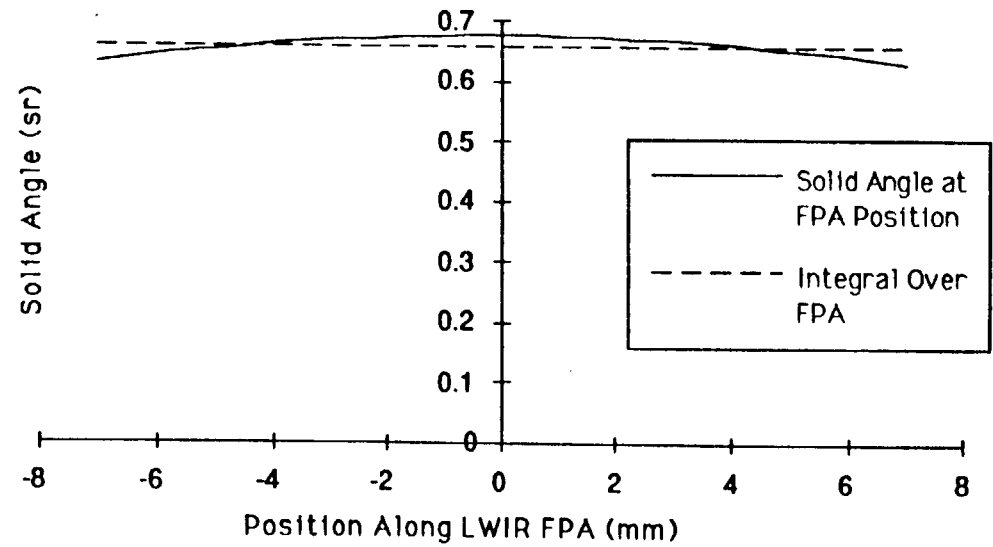


FPA

F-CONE Defines Window Geometry



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





SANTA BARBARA RESEARCH CENTER
a subsidiary

RADIOMETRIC SENSITIVITY

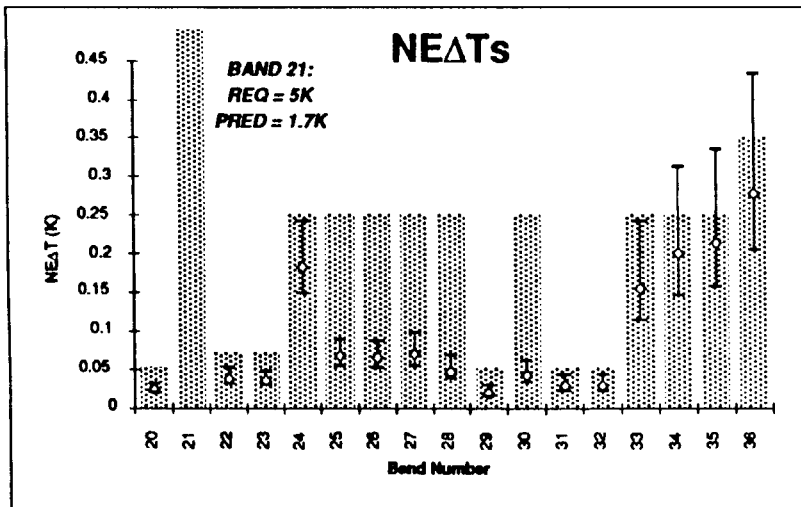
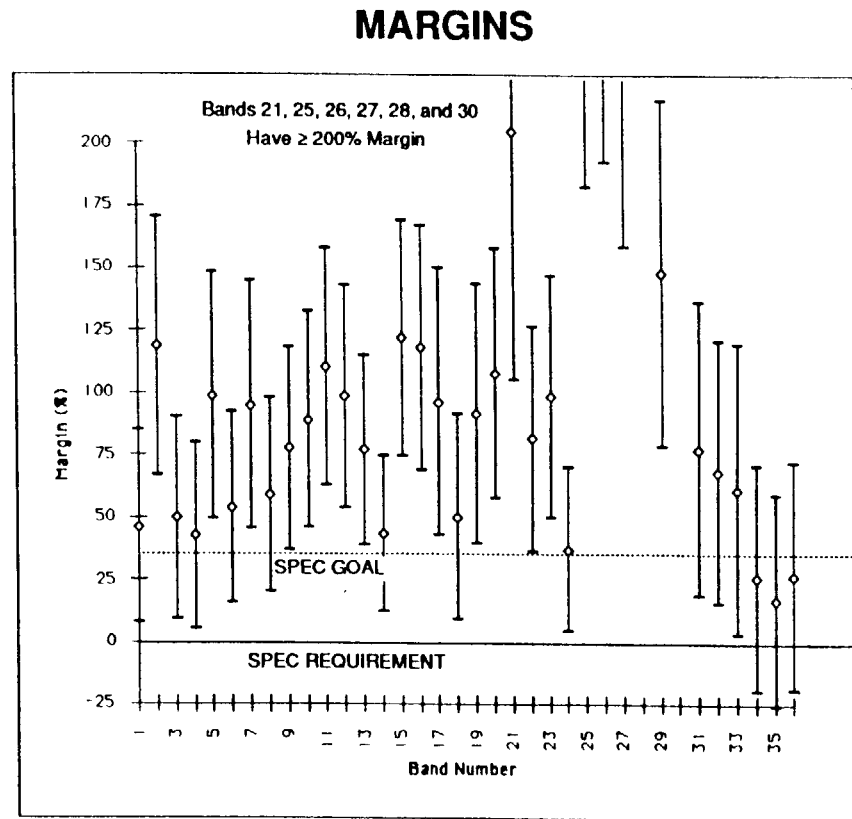
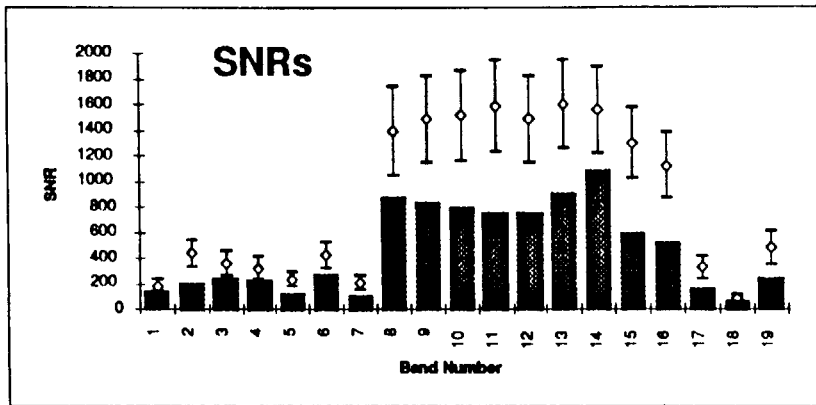
SNR, $NE\Delta T$



