MODIS Optical and Electronic Effects Characterization

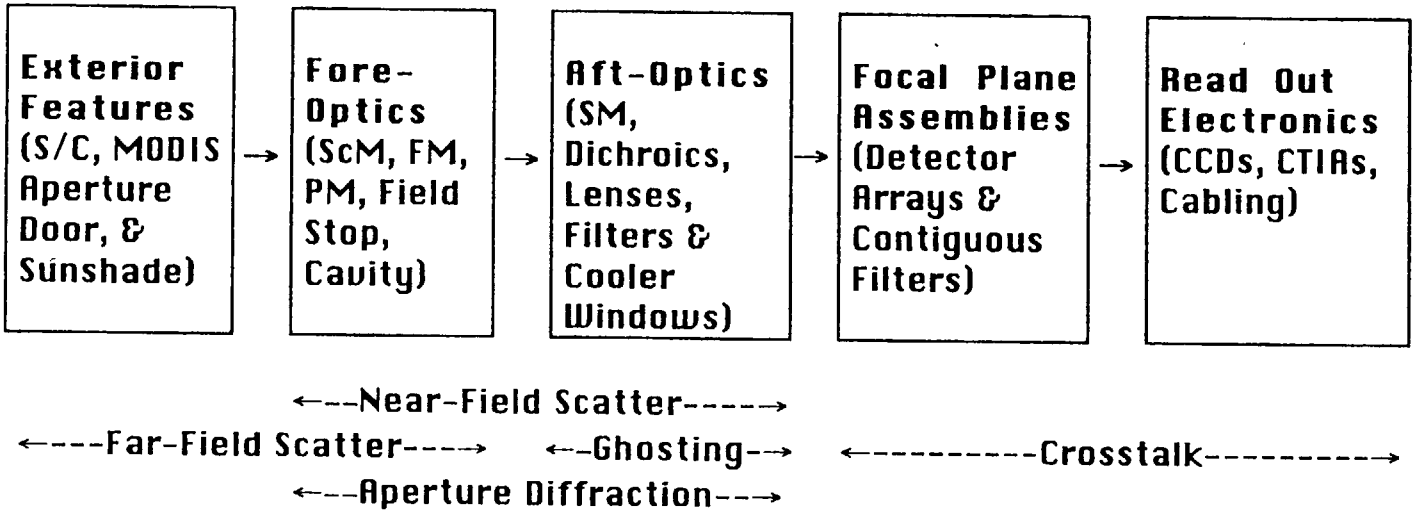
(Scattering/Diffraction, Ghosting, Optical and Electronic Crosstalk)

October 12, 1994

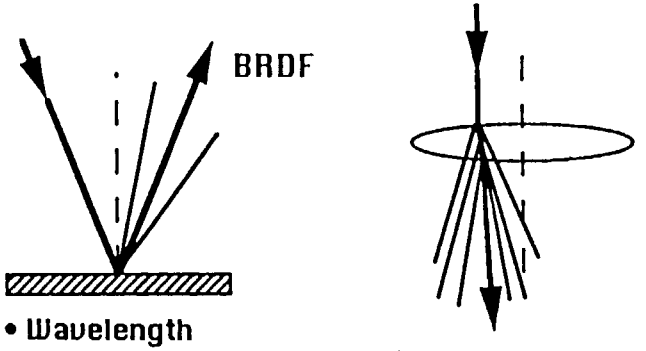
Outline

- Optical and Electronic Artifacts Definitions and Sources
- Key Issues
- Mitigation/Characterization/Accommodation Strategies
- Matrix Overview of Modeling and Test Efforts and Plans
- Qualitative Comparison Of Optical and Electronic Artifacts With Predecessor Instruments
- Highlights of MCST Scattered Light/Stray Light Analysis

MODIS Optical and Electronic Artifacts Sources



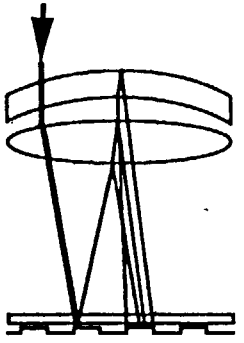
Scatter



- Wavelength
- Surface Microroughness/Defects
- Substrate
- Coating Uniformity
- Contamination Level

Dependencies (Time Varying)

