MODIS
SYSTEM PERFORMANCE vs. SPEC
WORKSHOP SESSION
22 JUNE 93

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Attach. #1
Tech Team mtg - 6/24/93

Agenda / Overview

- Ghosting Levels in Excess of Budgeted Allowance
- Contributes to Instrument Response Outside the IFOV
- Modeling Done for SeaWiFS and MODIS: Agrees with Data
- MODIS Stray Light Met in VIS, NIR, But not in IR Due to Ghosting
- Transient Response Not Met Due to Ghosting
- Several Options Exists for Correcting Ghosting Error
- Plan in Place to Design, and Implement Solutions
- Several Questions Highlighted in Tuesday, 6/22/93 Meeting with NASA

EM PREDICTIONS SHOW IMPROVED SNR MARGIN (PARTICULARLY LWIR)

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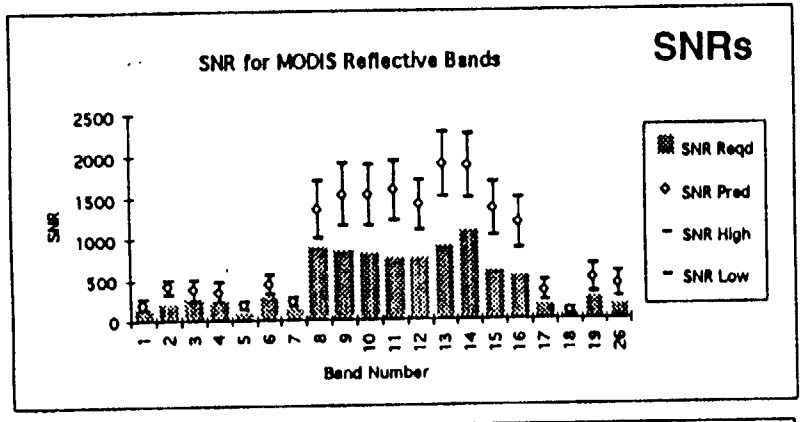
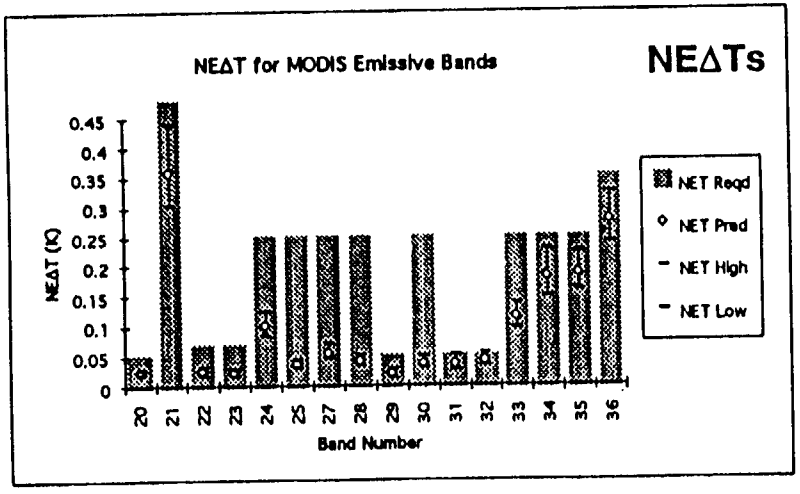
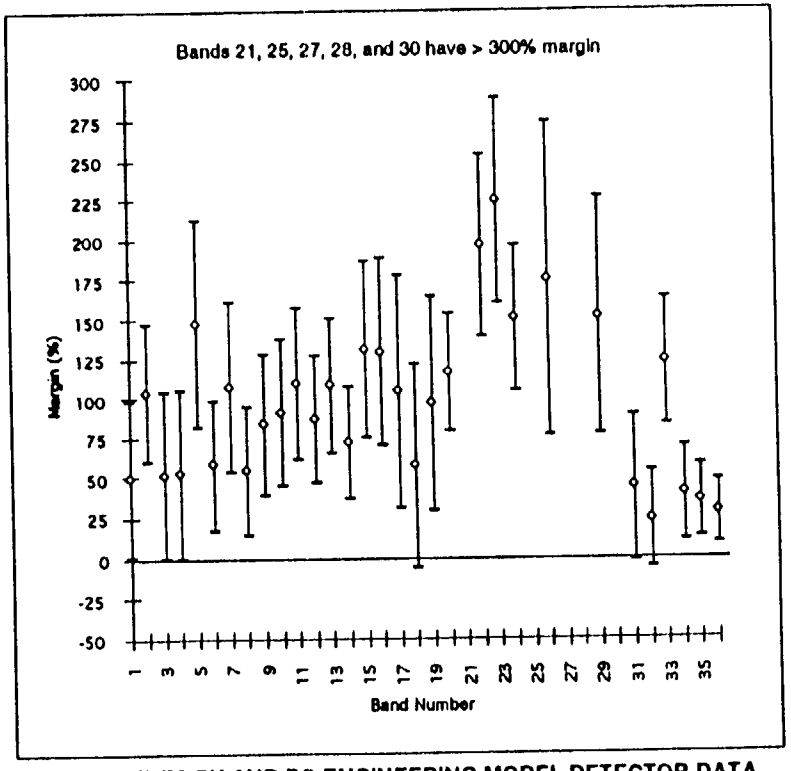




MARGINS



- INCLUDES PV AND PC ENGINEERING MODEL DETECTOR DATA
- INCLUDES UPDATED OPTICAL SYSTEM TRANSMISSIONS, FILTER BANDWIDTHS
- ERROR BARS ARE 3 SIGMA DEVIATIONS: INCLUDE PC IN-BAND VARIATIONS

RMM STORES 'LEFT' AND 'RIGHT' INTEGRATION LIMITS FOR OOB TRANSMISSION

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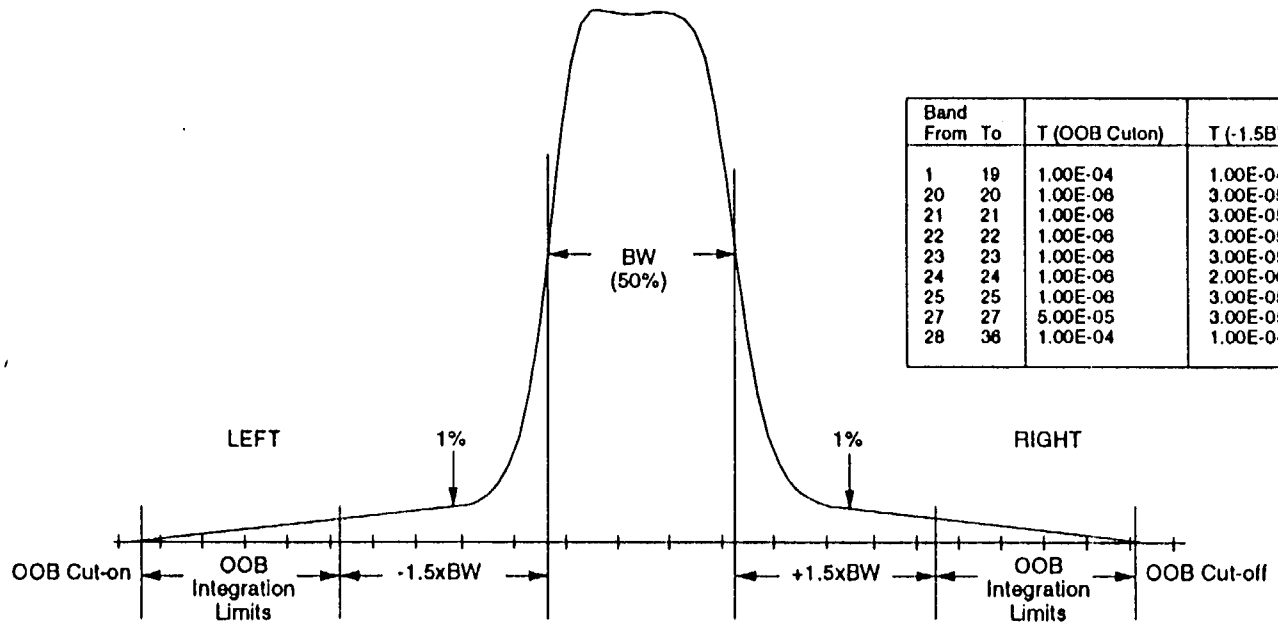

Band From	Band To	T (OOB Cuton)	T (-1.5BW)	T (+1.5BW)	T (OOB Cutoff)
1	19	1.00E-04	1.00E-04	1.00E-04	1.00E-04
20	20	1.00E-06	3.00E-05	1.00E-04	5.00E-04
21	21	1.00E-06	3.00E-05	1.00E-04	5.00E-04
22	22	1.00E-06	3.00E-05	1.00E-04	2.00E-04
23	23	1.00E-06	3.00E-05	1.00E-04	2.00E-04
24	24	1.00E-06	2.00E-06	1.00E-04	2.00E-04
25	25	1.00E-06	3.00E-05	1.00E-04	5.00E-04
27	27	5.00E-05	3.00E-05	1.00E-04	5.00E-04
28	36	1.00E-04	1.00E-04	1.00E-04	1.00E-03

OUT-OF-BAND TRANSMISSION MODELLED WITH SOLAR IR CONTRIBUTION

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- SOLAR OOB CONTRIBUTION IS SIGNIFICANT IN MWIR
- MODEL HAS CHANGED FROM A 'CONSTANT' OOB TRANSMISSION VALUE TO:
  - 'LEFT' AND 'RIGHT' INTEGRATIONS WITH LINEARLY INTERPOLATED TRANSMISSIONS
- ALLOWS FLEXIBILITY IN FILTER PROCESSING WHILE OPTIMIZING OOB REJECTION
- VENDOR FLOWDOWN SPEC HAS BEEN MODIFIED AS REQUIRED
  - NO SIGNIFICANT IMPACT TO FILTER MANUFACTURING AND DELIVERY

