ATTACHMENT D

MODIS

Out-of-Field Response Update

Presented to the NASA GSFC
Greenbelt, Maryland

5 May, 1994

T. Pagano

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GSFC SBRC

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Agenda

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- Out-of-Field Response Definitions/Error Contributors
- Transient Response Requirement/Budget Flowdown
    - Ghosting Review
    - Crosstalk Update
    - Scan Mirror Scatter
- Measurement Methodology
- Conclusions/Recommendations

Out-of-Field Response Definitions/Error Contributors

Out-of-Field Response Affects Sensor Performance

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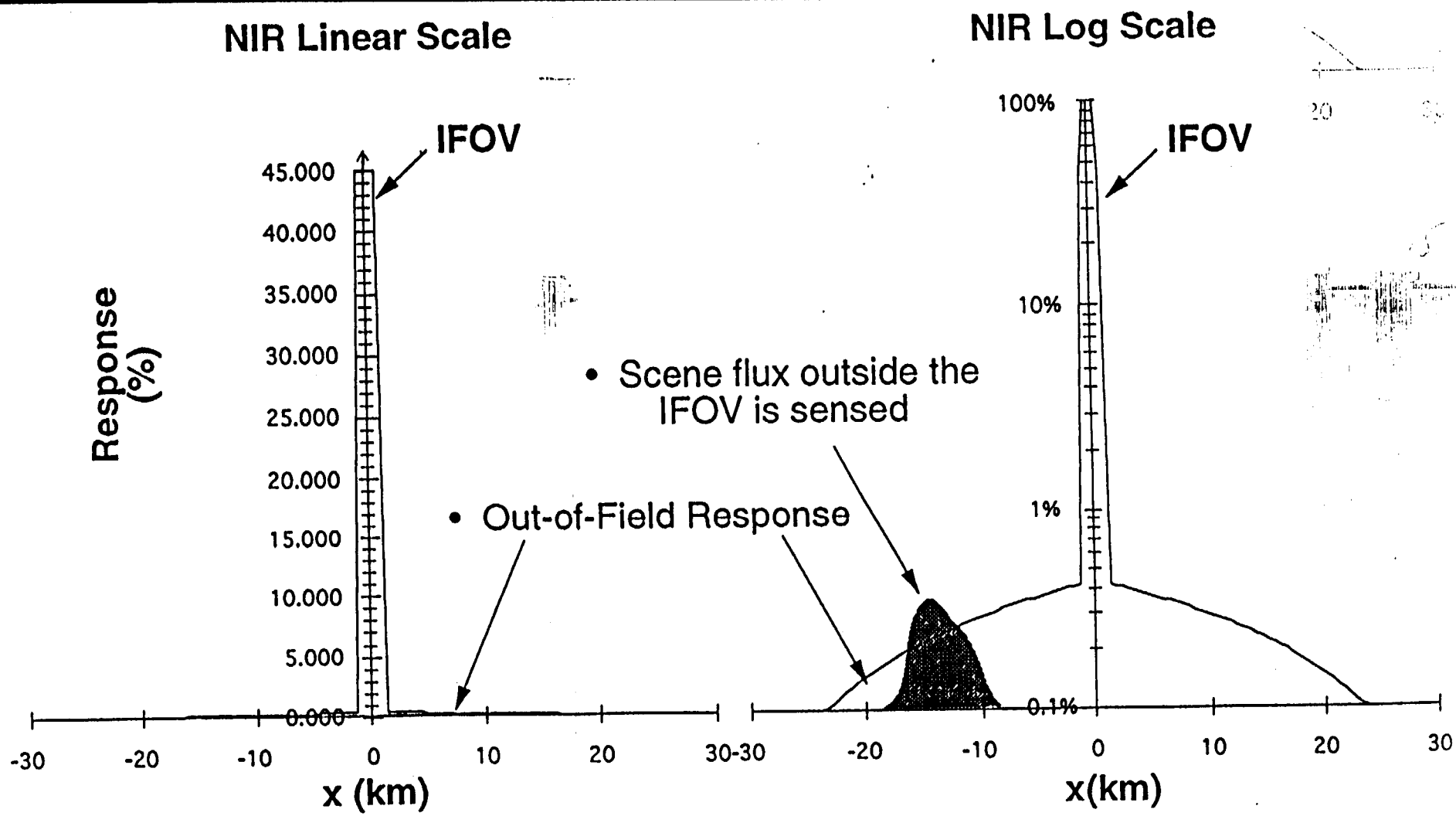

DIFFERENT COMPONENTS OF THE STRAY SIGNAL PROBLEM CONTRIBUTE TO DIFFERENT PORTIONS OF THE "TAILS"

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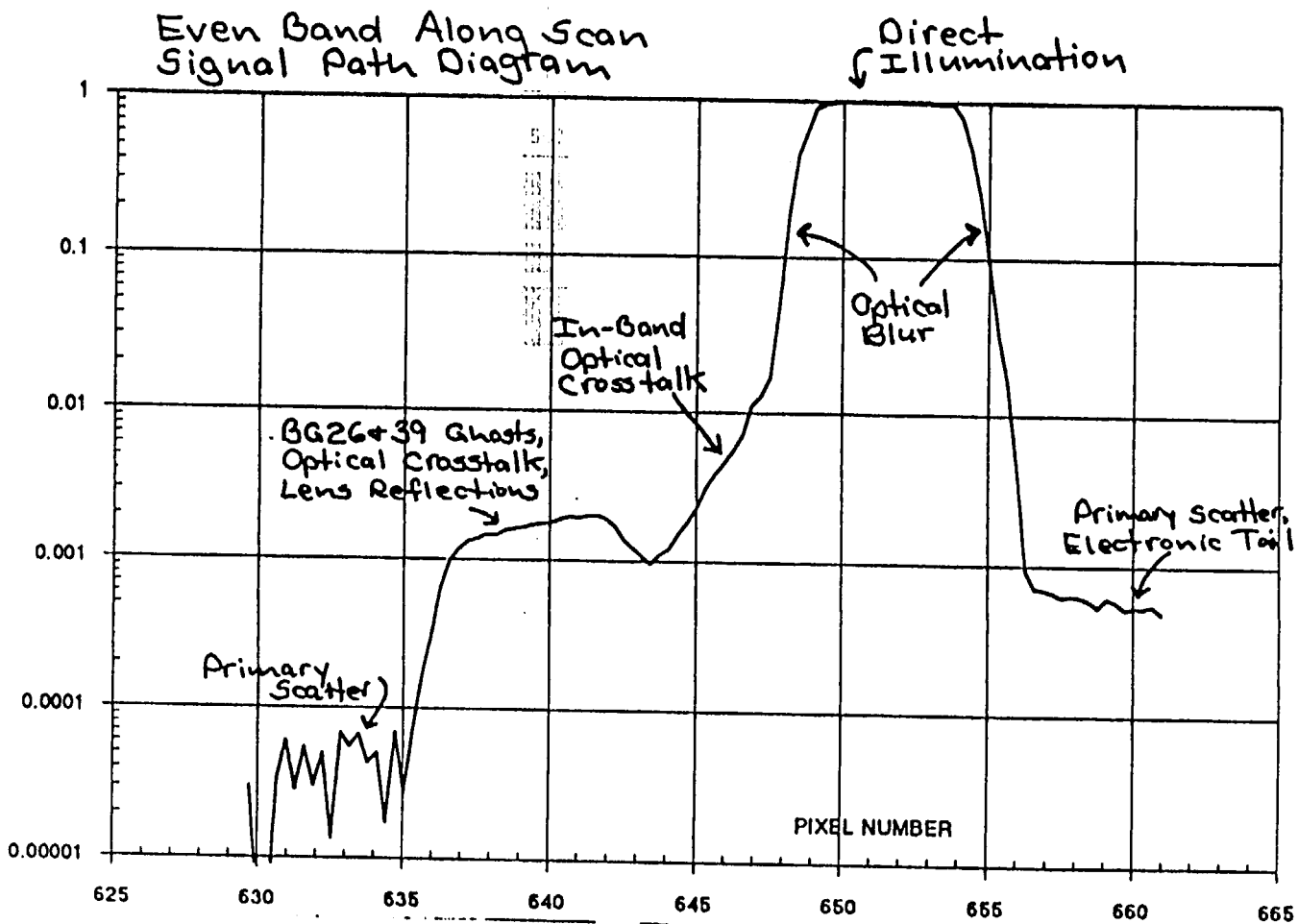
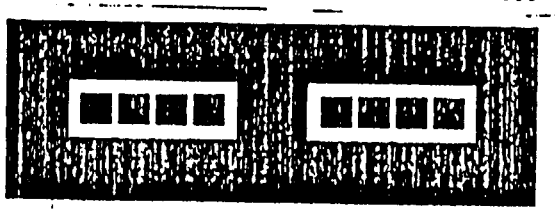
SeaWiFS