MARGINS EXCEED SPECS IN ALL BANDS



SANTA BARBARA RESEARCH CENTER
a subsidiary



• ERROR BARS REPRESENT 3 SIGMA UNCERTAINTY

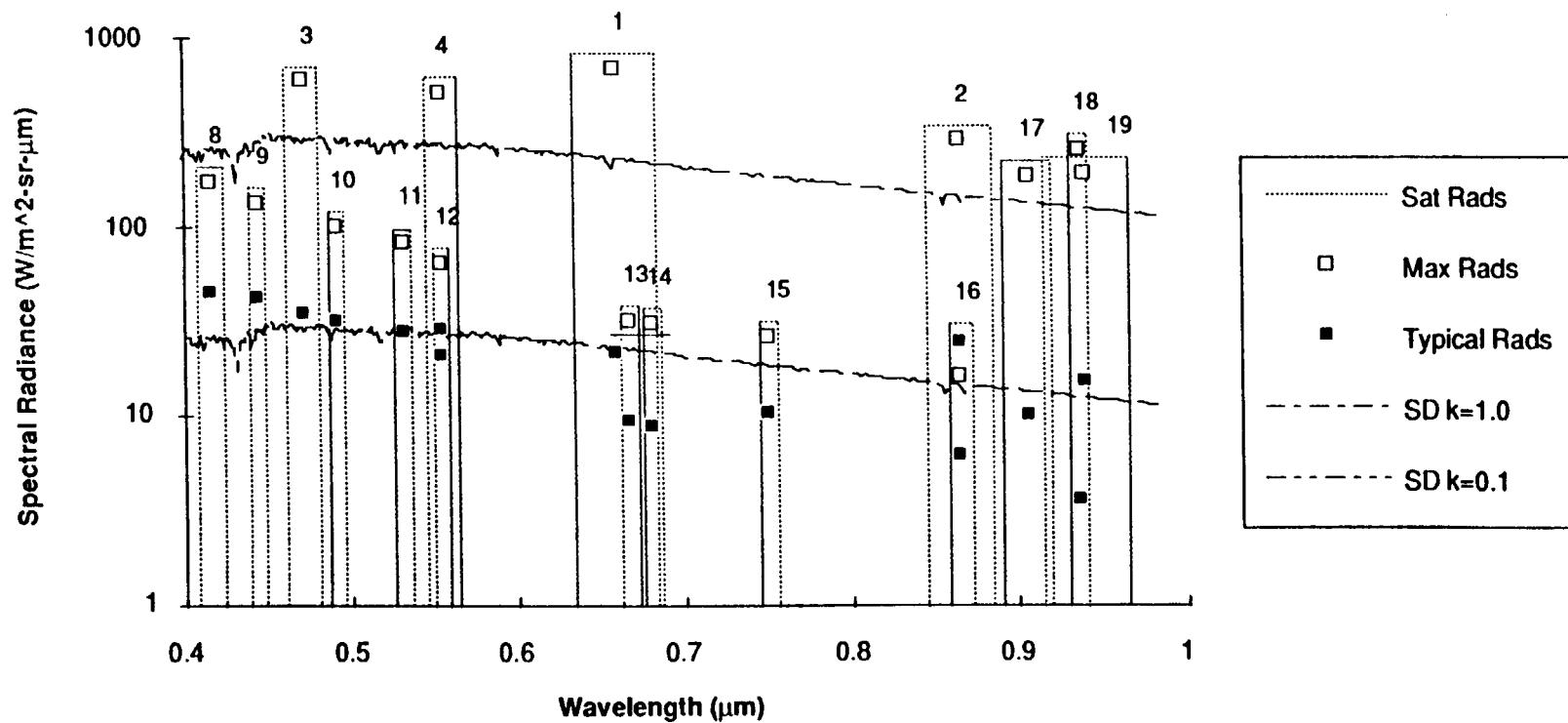


REFLECTIVE BANDS COVER WIDE SIGNAL RANGE



SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N