Out-of-Field Response Affects Sensor Performance

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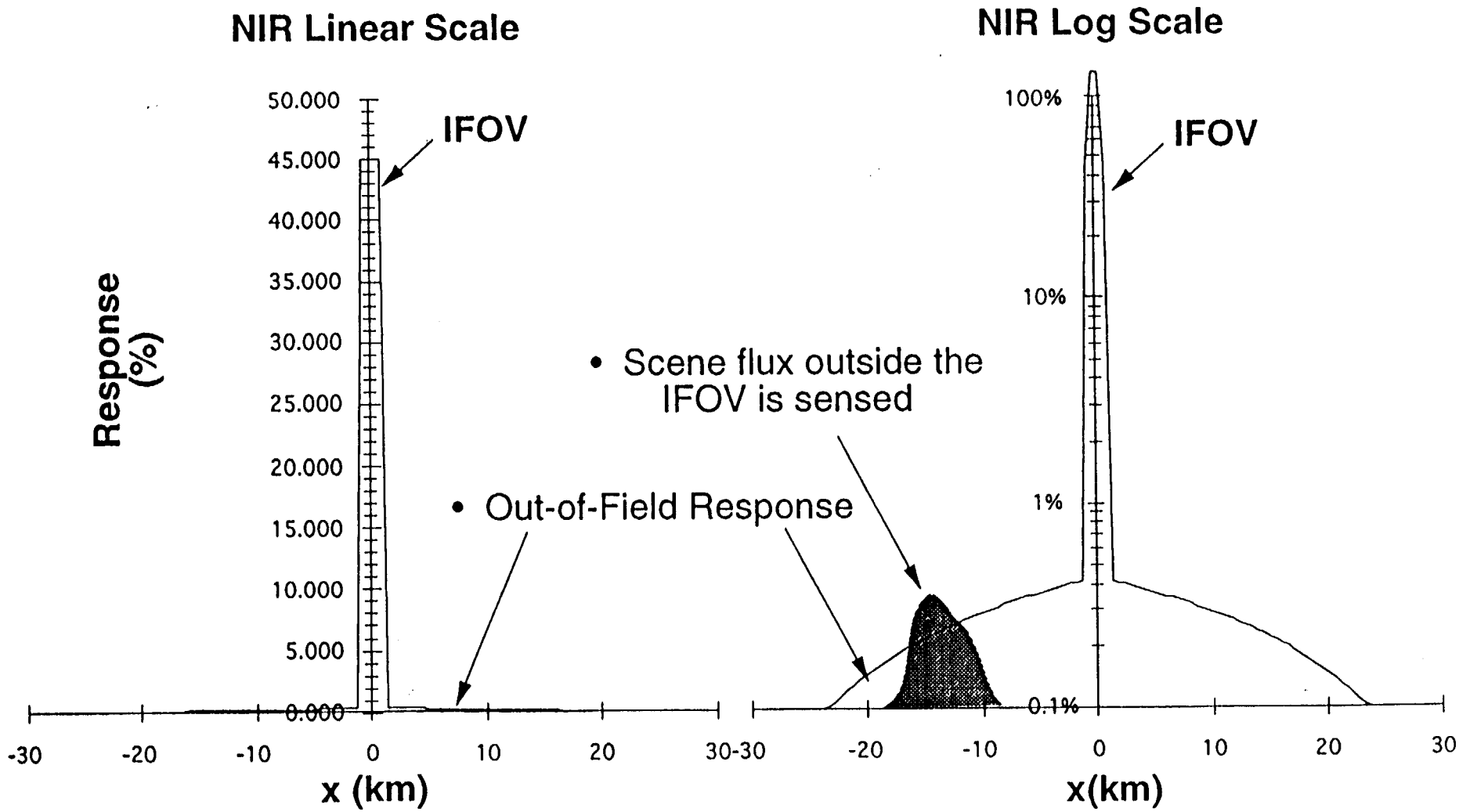
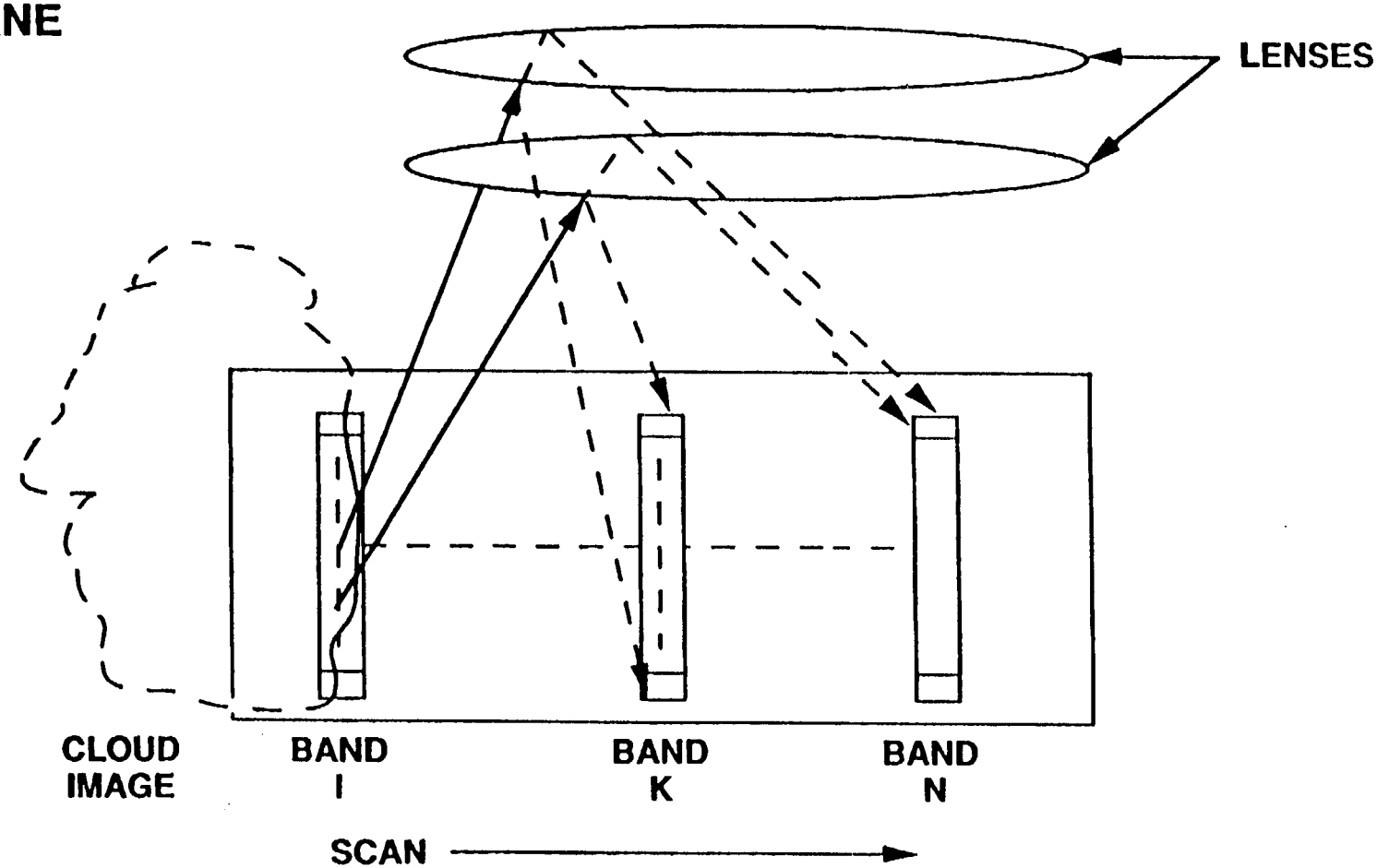


Ghosting/Backscatter Contributes to Out-of-Field (OOF) Response

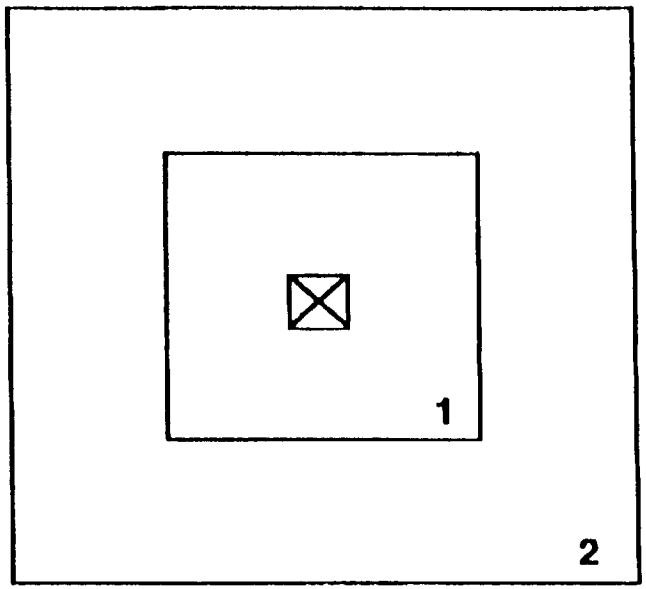
- REFLECTIONS OFF FOCAL PLANE ARE REFLECTED OFF OPTICS CAUSING ERRONOUS READINGS ON OTHER BANDS ON FOCAL PLANE



BANDS START TO "SEE" CLOUD BEFORE IT SHOULD BE DETECTED

STRAY LIGHT REQUIREMENTS (SPEC. SECTION 3.4.8)