← FPA Size and Position if Pixel Number refer to leading edge of 6 pixel wide slit

OOF Contributors Affect Four Performance Areas

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Out-of-Field Contributor	Performance Area	
• Ghosting	• Stray Light	OK
• Crosstalk (Optical, Detector, Electrical)	• Transient Response	TBD
	• Radiometric Accuracy	OK
• Scan Mirror Scatter	• Radiometric Accuracy with Clouds	TBD

RELATED

FROM JUNE 22, 1993 REVIEW AT GSFC

Transient Response Requirement/ Budget Flowdown

Transient Response Spec Often Lower Than Noise Spec

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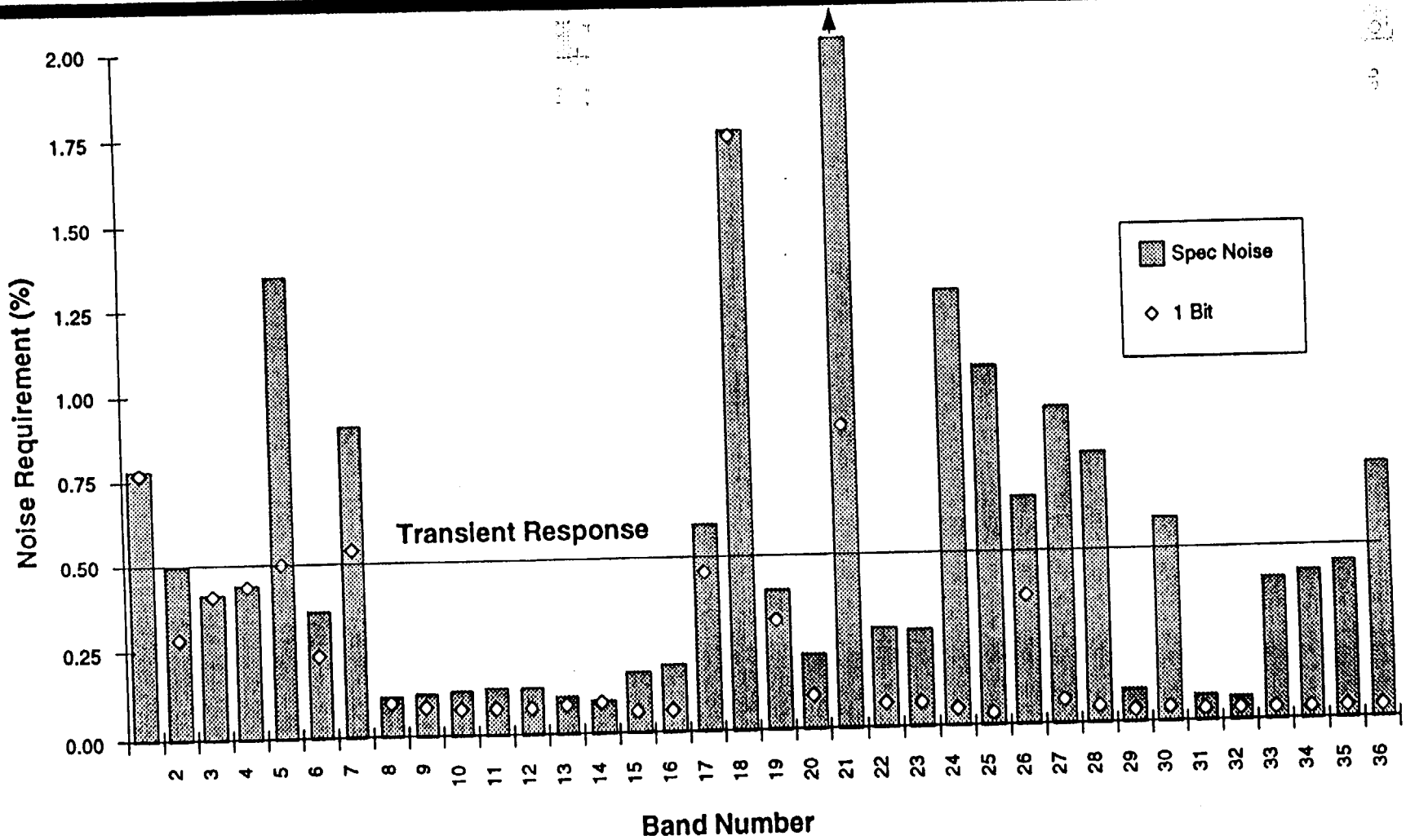

FOUR ORDERS OF MAGNITUDE EXTINCTION RATIO REQUIRED FOR TRANS. RESP.

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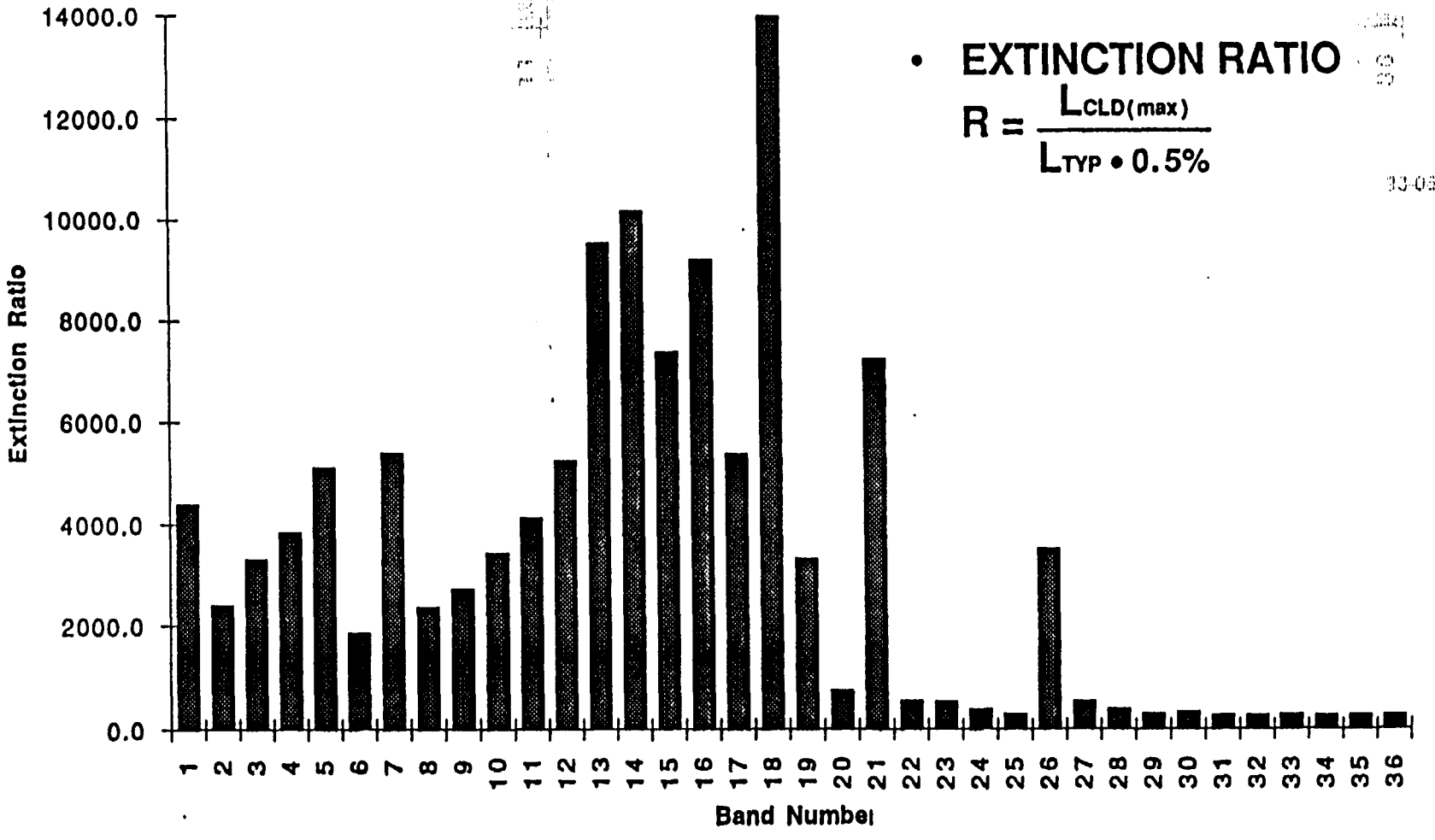