Ghosting



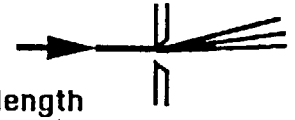
- Optical Configuration
- Surface Reflectivities
- Curvature/Cooler Window Tilt
- Scan/Track Direction

Dependencies

Crosstalk

- Reflectivies
- Filter Config./Orientation
- Mask Mechanical Alignment
- Scan/Track Dependencies

Diffraction



- Wavelength
- Aperture/Field Stop Size & Location
- Configuration Dependencies

Key Issues

- Diffuse Scatter, Diffraction, Ghosting and Optical and Electronic Crosstalk are Combined Effects Potentially Limiting Radiometric Accuracy in Mixed Scenes (i.e., close to clouds).

- Residual (TBD) Combined Effects Dependent on:
  - -Direction (Scan, Track)
  - -Wavelength
  - -Optical Surfaces/Media
  - -Contamination Level (Time Varying)
  - -Presence of Clouds in Scene

- Modeling and Preliminary/First Assembly Test Results To Date are Insufficient to Accurately Predict the Magnitude of These Effects.
  - - Micro-scale Effects are Important
  - - Developing/Refining Critical Test and Data Reduction Procedures
  - - Very Low Scattering Test Apparatus Required
  - - High Dynamic Range/Increased Source Brightness Required
  - - Detailed Alignment Adjustments in Process

- SBRC Engineering Model (EM) System Level Testing With the Newly Defined Scatter Measurement Assembly (ScMA) and GSFC Characterization/Modeling Efforts Will Produce Definitive Results for the April 1995 Science Team Meeting.

- Primary Design and Test Attention Concentrated on the Scan Direction Effects

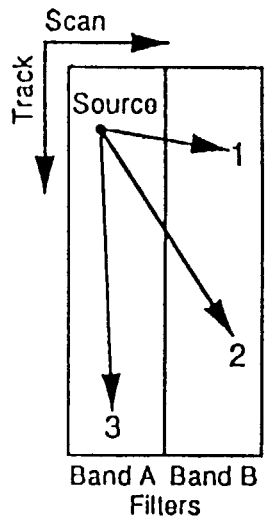
Ghosting and Crosstalk Differ in Scan and Track Directions

Ghosting Fixes	VIS	NIR	SWMIR	LWIR
Scan Direction				
Special AR Coatings	✓	✓	✓	✓
Opt. Lens Curvature	Lens#3	Lens#3	NA	NA
Inter. Filter Ass'y	NA	NA	6 zone	NA
Inter. Dichroic/Trap	NA	NA	NA	3 zone
Tilt Rad. Cooler Center Window	NA	NA	TBD	✓
Track Direction				
Special AR Coatings	✓	✓	✓	✓
Opt. Lens Curvature	Lens#3	Lens#3	NA	NA
Inter. Filter Ass'y	NA	NA	2nd order	NA
Inter. Dichroic/Trap	NA	NA	NA	2nd order
Tilt Rad. Cooler Center Window	NA	NA	TBD	✓

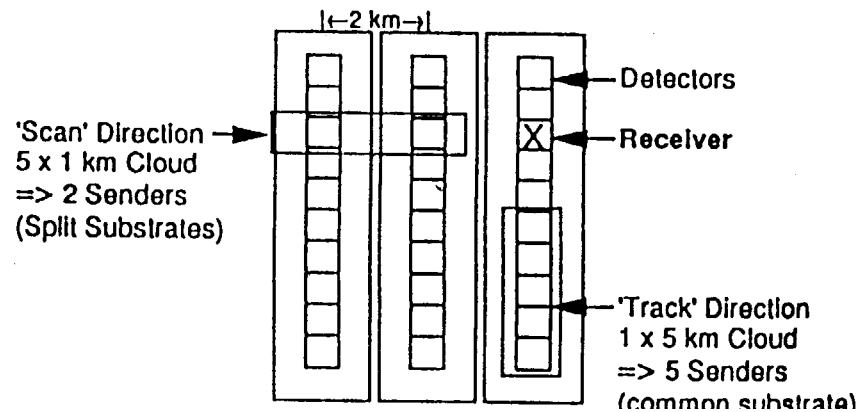
Crosstalk Fixes				
Scan Direction				
AR Filter Coatings	✓	✓	✓	✓
FPA Filter Masks	✓	✓	✓	✓
Track Direction				
AR Filter Coatings	✓	✓	✓	✓
FPA Filter Masks	NA/2nd order	NA/2nd order	NA/2nd order	NA/2nd order