- EASIER REQUIREMENT ON PERFORMANCE



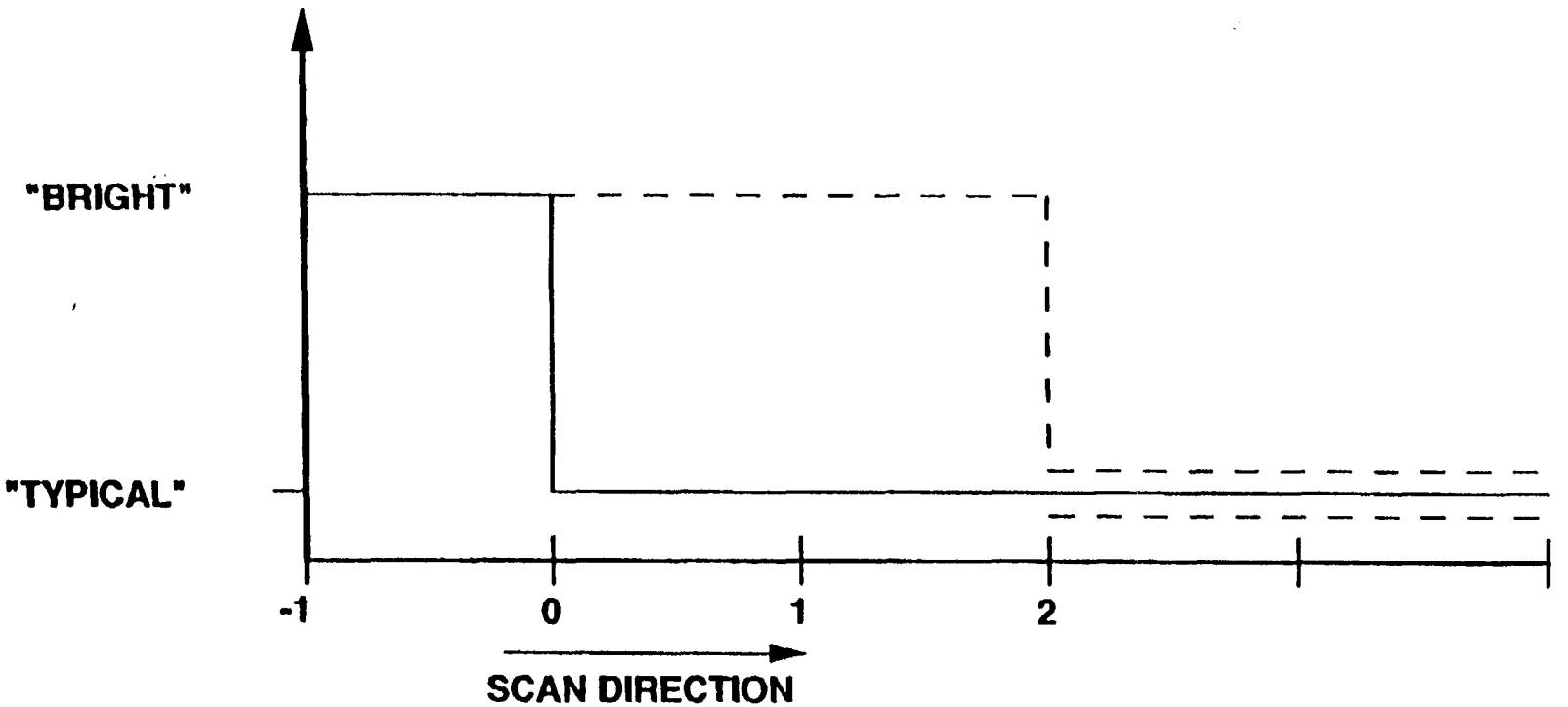
A. VIS/NIR

- 21 x 21 IFOV REGION (REGION 1)
- CHANGE REGION 2
- CENTER PIXEL OF REGION 1 MAY NOT CHANGE MORE THAN 0.004 BRIGHT

B. THERMAL

- 5 x 5 IFOV REGION (REGION 1)
- CHANGE REGION 2
- CENTER PIXEL MAY NOT CHANGE MORE THAN 1%

TRANSIENT RESPONSE REQUIREMENT (SPEC. PARAGRAPH 3.4.4)



- +/- 0.005 "TYPICAL" AFTER 2 Km
- RATIO "BRIGHT": "TYPICAL"
  - 2.6:1 TO 71.1:1 IN VIS/NIR
  - 1.4:1 TO 36.1:1 IN THERMAL BANDS

——— SOURCE

– – – – RESPONSE ENVELOPE

Ratio of Cloud to Typical Radiance is High; Many Bands

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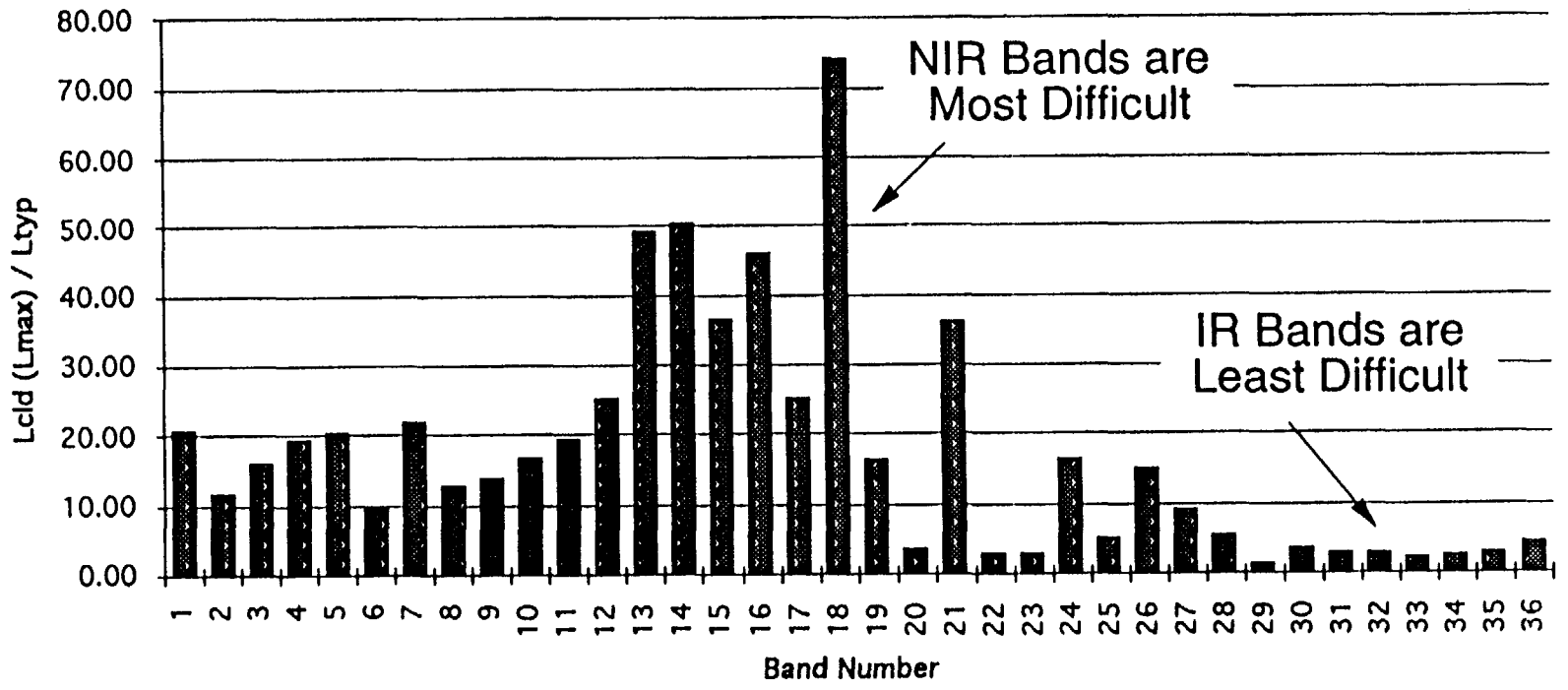
• Reducing Lcld, or Increasing Ltyp will Ease Transient Response Requirement



SeaWiFS Used as Test Case for MODIS Backscatter Modeling

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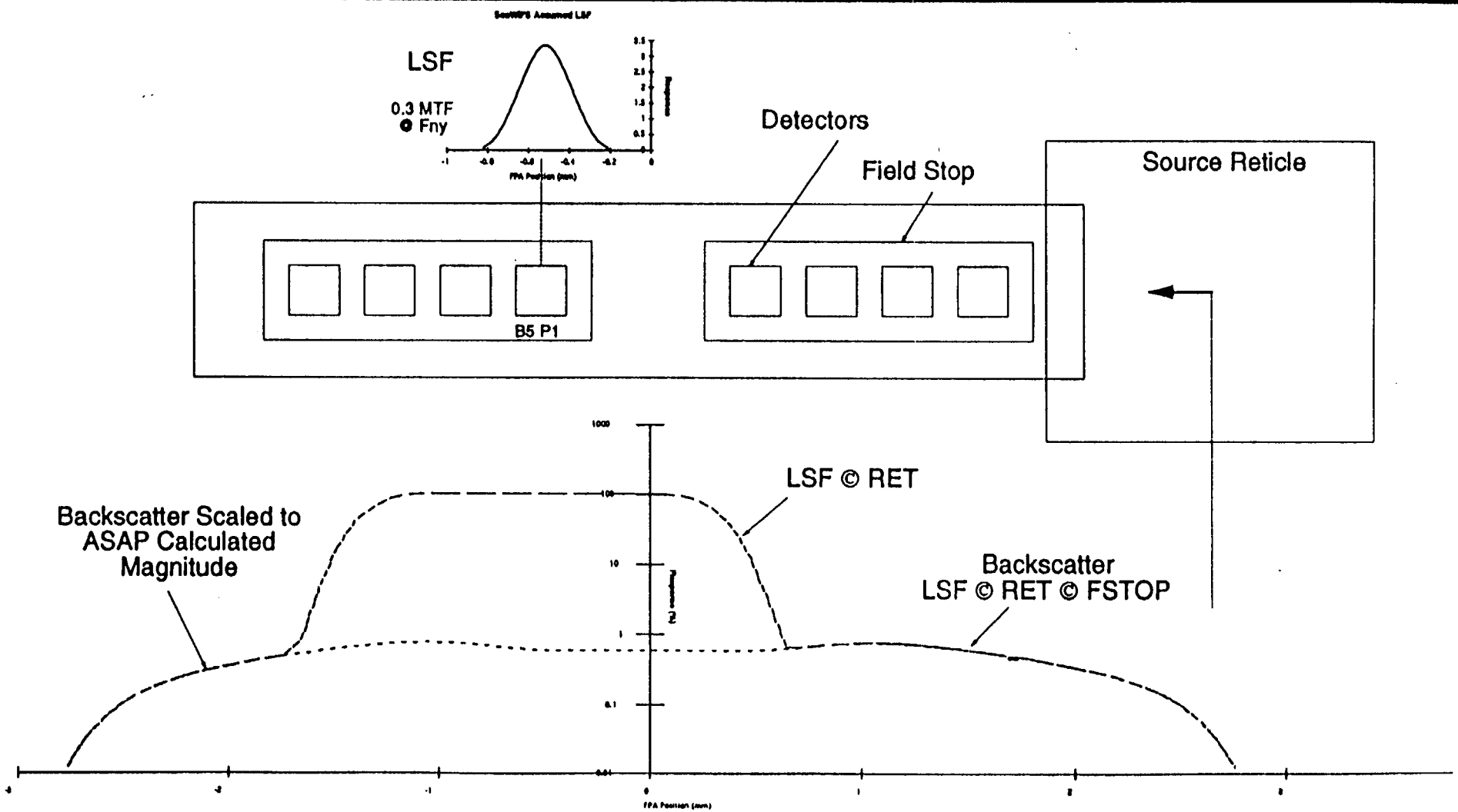