- EXTINCTION RATIO

$$R = \frac{L_{CLD(max)}}{L_{TYP} \bullet 0.5\%}$$

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WORST CASE ILLUMINATION CONDITIONS ASSUMED

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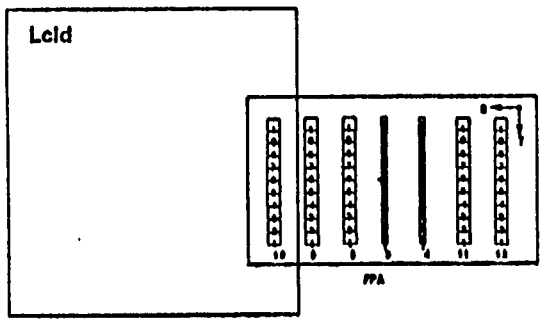
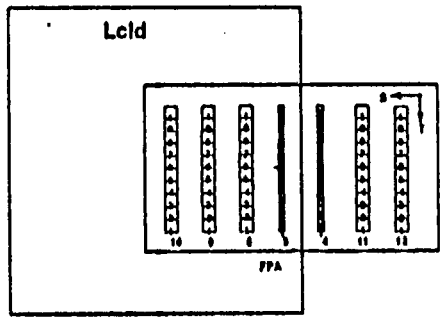
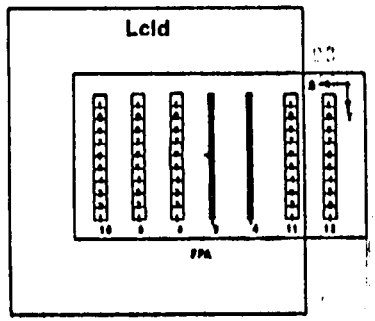
Low Ghosting



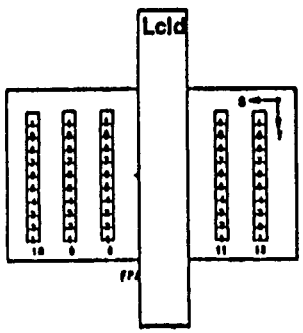
Medium Ghosting

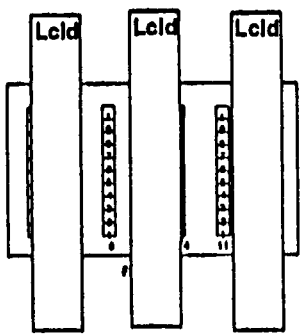


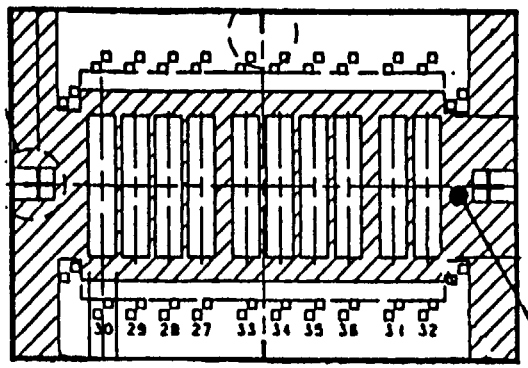
High Ghosting



- Fractional Cloud Cover Is Possible







- Additional Benefit From Mask Absorption

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

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Transient Response Reqmts Flowdown Complete

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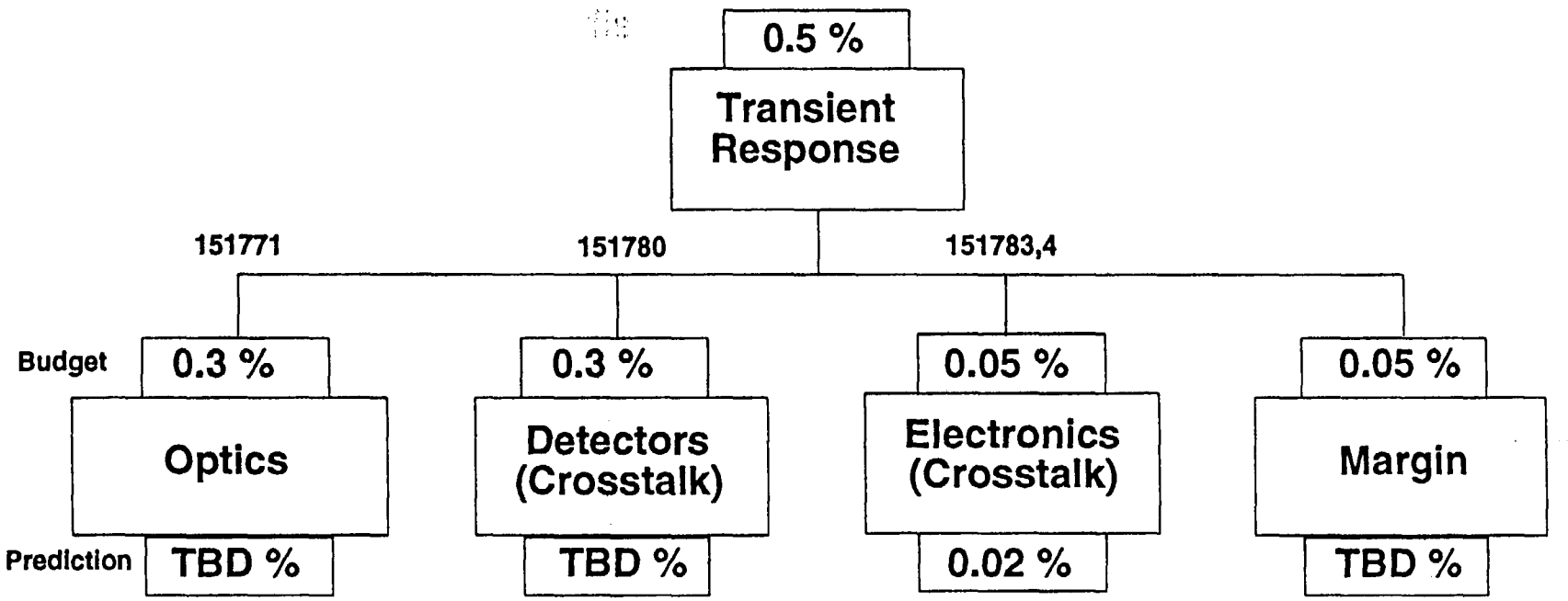

- Ghosting
- Mirror Scatter
- Lens Scatter
- Filter Scatter
- Filter Reflections

- Readout
- Cables
- Substrate Reflections

- Readout
- Cables
- EMI

Ghosting Review

GEOMETRICAL RAY-TRACING USED TO DETERMINE SIZE OF GHOST IMAGE

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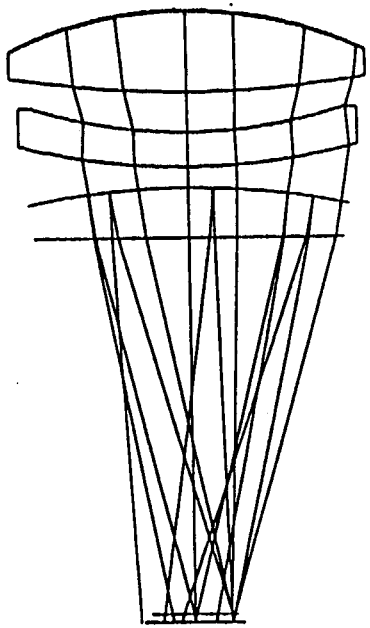
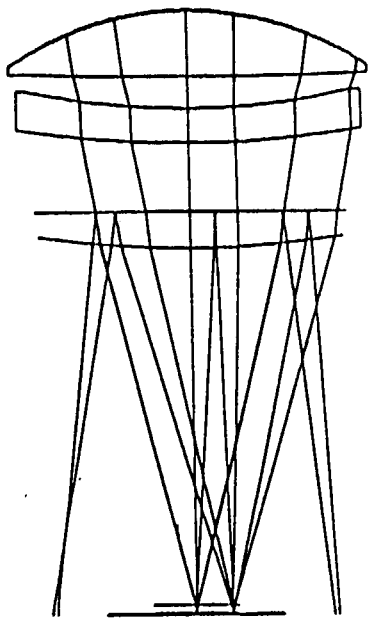
NIR ENG MODEL OBJECTIVE



MODIFIED NIR OBJECTIVE



- OPTICAL ANALYSIS CONDUCTED WITH CODE V DESIGN/ ANALYSIS SOFTWARE
- INCREASING THE DIAMETER OF THE GHOST IMAGE REDUCES IT'S FLUX DENSITY

	NIR ENG MOD OBJ	MODIFIED OBJECTIVE
SECONDARY GHOST DIA.	8 mm	47 mm

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NIR COATINGS OPTIMIZED FOR HIGH SNR BANDS; 13, 14