Typical, Saturation and Diffuser Radiances



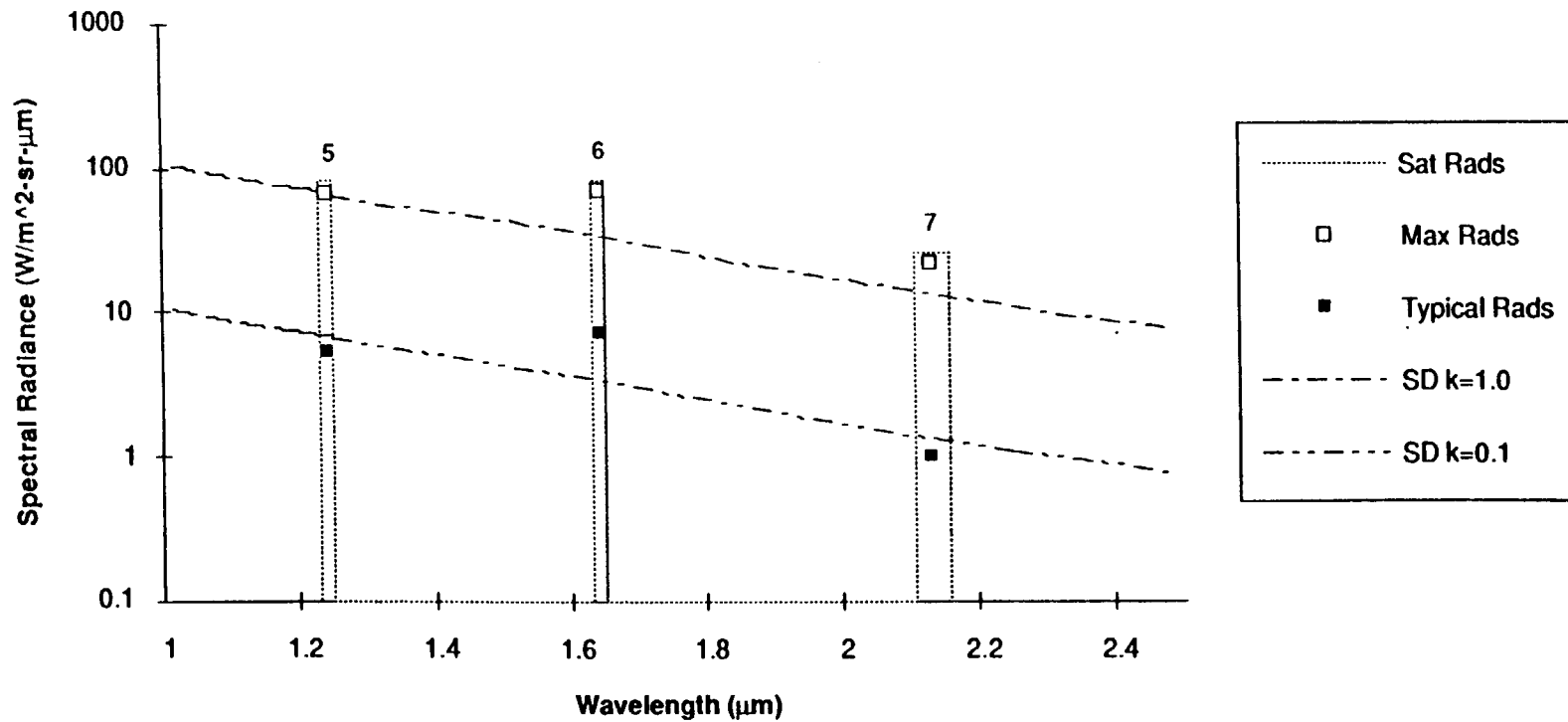


SIGNAL LEVELS FOR SWIR BANDS



SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N
Typical, Saturation and Diffuser Radiances