Good Agreement Found for SeaWiFS Test Case

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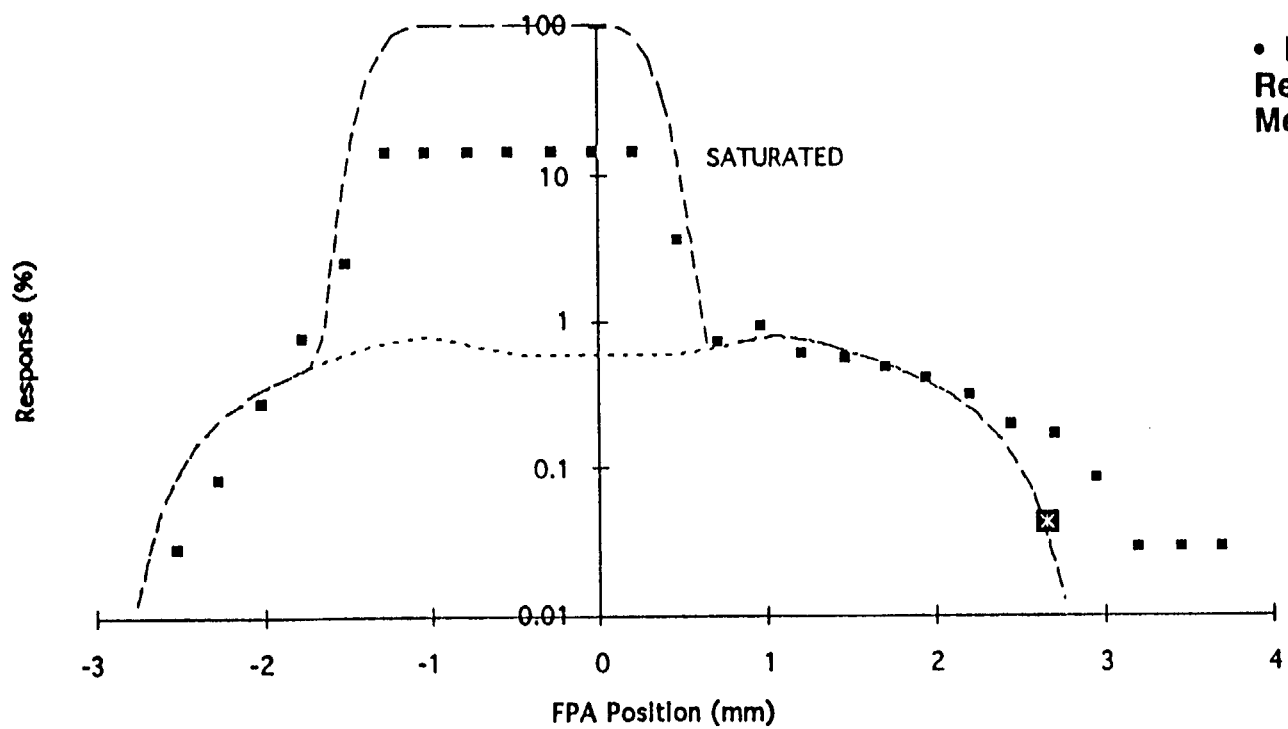
SeaWIFS Optical Backscatter Compared with Theory



- Electrical Component Removed from SeaWIFS Measured Data

Measured Data
Input+Bkscat
Backscatter
Spec

ASAP Backscatter & Latest Coating Data Used in Model

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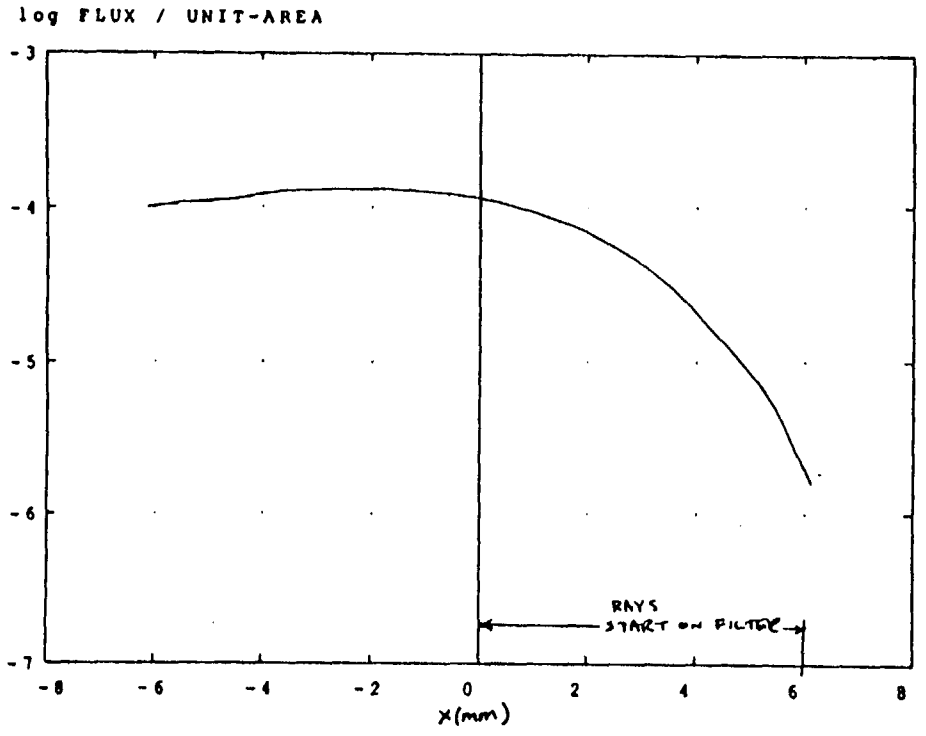
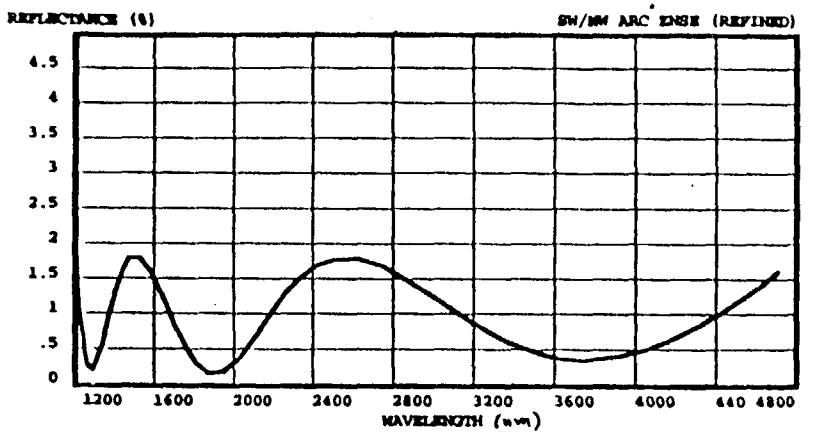
- ASAP NIR Example: 6mm x 1mm



- Optical Coating Data Example
- Average Value Used for All Bands



Ref. PL3095-M02527; Systems Analysis: T. Pagano
PL3095-Q02528; ASAP Optics Analysis: M. Sullivan
PL3095-Q02536; Filter Coating Analysis: S. Pellicori