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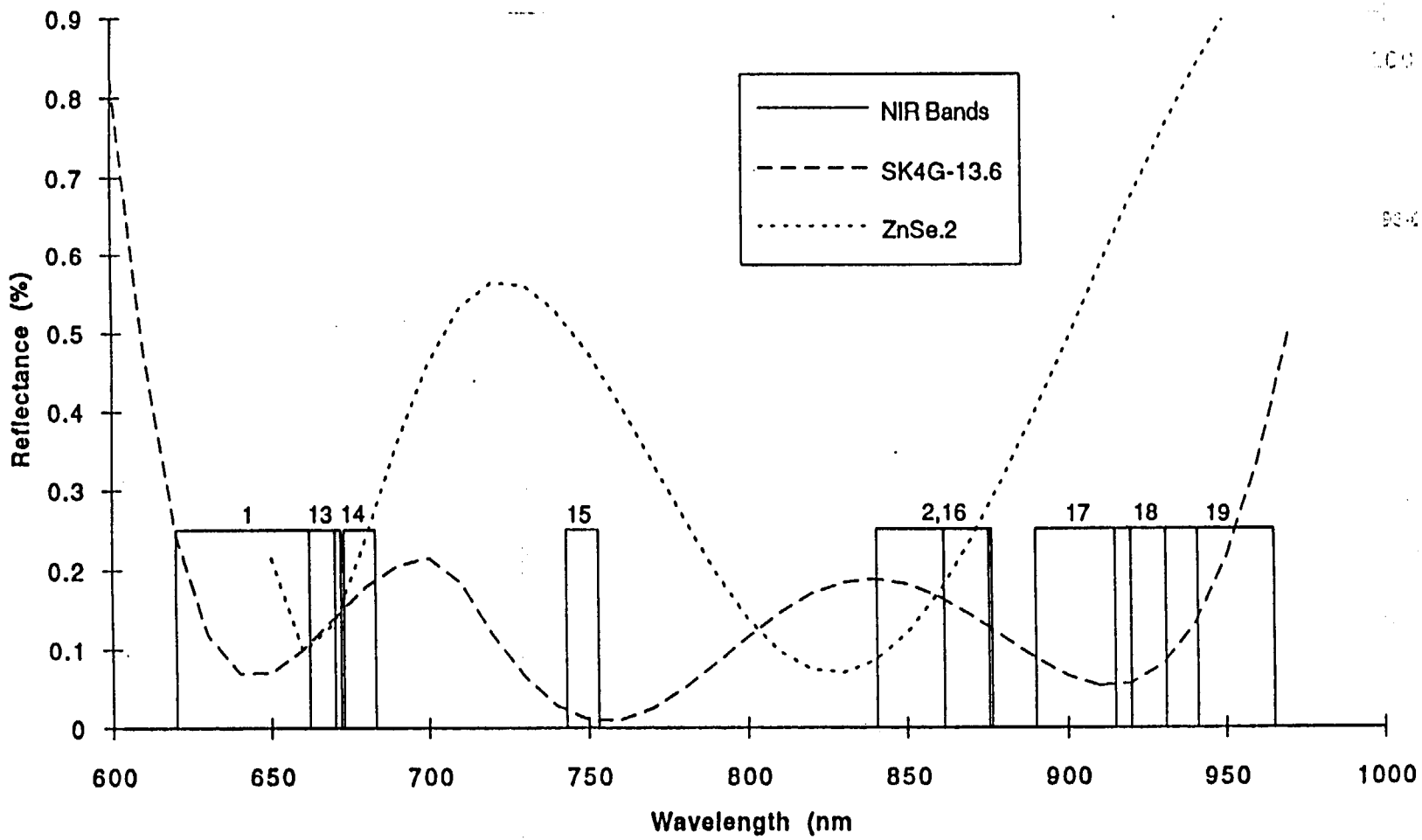

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HIGH PAYOFF TO TRANSIENT RESPONSE WITH GHOSTING SOLUTIONS

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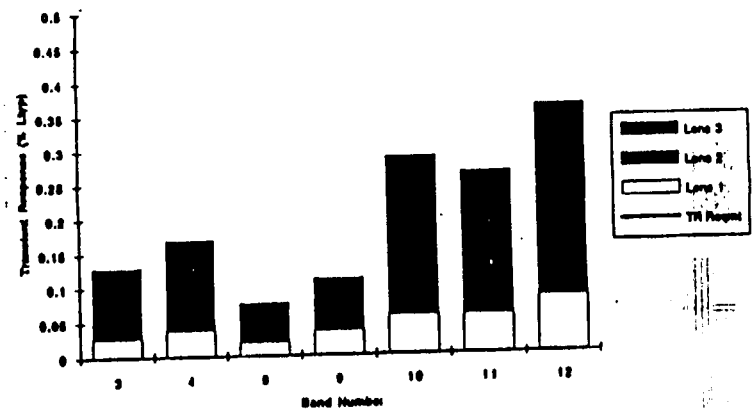
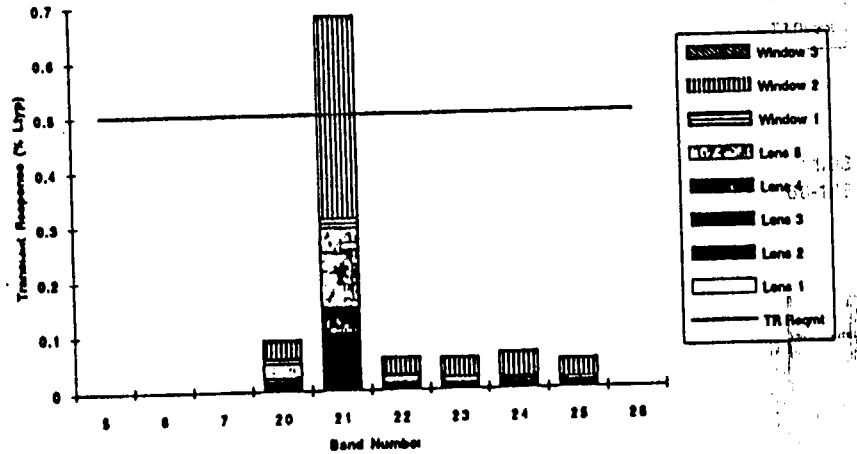
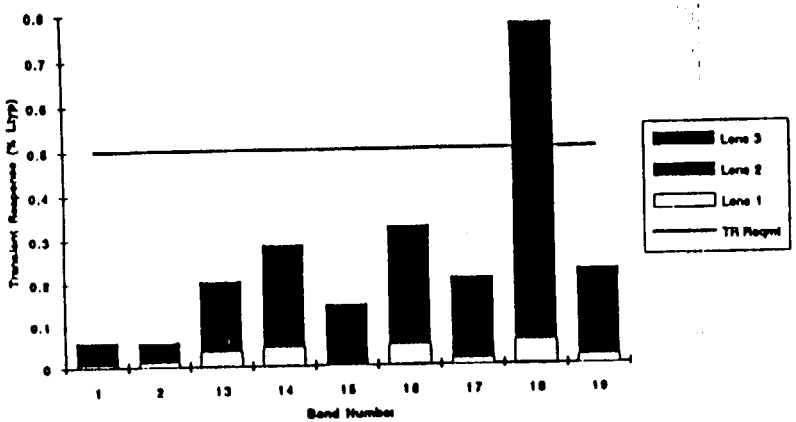


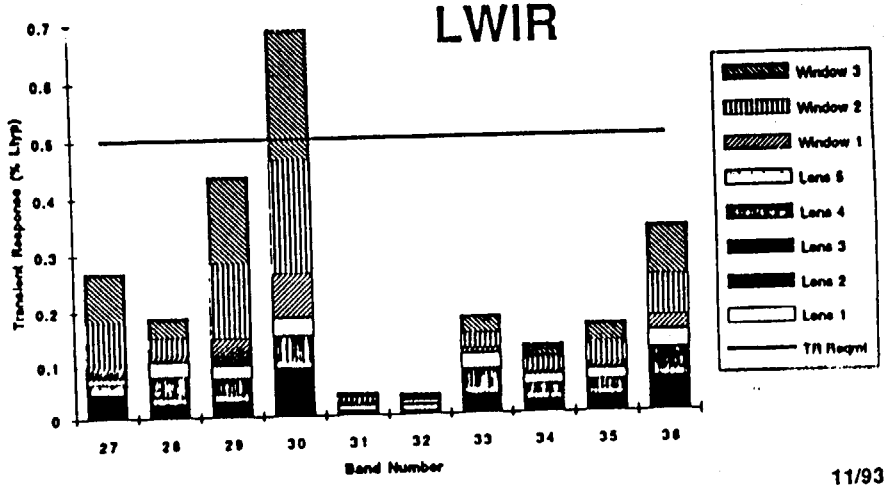
SW/MWIR



NIR



LWIR



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- Approval from NASA Science Team for Non-compliance on Bands 18, 21, and 30
- Effects of Crosstalk Still Under Investigation and Test

Crosstalk Update

Crosstalk Update

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- LWIR PC Measured First
  - Successive Pixels Masked Off
- LWIR PV Measured Second
  - 3 IFOV Wide Slit Scanned Across FPA
- NIR Measured Last. Data made available 4/28/94
  - Same as LWIR PV, Except With, and Without Filter Mask (No difference seen with or without mask in most cases)
- Measurement Error Sources Significant (Instrumentation Noise, Light Leakage, Set-up Reflections)
- Data Currently Being Analyzed