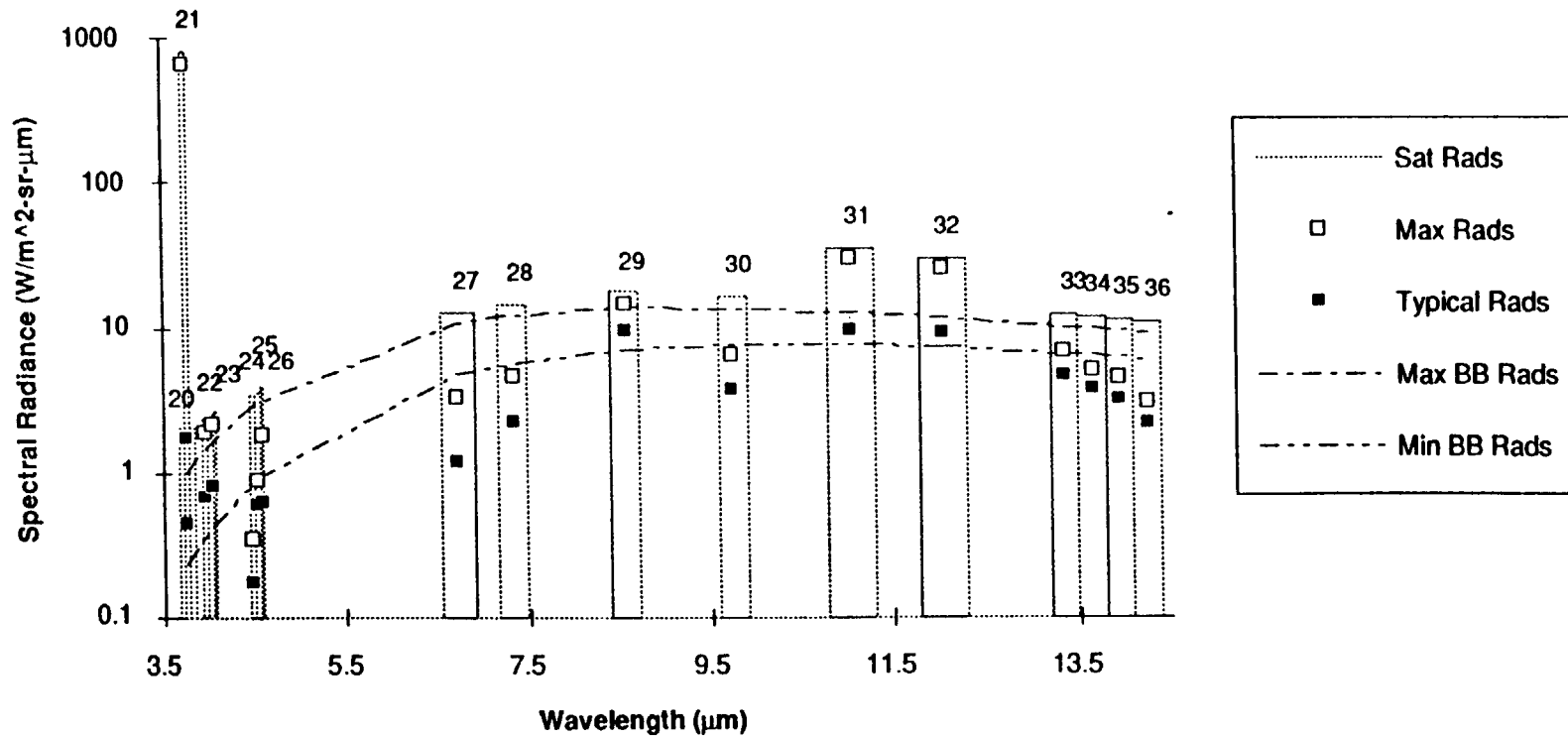
EMISSIVE BANDS ACCOMMODATE FULL RANGE OF SIGNAL LEVELS



SANTA BARBARA RESEARCH CENTER
a subsidiary