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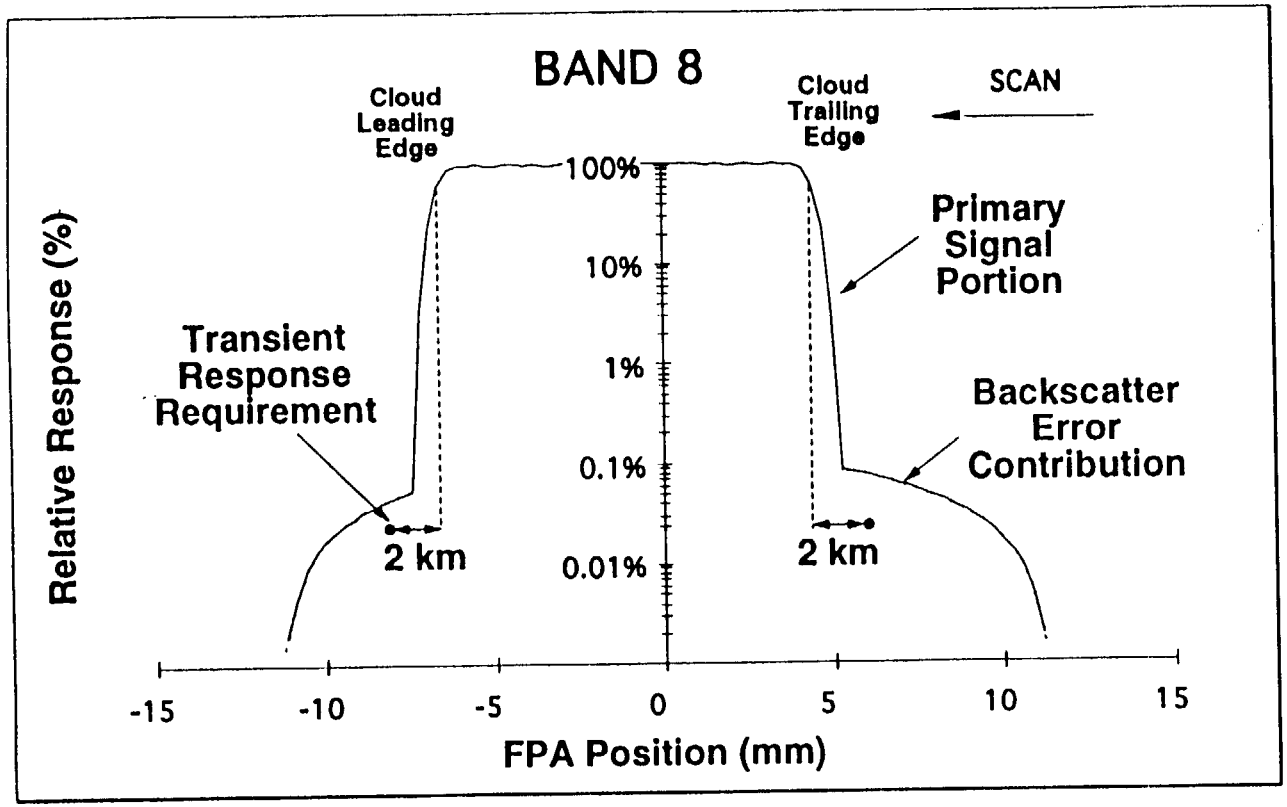
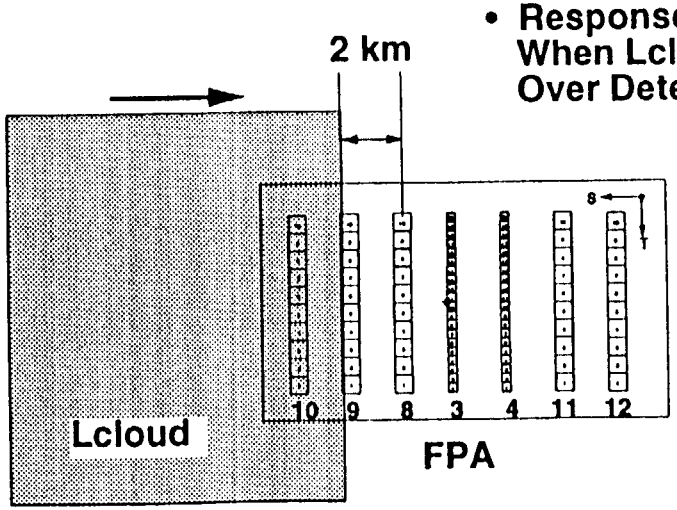
MODIS Bands Off-Axis Have Assymmetric Response



- Response is Signal Measured When Lcloud is Passed Over Detector



MODIS
Has Four FPAs

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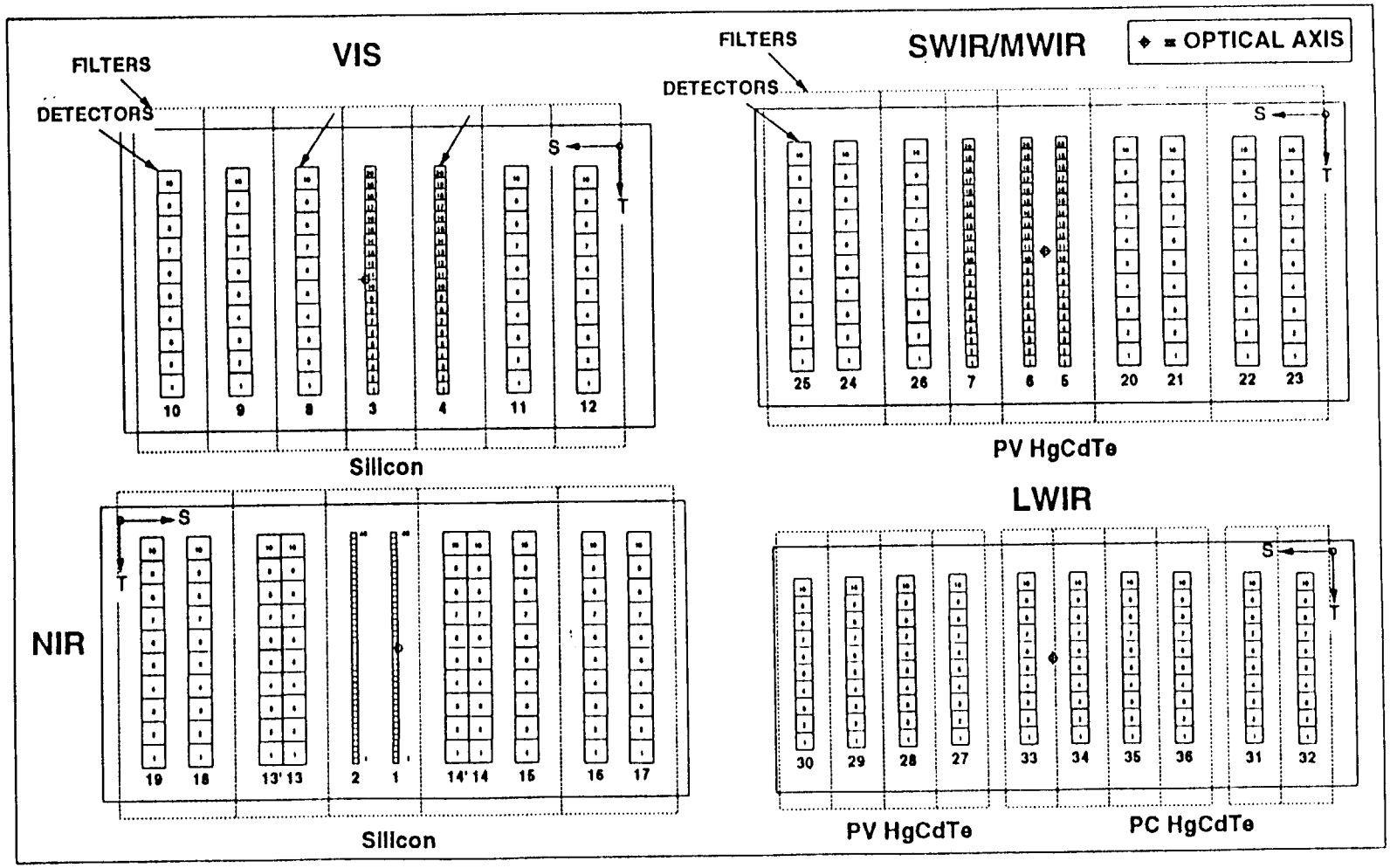

Stray Light Spec Satisfied in VIS and NIR

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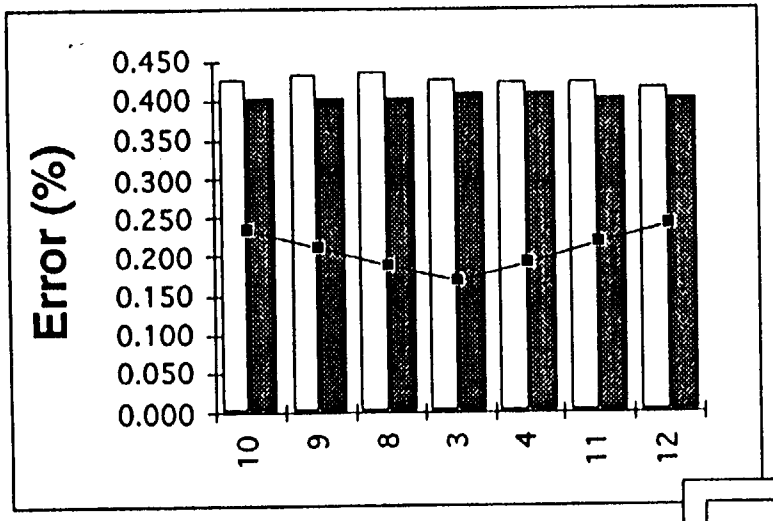
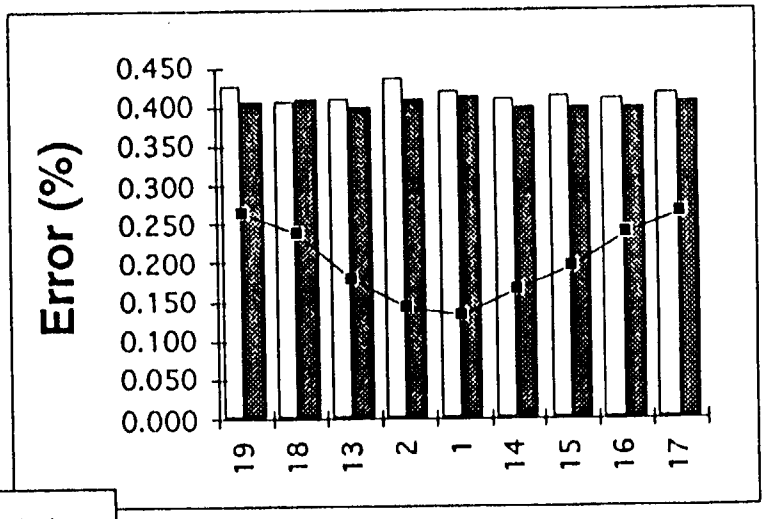
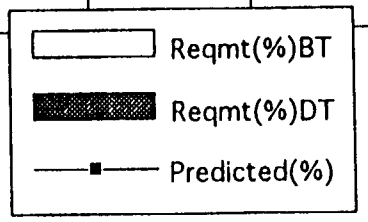
VIS



NIR





- Error Represents Response to Energy Outside the 21 x 21 km FOV
- Includes Ghosting and Scan Mirror Scatter

- Bright Target Spec: Error = 0.004 Lcld / (Lcld - Ltyp)
  Viewing Lmax
- Dark Target Spec: Error = 0.004 Lcld / (Lcld - 0.02 Lmax)
  Viewing Ltyp