Optical/Detector X-Talk Also Contributes to OOF Response

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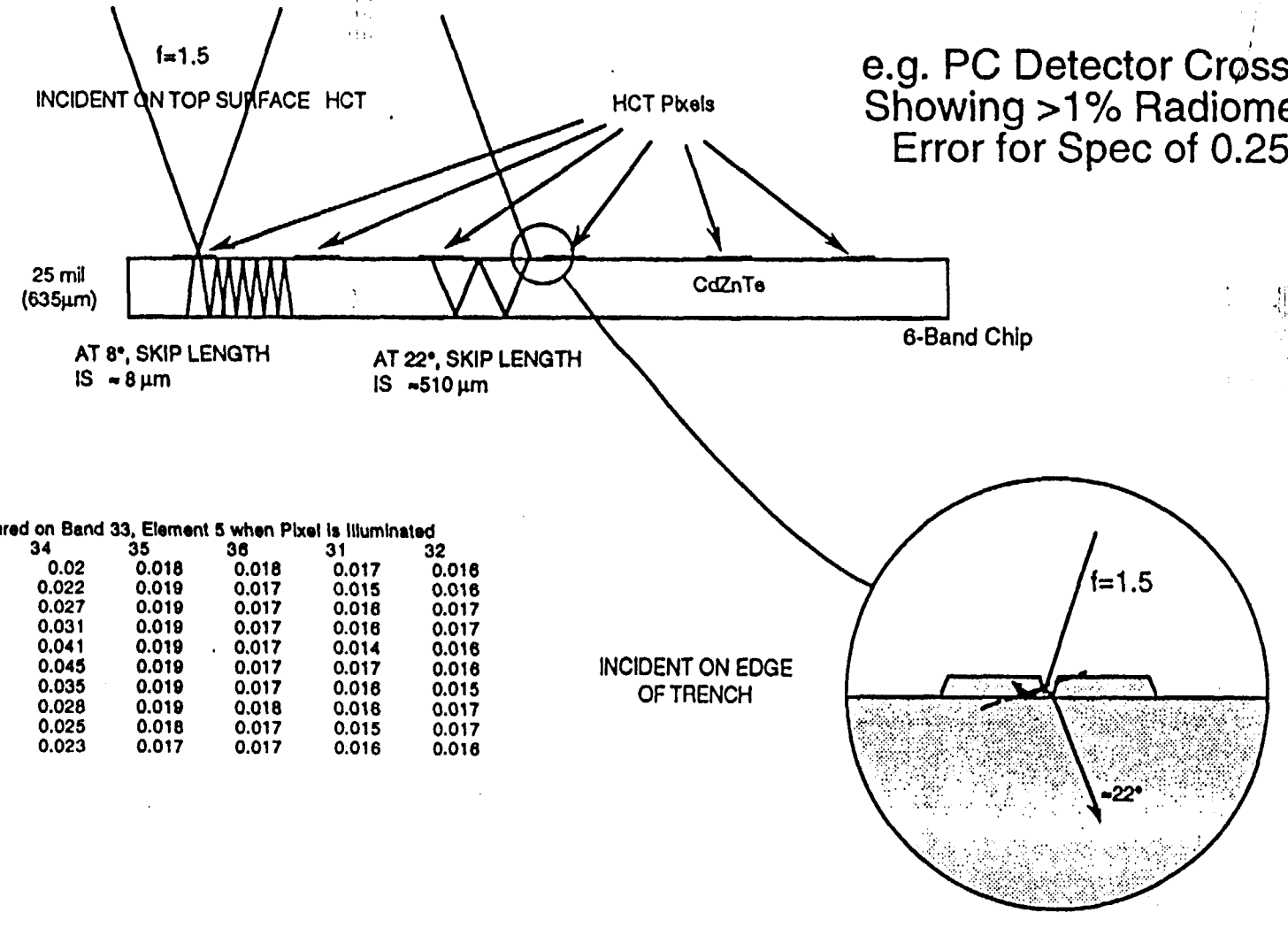
e.g. PC Detector Crosstalk Showing >1% Radiometric Error for Spec of 0.25%



Signal Measured on Band 33, Element 5 when Pixel is Illuminated

pixel	33	34	35	36	31	32
1	0.13	0.02	0.018	0.018	0.017	0.016
2	0.32	0.022	0.019	0.017	0.015	0.016
3	0.489	0.027	0.019	0.017	0.016	0.017
4	0.294	0.031	0.019	0.017	0.016	0.017
5	2.08	0.041	0.019	0.017	0.014	0.016
6	93.15	0.045	0.019	0.017	0.017	0.016
7	7.3	0.035	0.019	0.017	0.016	0.015
8	0.482	0.028	0.019	0.018	0.016	0.017
9	0.617	0.025	0.018	0.017	0.015	0.017
10	0.307	0.023	0.017	0.017	0.016	0.016

Scan Mirror Scatter

Scan Mirror Scatter Update

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- Scan Mirror Meets All Specifications. Very Good Mirror!
- Measurements Made at TMA on Scatter
- TIS Better Than 0.043%. Spec is 0.15%.
- Mirror Performance is "State-of-the-Art" for Mirror of this Size
- Recent Concern is "Near-Field Scatter" in Relation to Transient Response Spec as Currently Written.
- Awaiting Digital Data from TMA to Perform System Level Analysis.

Scan Mirror Scatter Affects Stray Light Performance

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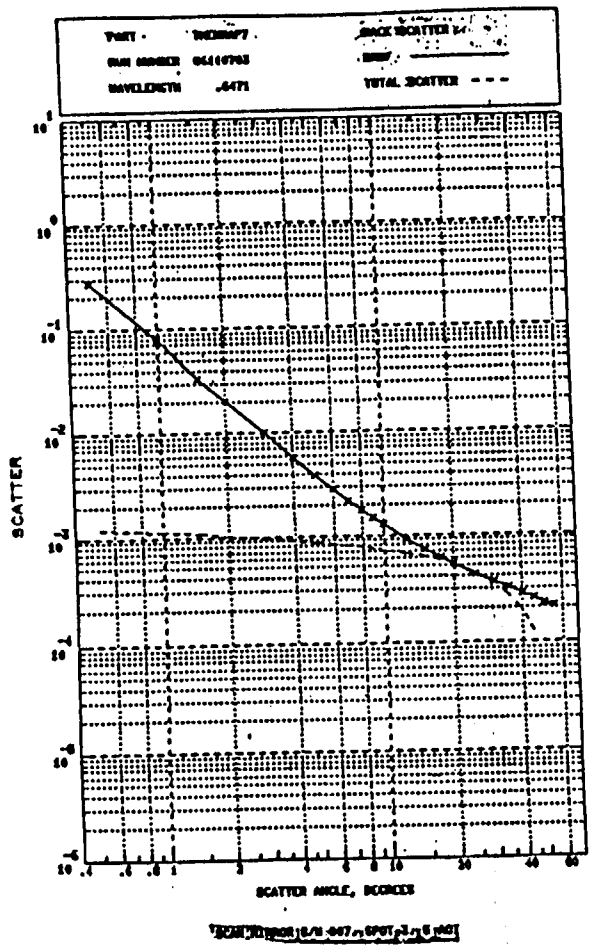
Typical TM Mirror BRDF



- Response Essentially Flat over FPA FOV
- Extends many 10's of km
- Symmetric for All Detectors
- $\Delta L = L_{inc} \cdot TIS \cdot \Omega/\pi$
- TIS = 0.2% at 0.65 μm
- Ω = 2 sr (Worst Case Used)
- Scales Inversly with λ