MODIS-N

Typical, Saturation and Blackbody Radiances

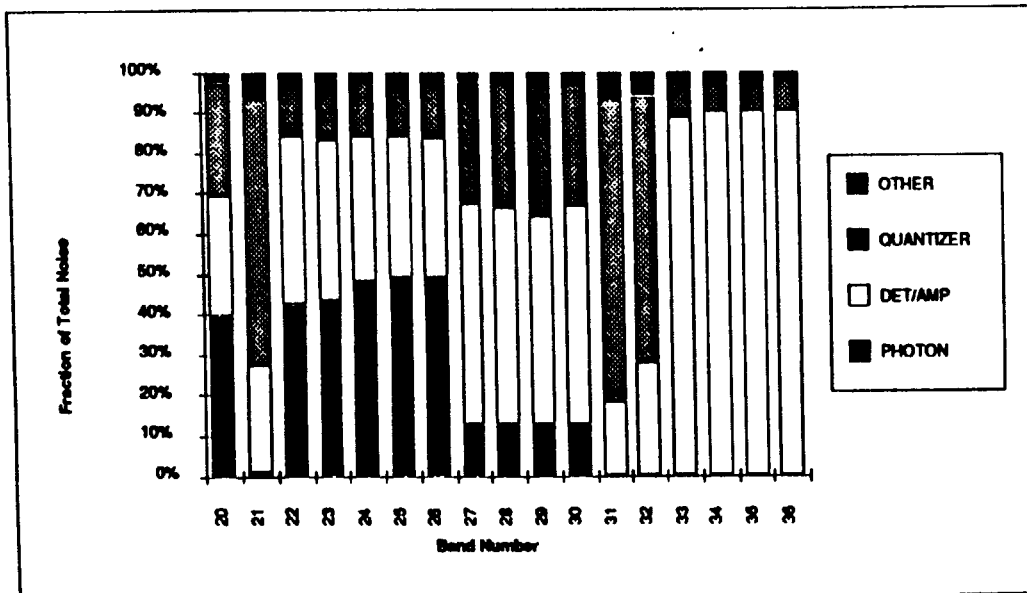
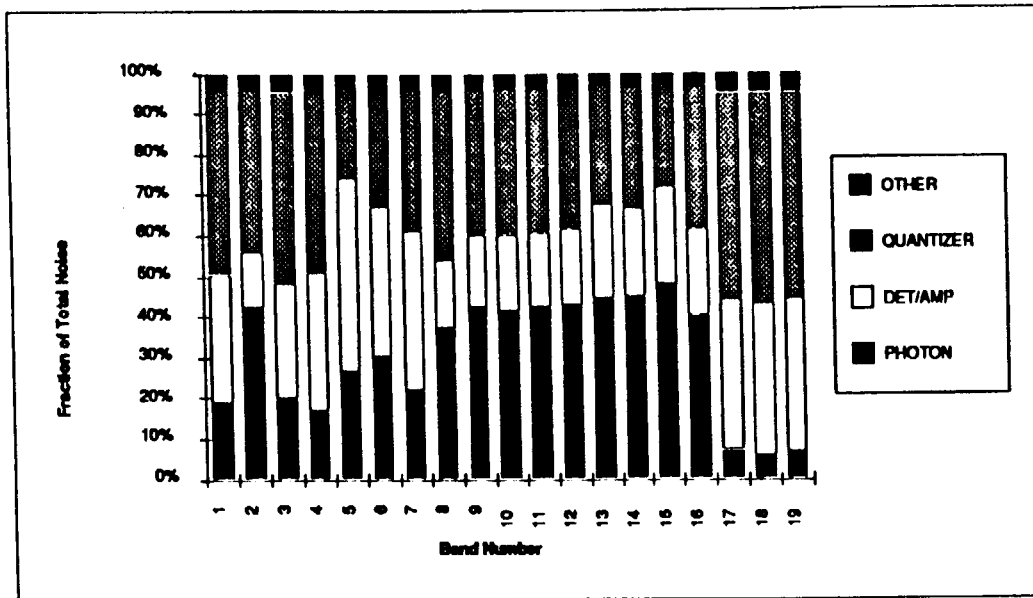