Stray Light Performance in IR Does Not Meet Spec

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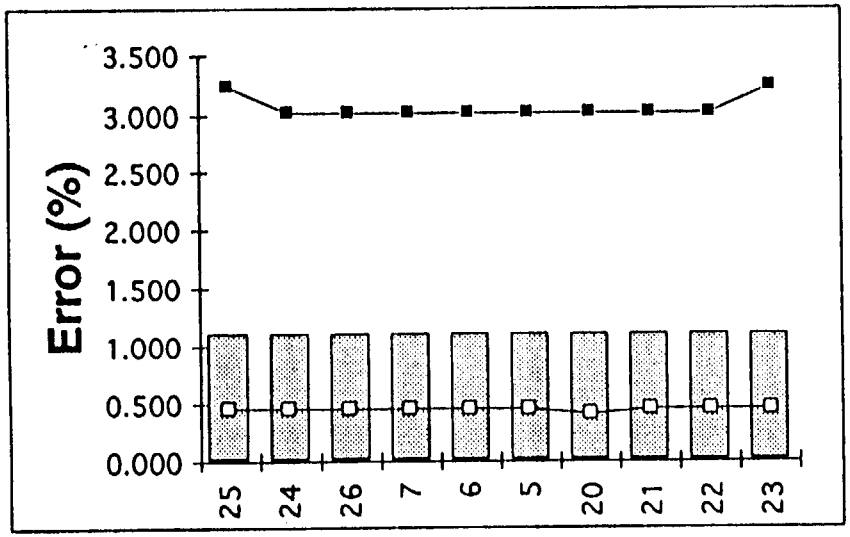
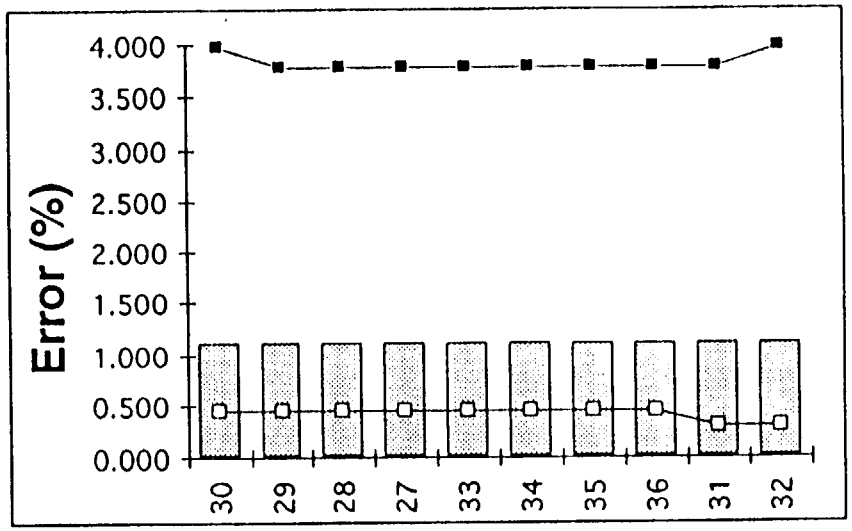
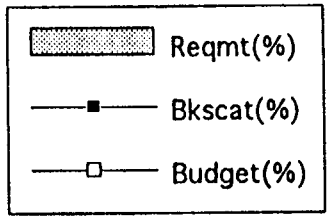
SWIR/MWIR



LWIR



- Error Represents Response to Energy Outside the 5 x 5 km FOV



- Includes Ghosting and Scan Mirror Scatter

- Warm Target Spec: Error = 0.01 Ltyp / (Ltyp - 0.1Ltyp)
  Viewing Ltyp

OOF Requirements Already Defined to Meet Accuracy

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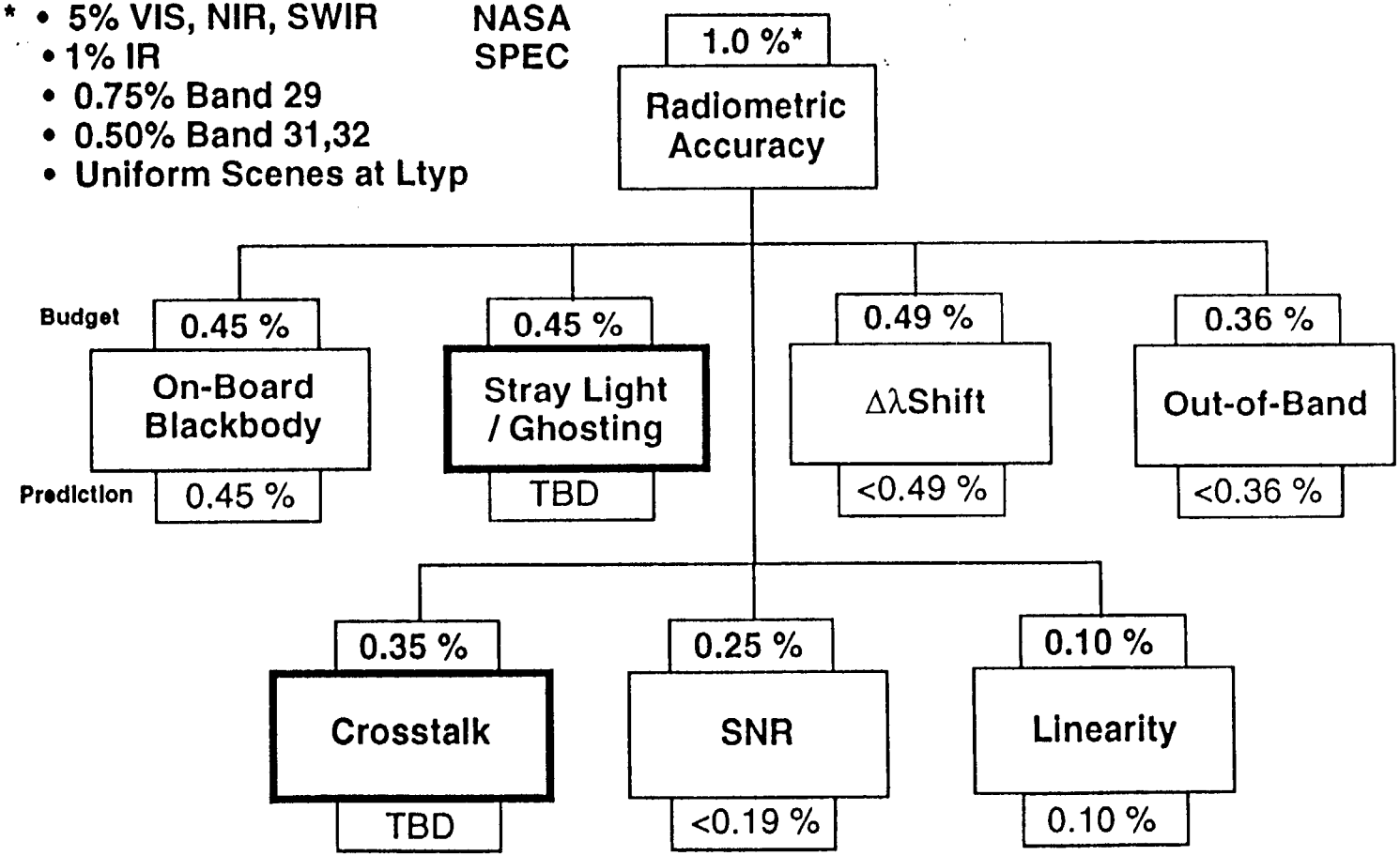
* • 5% VIS, NIR, SWIR
• 1% IR
• 0.75% Band 29
• 0.50% Band 31,32
• Uniform Scenes at Ltyp

NASA SPEC



SBRC Accuracy Flowdown Often Tighter Than NASA Spec

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Major Accuracy Error	NASA Requirement	SBRC Spec Needed to Meet Accuracy
Wavelength Shift	< 1% IR	<0.1% IR
Out-of-Band	< 5%	< 0.01 %
Det/Elect Crosstalk	1 LSB/Band (0.1% - 0.025%)	0.25%/FPA
Stray Light/Ghosting	0.4%, 1% IR	0.4%, 0.45% IR
Linearity Knowledge	None	0.1%
SNR	Spec./Band	Spec./Band

Ghosting
Improvement Options

Several Surfaces are Dominant Ghosting Contributors

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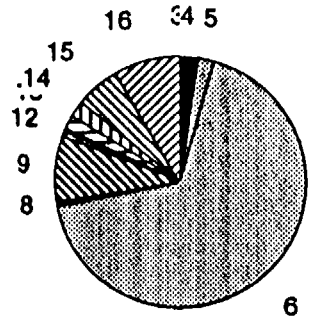
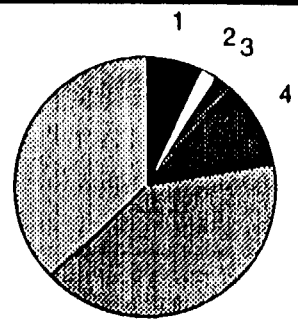
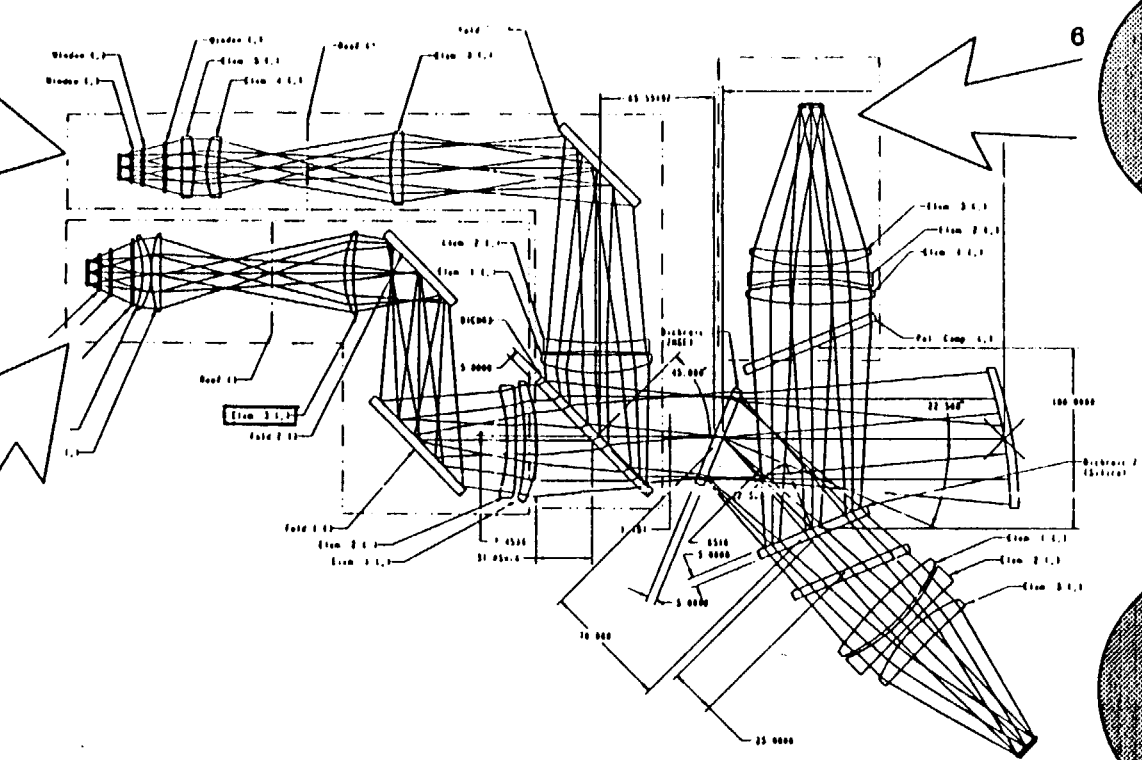