Region	Error (%)
VIS	0.17
NIR	0.10
SWIR/MWIR	0.03
LWIR	0.01

FROM JUNE 22, 1993 GHOSTING WORKSHOP

MODIS EM SCAN MIRROR

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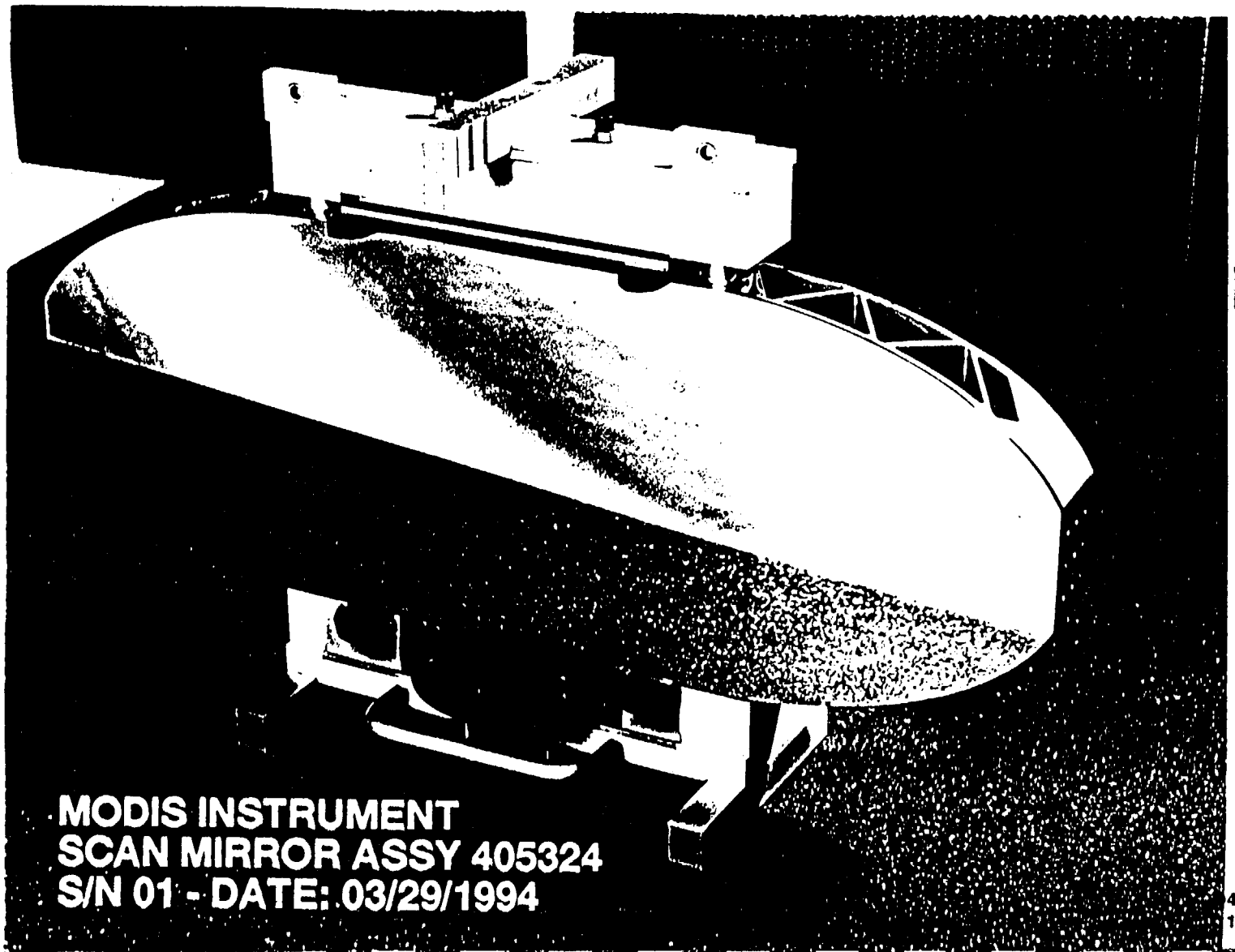

MODIS EM SCAN MIRROR MEETS ALL CRITICAL OPTICAL PERFORMANCE REQUIREMENTS

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	SPEC	MEASURED
• SURFACE FLATNESS		
SIDE A	0.5λ (633 nm)	0.49λ
SIDE B	0.5λ	0.34λ
• SCATTER		
SIDE A	$\leq 1.55 \times 10^{-3}$	0.43×10^{-3}
SIDE B	$\leq 1.55 \times 10^{-3}$	0.32×10^{-3}
• REFLECTANCE	IN SPEC, ALL BANDS	
• POLARIZATION	IN SPEC, ALL BANDS	
• ENVIRONMENTAL DURABILITY PER MIL-M-13508	PASSED	

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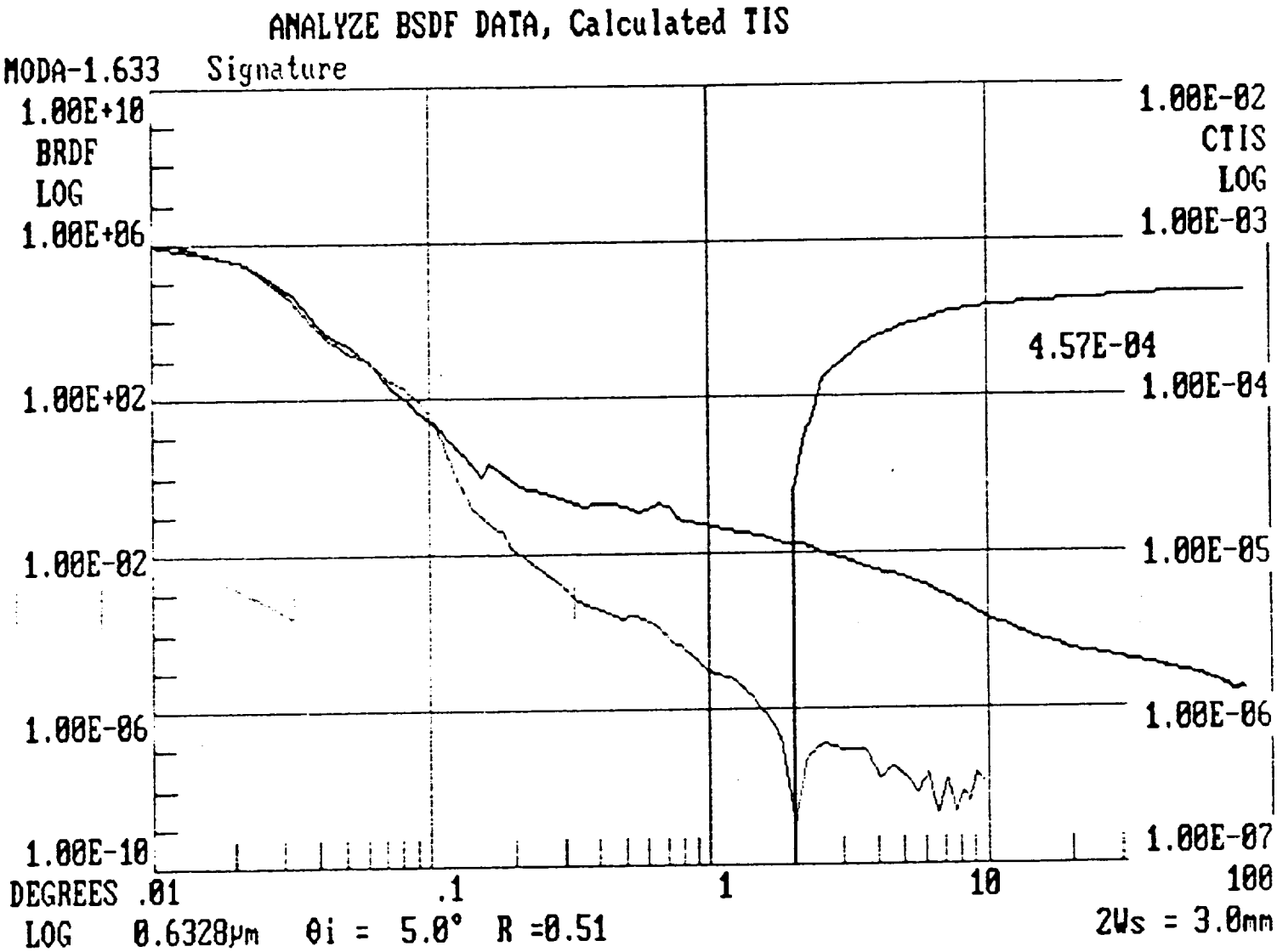
94-0317-TK12


ANALYZE BSDF DATA, Calculated TIS
MODA-1.633 Signature
1.00E+10
BRDF
LOG
1.00E+06
1.00E+02
1.00E-02
1.00E-06
1.00E-10
1.00E-02
CTIS
LOG
1.00E-03
4.57E-04
1.00E-04
1.00E-05
1.00E-06
1.00E-07
DEGREES .01
.1
1
10
100
LOG 0.6328μm θi = 5.0° R =0.51
2Ws = 3.0mm

PL 3095-N03645
J. Young

DISCUSSION

The Harvey Shack BRDF model is used in this current analysis

$$BRDF = bb0 + aa0 * (\frac{\sin(angle)}{0.01})^{M} \quad (1)$$

The exponent M is in the -1 to -3 region for most optical mirror surfaces. The modeling has been based upon mirrors that have a TIS = 0.001 wherein the integration limits are from 0.034 to 1.57 radian. An example of the equations used in Mathcad is given below.

Table I Mathcad input and calculated TIS and Effective Reflectance

$bb0 := 0 \qquad aa0 := .5 \qquad M := -2.0$

$$TIS = \int_{0.034}^{1.57} \left[bb0 + aa0 \cdot \left(\frac{\sin(ang)}{0.01} \right)^{M} \right] \cdot 2 \cdot \pi \cdot \sin(ang) \cdot \cos(ang)\, dang = 0.001069 \quad (2)$$

$$TIS = \int_{.003}^{1.57} \left[bb0 + aa0 \cdot \left(\frac{\sin(ang)}{0.01} \right)^{M} \right] \cdot 2 \cdot \pi \cdot \sin(ang) \cdot \cos(ang)\, dang = 0.001917 \quad (3)$$

$$Reflectance = \int_{0.003}^{.1} \int_{-.1}^{0.1} \left[bb0 + aa0 \cdot \left(\frac{\sin\left(\sqrt{angX^2 + angY^2}\right)}{0.01} \right)^{M} \right] dangY\, dangX = 4.637285 \cdot 10^{-4} \quad (4)$$

Two models were used. One was the Mathcad model which the above data is a representative sample. The other model was an EXCEL spreadsheet model. Examples of this will be given below.