SANTA BARBARA RESEARCH CENTER
a subsidiary

NOISE LEVELS FOR MODIS-N REFLECT SIGNAL AND DYNAMIC RANGE REQ'D

- QUANTIZATION AFFECTS 21, 31, 32
- HIGH DETECTOR NOISE IN 33-36





SANTA BARBARA RESEARCH CENTER
a subsidiary

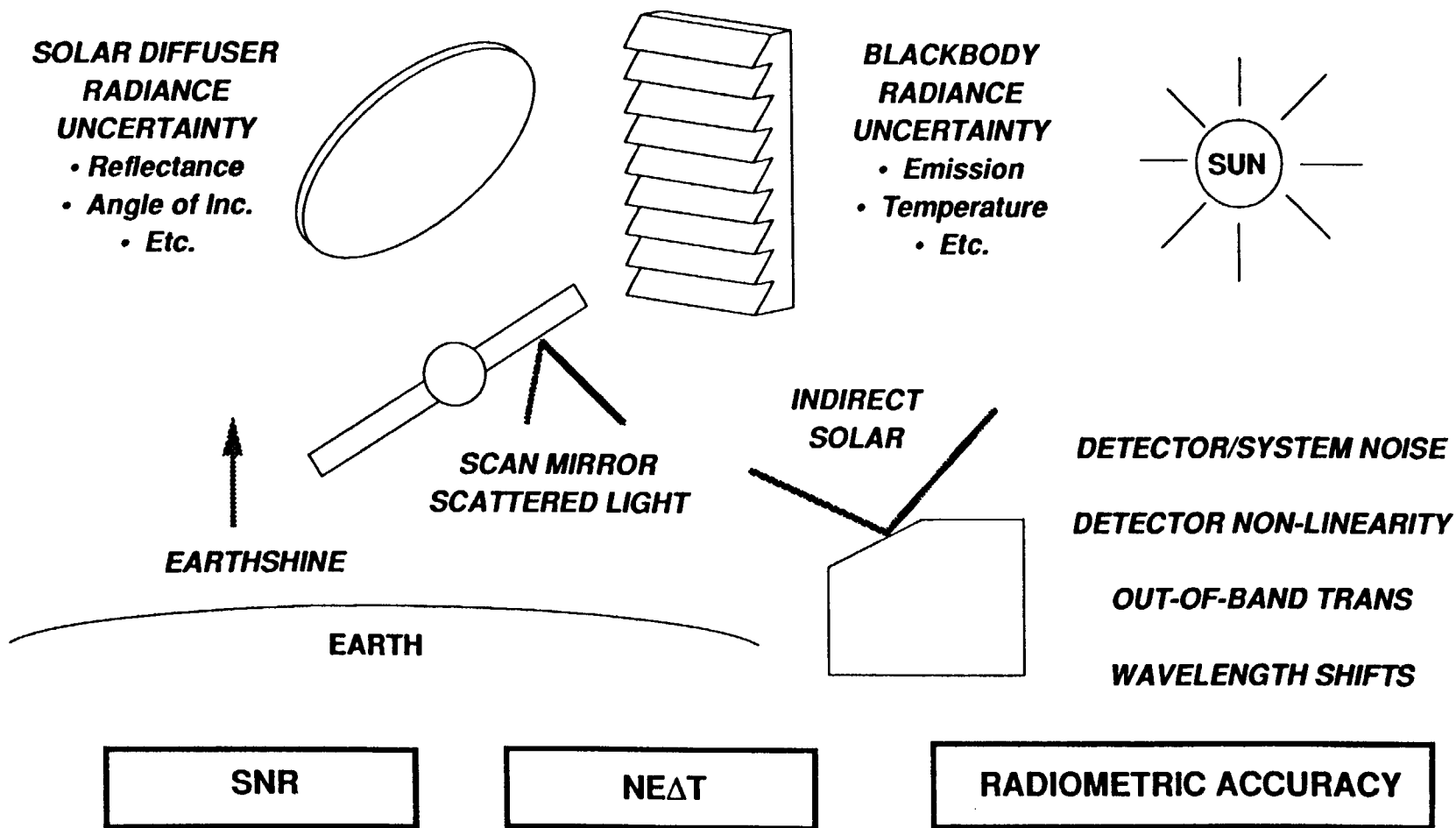
RADIOMETRIC ACCURACY
REFLECTIVE, EMISSIVE BANDS



RADIOMETRIC MATH MODEL INCLUDES MANY CONTRIBUTORS

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary





REFLECTIVE BAND IN-FLIGHT RADIOMETRIC ACCURACY ASSUMPTIONS



SANTA BARBARA RESEARCH CENTER
a subsidiary

SCENE

- SINGLE PIXEL BASIS (NO AVERAGING OF SCENE DATA)
- SCENE UNIFORM ACROSS SAMPLE (NO MTF ERRORS)
- NO SPECTRAL BAND REGISTRATION ERRORS
- 50% SCENE POLARIZATION, 2% INSTRUMENT

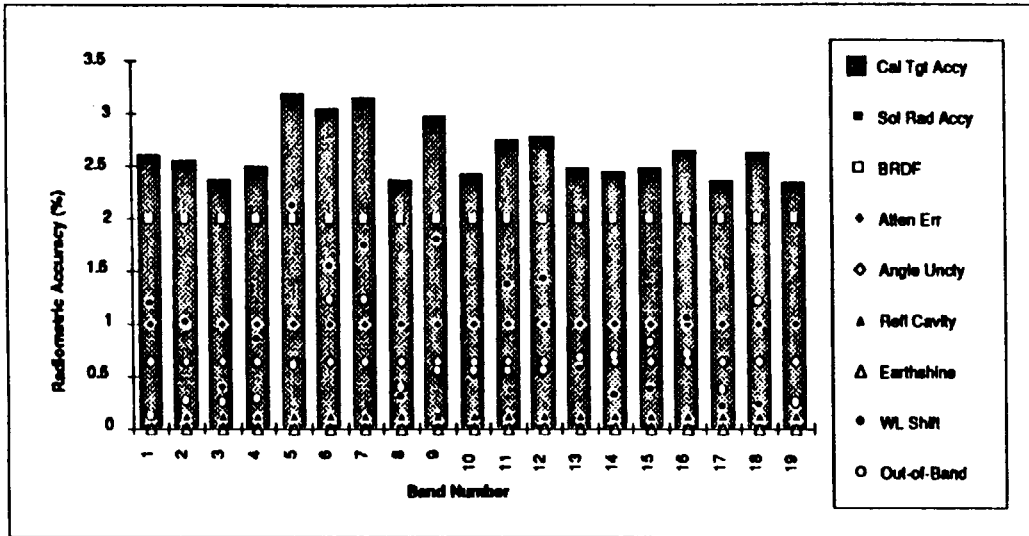
DIFFUSER

- NO SOLAR IRRADIANCE UNCERTAINTY
- BRDF: $1/\pi \pm 2\%$
- AOI SUN ON DIFFUSER: $62.6^\circ \pm 0.3\%$
- 15 SAMPLES AVERAGED ON SOLAR DIFFUSER
- SCREEN TRANSMISSION: $0.1 \pm 1\%$
- NO INDIRECT SOLAR
- NO EARTHSHINE ON SOLAR DIFFUSER