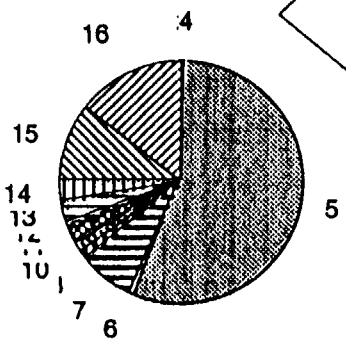
SWIR/MWIR



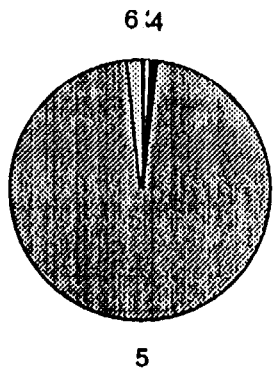
VIS



LWIR



NIR



- **MODIFICATION OF SURFACE CURVATURE HAS POTENTIALLY SIGNIFICANT BENEFIT**

Fraction of FPA Illuminated Determines Ghosting Magnitude

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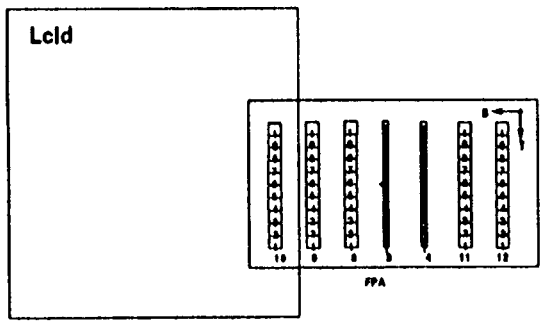
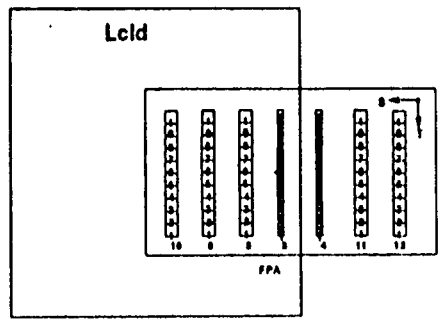
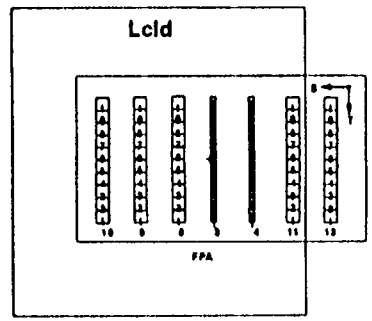
Low Ghosting



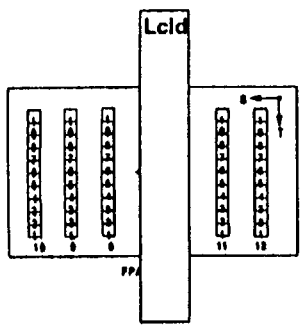
Medium Ghosting

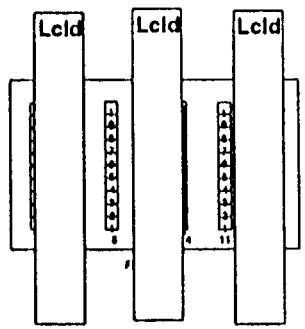


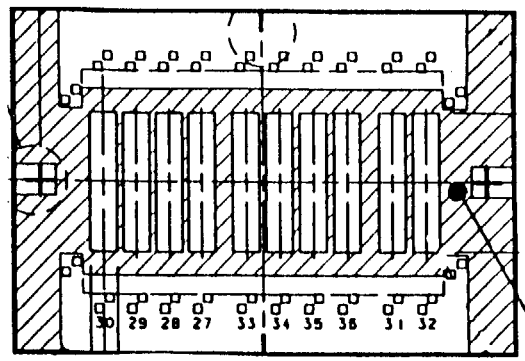
High Ghosting



- NASA Spec Does Not Define Cloud Size or Cover







- Additional Benefit From Mask Absorption

Current Analysis Uses Cloud Cover of Top Row (Worst Case)

Window Optmization will Reduce Ghosting

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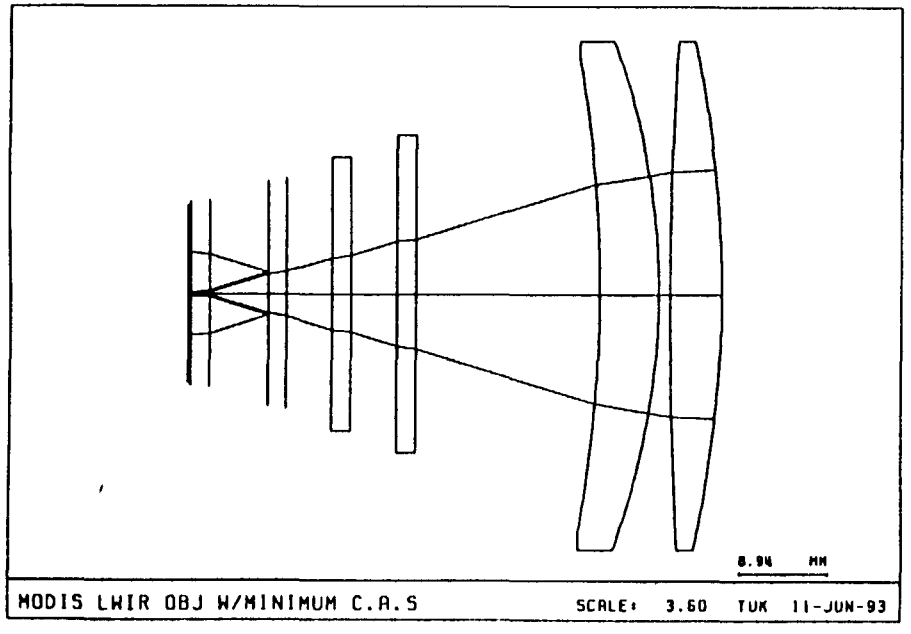
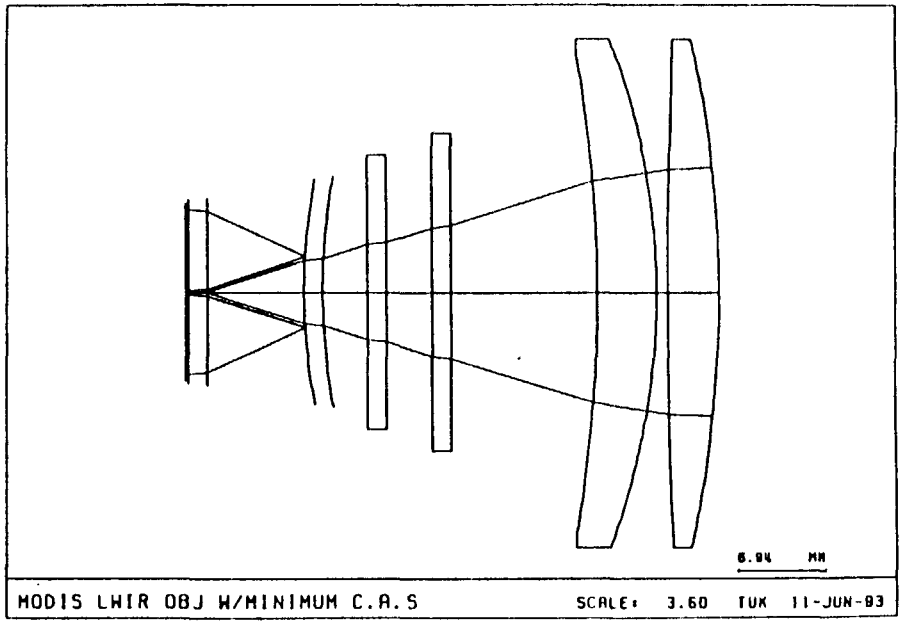
- Cooler windows are major contributors in SWIR/MWIR and LWIR
- Curving windows and adjusting spacings will help.