The Mathcad model has as inputs: bb0, aa0, M. From this the TIS (first expression) is calculated for limits of integration of 0.034 to 1.57 radian. The second TIS has limits of 0.003 to 1.57 radian. It should be noted that the equation used assumes rotational symmetry, where angle of incidence (AOI) ≈ 0. This is the way the mirror is being measured but it should be remembered that the AOI varies from 10 to 65 degrees in actual operation.

The third expression is the effective reflectance associated with a near by cloud that has an angular extent of 0.2 radian in the along track direction and 0.097 radian in the scan direction. Furthermore the edge of the cloud is 0.003 radian from the IFOV being considered.

An example of the EXCEL spreadsheet is given below, Table II. It is for the same input as the Mathcad equations above. As can be seen the integrated results are very close:

TIS is 0.001069 versus 0.001062.

Reflectance is 0.0004637 versus 0.00462

Measurement Methodology

SSMA Spectral/Scatter Measurement Assy

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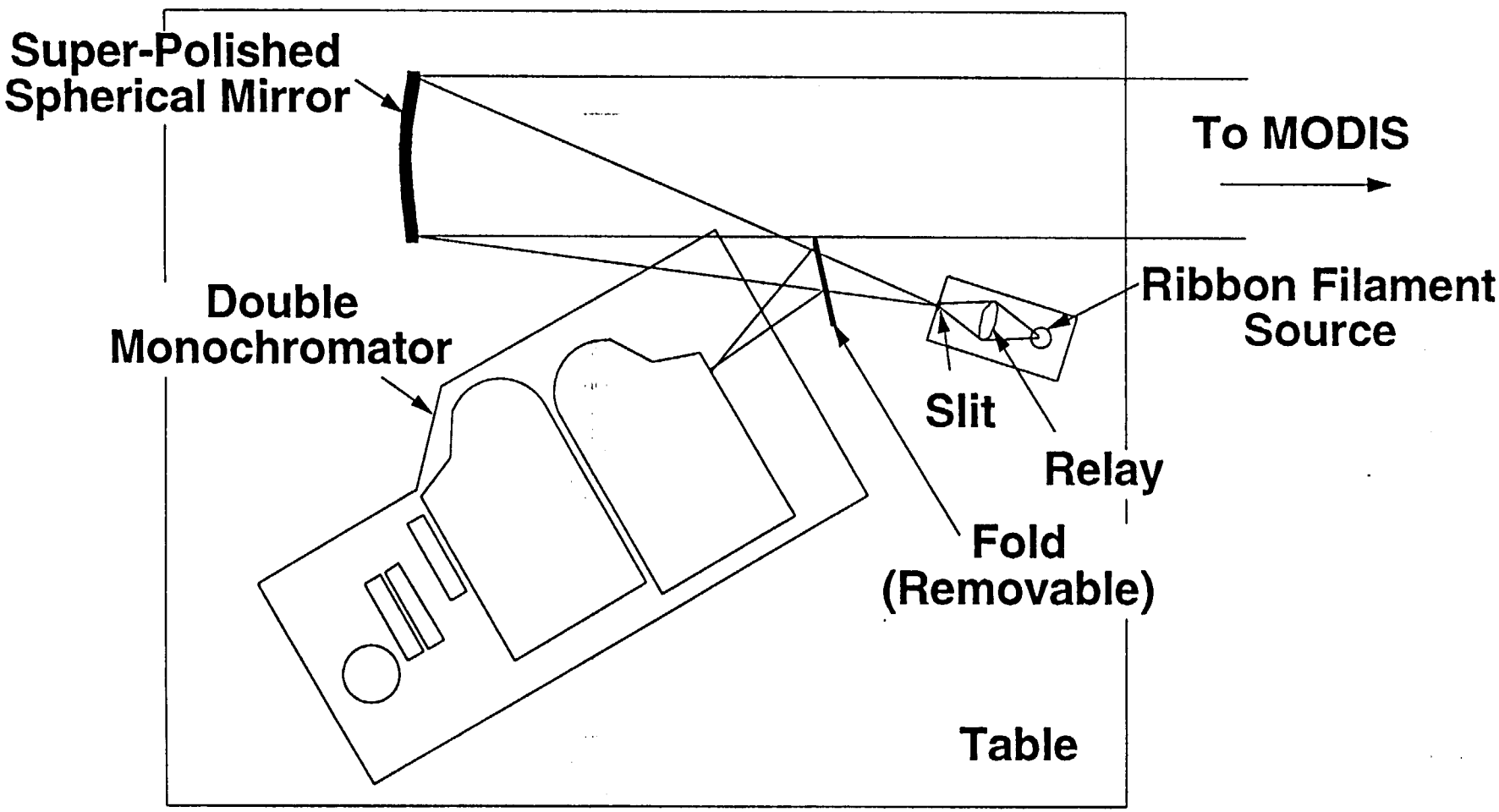

SSMA Probes Pixel Response

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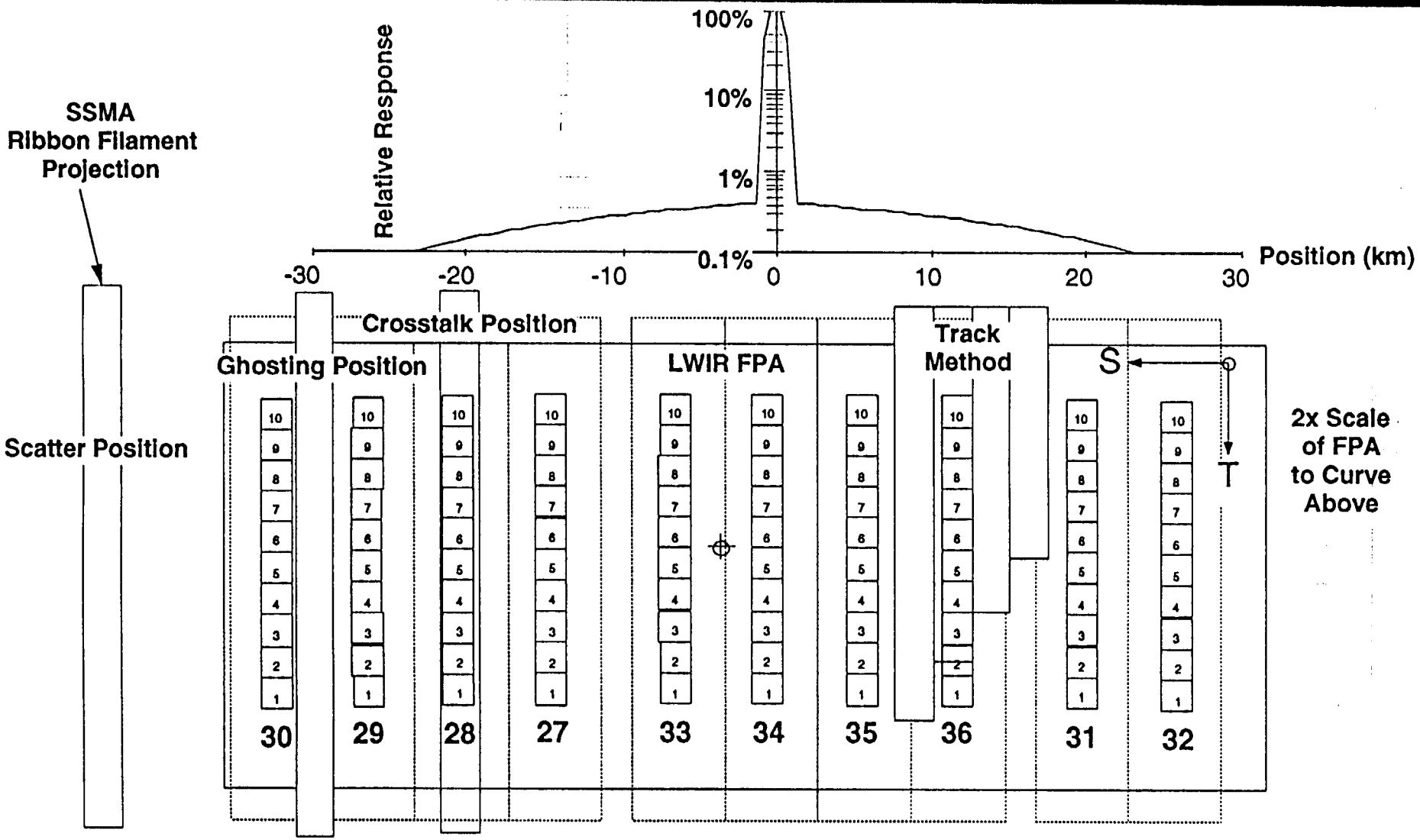