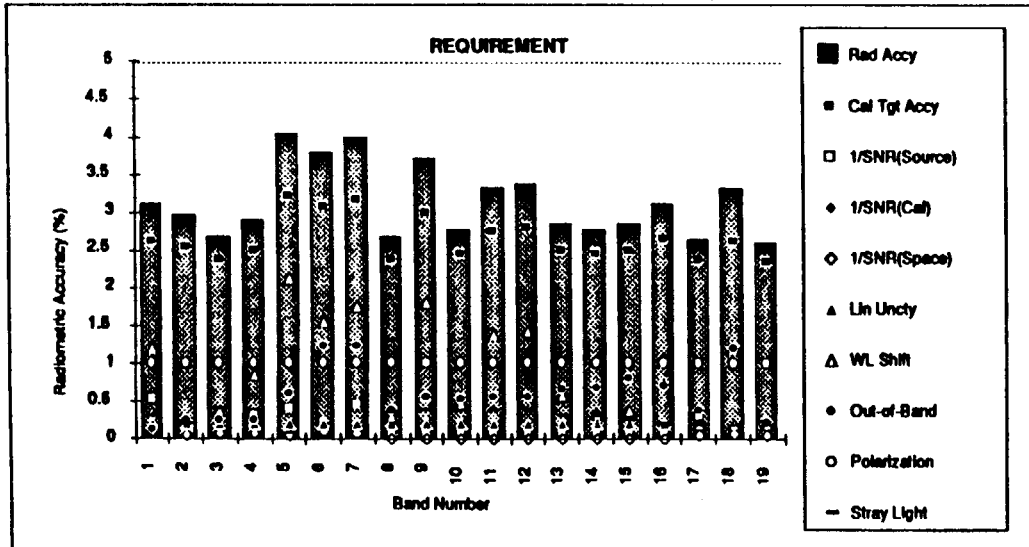
INSTRUMENT

- UNCORRELATED WAVELENGTH SHIFT: SCENE TO DIFFUSER
- OUT OF BAND TRANSMISSION: 0.0001
- BACKSCATTERED ENERGY: 0.13%
- 0.2% KNOWLEDGE OF TRANSFER FUNCTION (LINEARITY)
- 0.2% SCAN MIRROR SCATTER, $\Omega = 2$ sr, $\rho_{\text{Earth}} = 50\%$

ACCURACY OF DIFFUSER RADIANCE



ACCURACY OF SCENE RADIANCE



SANTA BARBARA RESEARCH CENTER
a subsidiary

REFLECTIVE
IN-FLIGHT
RADIOMETRIC
ACCURACY
MEETS SPECS
IN ALL BANDS





EMISSIVE BAND IN-FLIGHT RADIOMETRIC ACCURACY ASSUMPTIONS



SANTA BARBARA RESEARCH CENTER
a subsidiary

SCENE

- SINGLE PIXEL BASIS (NO AVERAGING OF SCENE DATA)
- SCENE UNIFORM ACROSS SAMPLE (NO MTF ERRORS)
- NO SPECTRAL BAND REGISTRATION ERRORS
- NO POLARIZATION ERRORS

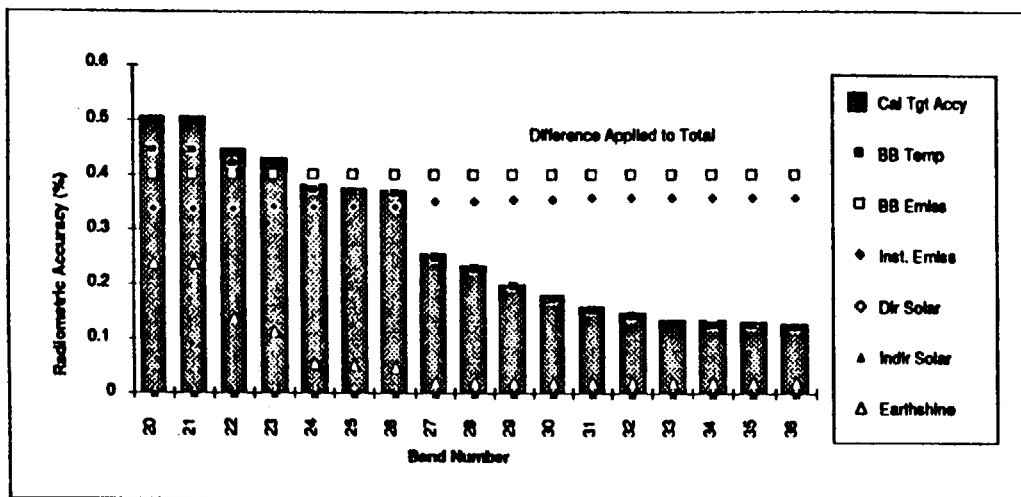
BLACKBODY

- EMISSIVITY: $0.992 \pm 0.4\%$
- BLACKBODY TEMPERATURE: $295\text{K} \pm 0.1\text{K}$
- 15 SAMPLES AVERAGED ON BLACKBODY
- NO DIRECT SOLAR ON BLACKBODY
- NO INDIRECT SOLAR ON BLACKBODY
- EARTHSHINE ON BLACKBODY: $\Omega = 0.081 \text{ sr}$, $T=295\text{K}$ $\text{Rho} = 50\%$