Filter Tilt Concepts Should Be Investigated (RECENT UPDATE)

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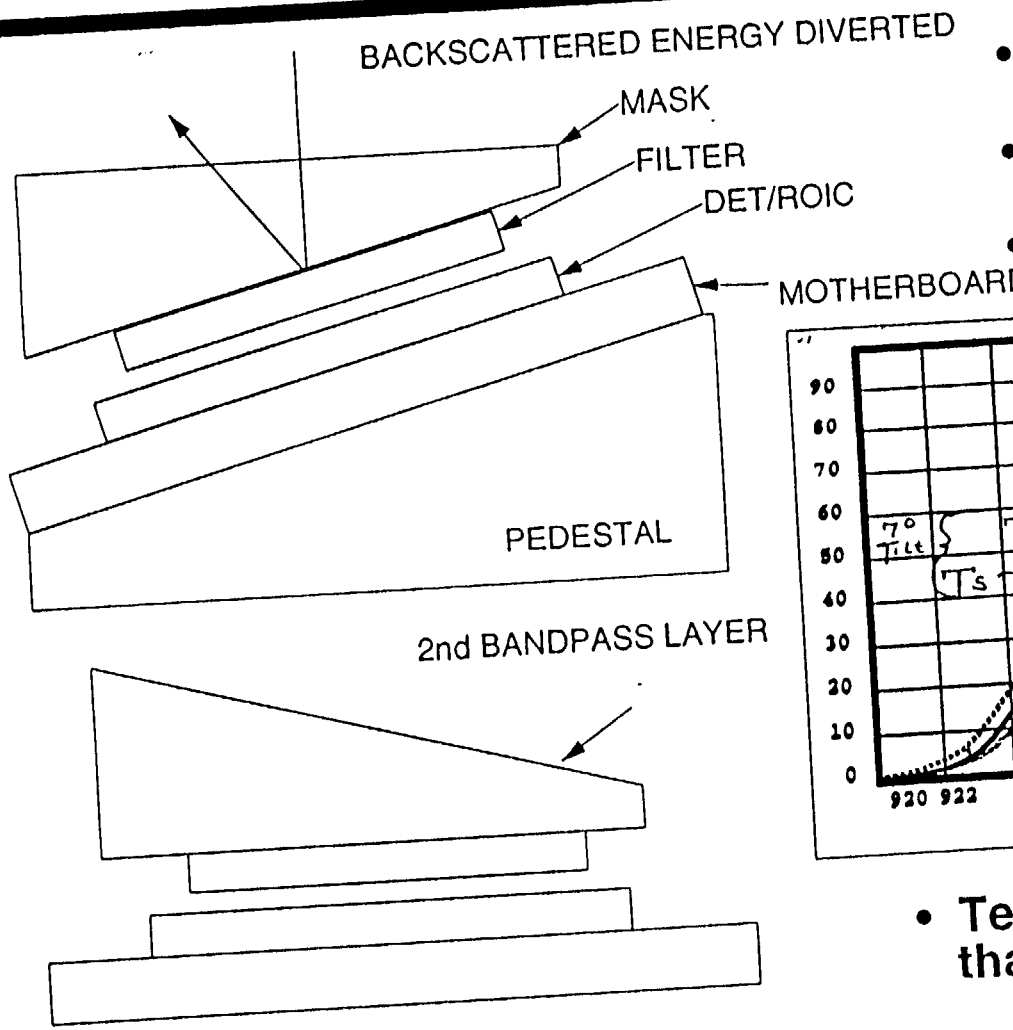
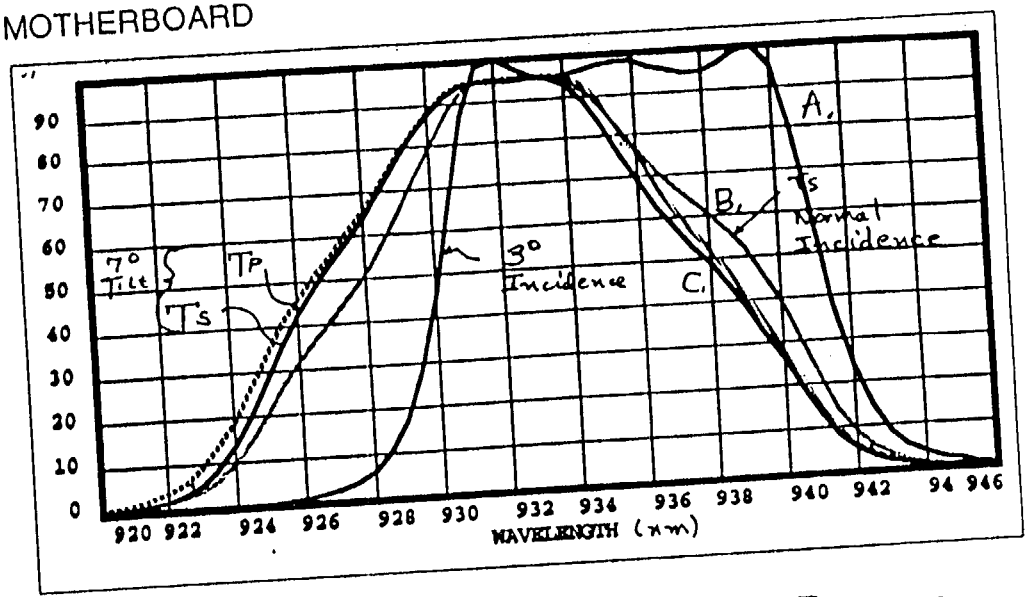


- ERROR IN EARLIER MODEL
- EXISTING FILTERS OK
- POTENTIALLY HIGH PAYOFF



- Test Run for Band 18 at 7° Proves that existing filters will work.

Reticle Concepts will Test X-Talk and Transient Response

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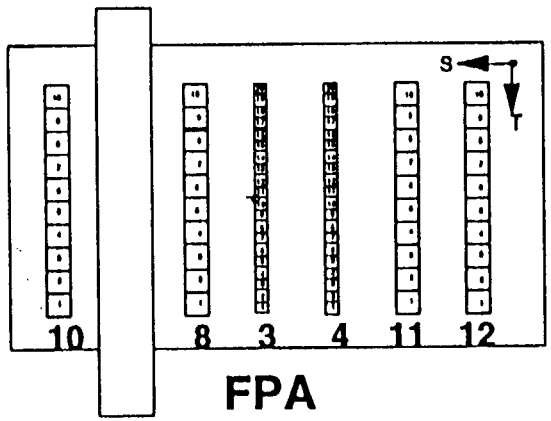
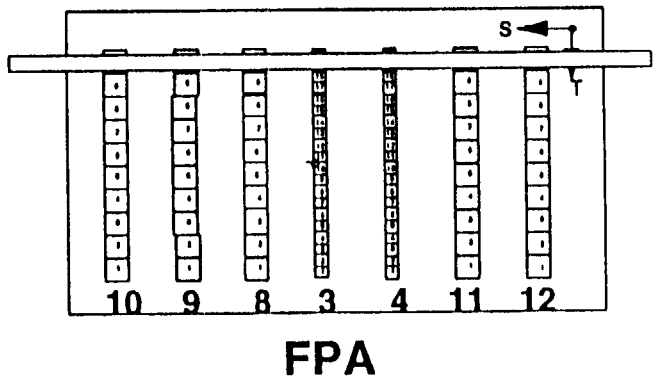
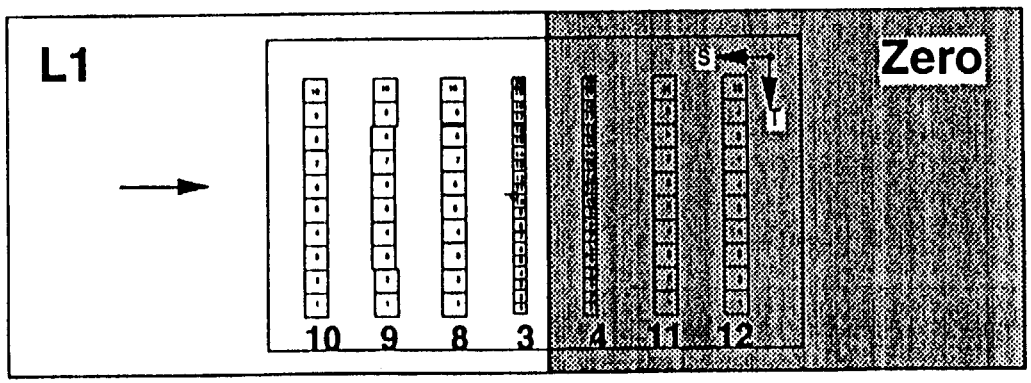
- Scan and Track Reticles for Crosstalk Illuminate One Band or Row





- Transient Response Reticle is Simple Aperture



- Assumes Error Scales with Radiance

$$\Delta L_{error} = \Delta L_{meas} \cdot L_{cld} / L1$$

- L1 Set to Prevent Saturation

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Ghosting Analysis Schedule

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CALENDAR MONTH / TASK AREA	JUNE	JULY	AUGUST	SEPTEMBER
1) Optics Surface Radii	Optics	Mechanics		Drawings
2) Radiative Cooler Windows	Optics	Mechanics		Drawings
3) Coating Optimization	Optics	Systems		
4) Filter Tilt Concepts				
5) Filters at Intermediate Stop and Absorbing Glasses				
6) Algorithm Support				
7) Test Methods				
8) Award Fee Milestone			AFM 8/17	

Clarifications/Questions from 6/22 Meeting with NASA

- **Ratio of Lcld to Ltyp to be defined for consistent solar zenith angle:**
  (Current Spec has Lcld for 22.5° solar zenith, Ltyp at 70° solar zenith)
- **Why Lmax in Transient Response Spec for IR instead of Lcld?**
  (Many IR Bands Not Impacted by Cloud Cover)
- **Coatings Can Be Optimized for Certain Bands/Spectral Regions**
  - Assume High SNR Bands Most Critical
- **What Cloud Cover Fraction Should We Assume for Transient Response Calculations?**
  - 66% for Global Average, with 50% within the FPA Field of View
- **Corrective Measures to be Implemented in Engineering Model As Retrofit Only to Maintain Schedule. Full Implementation in Protflight**

Summary and Conclusions

- Ghosting Levels in Excess of Budgeted Allowance
- Limits Ability of Instrument to Meet Stray Light, Accuracy and Transient Response Specs
- Several Realistic Options Exists for Correcting Ghosting Error
- High Confidence Exists in Ability to Reduce Ghosting to Acceptable Levels
- Questions for Analysis Details Being Addressed by NASA/Science Team
- Plan in Place to Design, and Implement Solutions
- Solutions To Be Implemented in Engineering Model As Retrofit Only Full Implementation in Protoflight