Measurement of Ghost to Spec Levels Possible

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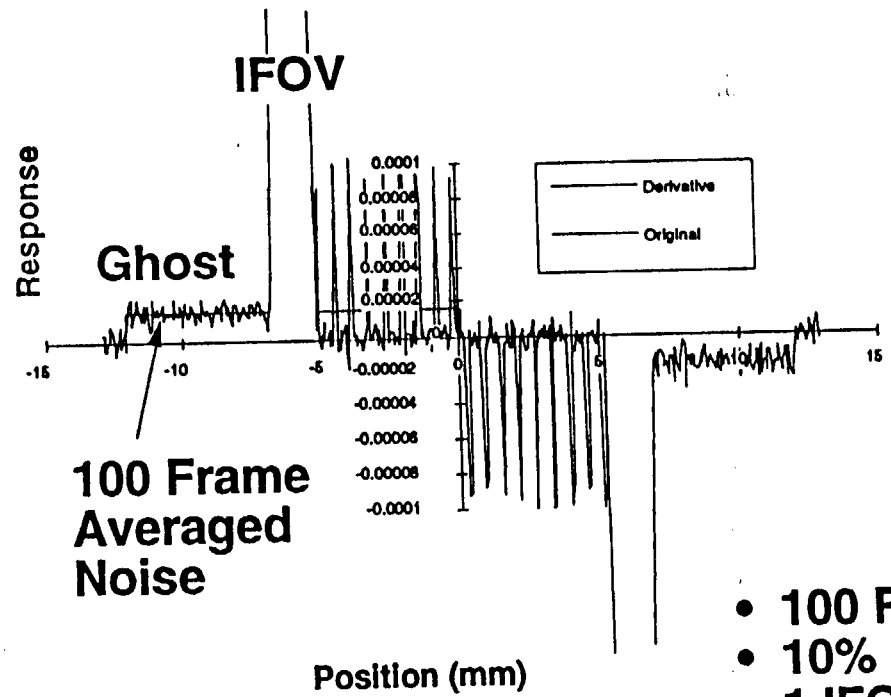
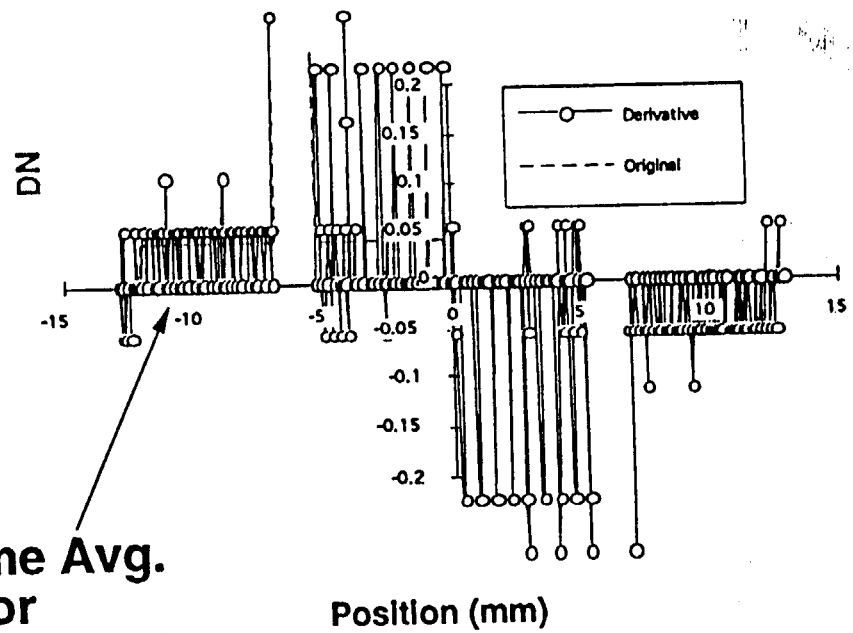
- 11 IFOV Slit Scanned. Profile Through Differentiation. Simulation.

Analog Signal



Digitized Signal



- 100 Frame Avg.
- 10% Error
- 1 IFOV Resolution

Conclusion/Recommendations

Conclusions/Recommendations

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- Optics, FPA, Mirror Technologies and EM Hardware Are "State-of-the-Art"
- Subsystem Measurements of Out-of-Field Response Are "In the Noise"
- Transient Response Requirement As Currently Written May Be Unachievable
- Recommendations:

1) Proceed With Build. Hardware is Very Good.

2) Perform System Level Analysis With Subsystem Data to Better Understand Performance Limitations

But 3) Wait for System Level Tests (1/95) to Determine Compliance

IN-FLIGHT RADIOMETRIC ACCURACY DEPENDS ON PRE-FLIGHT CHARACTERIZATION AND SRCA/SDSM

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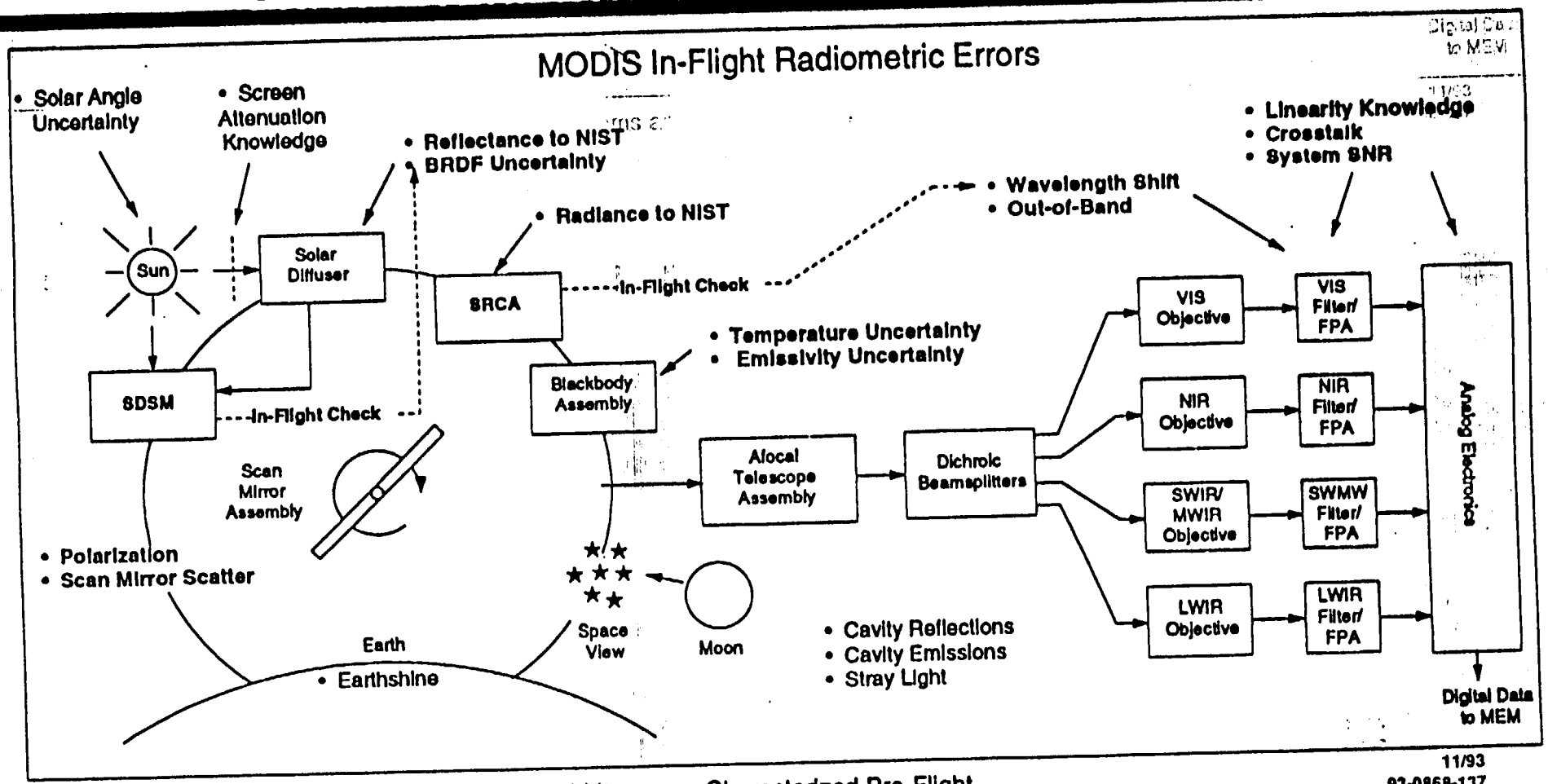

• Bold Items are Characterized Pre-Flight

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