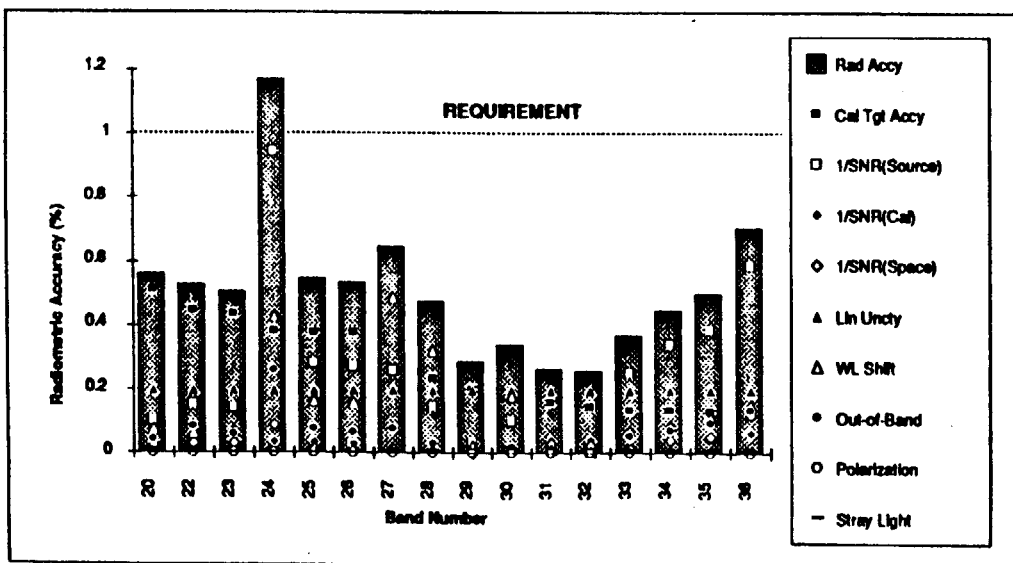
INSTRUMENT

- INSTRUMENT TEMPERATURE: 293K
- OUT OF BAND TRANSMISSION: 0.001
- CORRELATED WAVELENGTH SHIFT OF SCENE AND BLACKBODY
- CORRELATED OUT-OF-BAND OF SCENE AND BLACKBODY
- CORRELATED INSTRUMENT AND BLACKBODY EMISSIONS
- 0.2% KNOWLEDGE OF TRANSFER FUNCTION (LINEARITY)
- 0.2% SCAN MIRROR TOTAL INTEGRATED SCATTER

ACCURACY OF BLACKBODY RADIANCE



ACCURACY OF SCENE RADIANCE



SANTA BARBARA RESEARCH CENTER
a subsidiary

EMISSIVE IN-FLIGHT RADIOMETRIC ACCURACY MEET WITH MARGIN IN MOST BANDS

• BAND 24 LIMITED BY SNR AT Ltyp





SANTA BARBARA RESEARCH CENTER
a subsidiary

FUTURE REFINEMENTS
SUMMARY AND CONCLUSIONS



FUTURE REFINEMENTS FOR THE RADIOMETRIC MATH MODEL



SANTA BARBARA RESEARCH CENTER
a subsidiary

- **USER-FRIENDLY INTERFACE**
 - **MENUS**
 - **GRAPHICS**
 - **ALLOW LOOPS FOR ITERATIONS**
- **INCORPORATE SRCA RADIANCE MODEL TO "CALRADS"**
- **INCORPORATE SOLID ANGLE MODEL**
- **INCLUDE BANDPASS FILTER PROFILES FOR ALL BANDS**
- **POLARIZATION**
 - **USE CURRENT PREDICTIONS FOR ALL BANDS**
 - **INCORPORATE PHASE CAPABILITY**
- **SCAN MIRROR AFFECTS: REFLECTANCE WITH SCAN ANGLE**
- **1/f NOISE FOR PC BANDS TO BE IN TERMS OF NOISE AT 1 Hz
(CURRENTLY IN TERMS OF Fknee)**



SUMMARY AND CONCLUSIONS



SANTA BARBARA RESEARCH CENTER
a subsidiary

- **RADIOMETRIC MATH MODEL "ENGINE" RUNNING**
- **INCLUDES CALCULATION OF SENSITIVITY AND ACCURACY**
- **MANY CONTRIBUTORS ACCOUNTED FOR**
- **PRELIMINARY BUDGETS SHOW ACCURACY SPEC DIFFICULT FOR SOME BANDS**
- **ADDITIONAL INFO NEEDED FOR CAL INPUT VARIABLES**
- **MODEL REFINEMENT IN PROGRESS CONTINUALLY**