Examples:

1. Residual Ghosting (SWMIR and LWIR):
   - -Paths 1 and 2 are Corrected
   - -Path 3 still occurs (at ~2% of In-Band Source)



2. Crosstalk (All Bands; Primarily 31-36):
   - -Track Direction has Common Filter/Detector Substrates (Fewer Barriers to Optical Crosstalk)
   - -FPA Crosstalk is Strongly Distance Dependent (Extended Objects Contain More "Close" Pixels)



Mitigation/Characterization/Accommodation Strategies

- Design Changes (Virtually Complete)
- Detailed Modeling of Each Optical Effect
- Progressive Subassembly/Assembly Level Modeling and Test Characterization
- Determine Data Characterization/Validation Ranges
- Determine (Potential) Optical Effects Reduction Algorithms (If Required)
  - Notional Correction Matrix Algorithm: $S' = S - A\,S$, where
    - S' = the corrected signal
    - S = the measured signal
    - A = the combined effects measured or modeled correction matrix
  - Correction Matrices, $A_n(i,j)$ for each FPA, are a Function of Instrument Contamination Level and Time.
  - Determination Requires Measurement (or detailed modeling) of Many Small Magnitude Coupling Coefficients.
  - Twenty-Six Spectral Bands Saturate from Lcloud Radiance Levels

MODIS Optical / Electronic Effects Characterization Overview

	Effect	VIS		NIR		SWMIR		LWIR	
		Model	Test	Model	Test	Model	Test	Model	Test
Scatter	In-Field Scatter (Incl. Diffraction)	MCST APART 1	Combined Effects / ScMA 2	SBRC APART / MCST APART 3	Combined Effects / ScMA 4	MCST APART 5	Combined Effects / ScMA 6	MCST APART 7	Combined Effects / ScMA 8
	Far-Field Scatter (Incl. Diffraction)	MCST APART 9	ScMA / SIS 10	SBRC APART / MCST APART 11	ScMA / SIS 12	MCST APART 13	ScMA / SIS 14	MCST APART 15	Not Planned 16
Ghosting	Ghosting / Scan Direction	SBRC/ASAP GSFC/ Monte Carlo 17	Combined Effects / ScMA 18	SBRC/ASAP GSFC/ Monte Carlo 19	Combined Effects / ScMA 20	SBRC/ASAP GSFC/ Monte Carlo 21	Combined Effects / ScMA 22	SBRC/ASAP GSFC/ Monte Carlo 23	Combined Effects / ScMA 24
	Ghosting / Track Direction	SBRC/ASAP GSFC/ Monte Carlo 25	Combined Effects / ScMA 26	SBRC/ASAP GSFC/ Monte Carlo 27	Combined Effects / ScMA 28	SBRC/ASAP GSFC/ Monte Carlo 29	Combined Effects / ScMA 30	SBRC/ASAP GSFC/ Monte Carlo 31	Combined Effects / ScMA 32
Crosstalk	Optical Crosstalk / Scan Direction	Filter/Mask Ray Trace 33	Combined Effects / ScMA 34	Filter/Mask Ray Trace 35	Combined Effects / ScMA 36	Filter/Mask Ray Trace 37	Combined Effects / ScMA 38	Filter/Mask Ray Trace 39	Combined Effects / ScMA 40
	Optical Crosstalk / Track Direction	Filter/Mask Ray Trace 41	Combined Effects / ScMA 42	Filter/Mask Ray Trace 43	Combined Effects / ScMA 44	Filter/Mask Ray Trace 45	Combined Effects / ScMA 46	Filter/Mask Ray Trace 47	Combined Effects / ScMA 48
	Electronic Crosstalk / Scan Direction	Gaussian Approx. 49	Single Pixel Injection 50	Gaussian Approx. 51	Single Pixel Injection 52	Gaussian Approx. 53	Single Pixel Injection 54	Gaussian Approx. 55	Single Pixel Injection 56
	Electronic Crosstalk / Track Direction	Gaussian Approx. 57	Single Pixel Injection 58	Gaussian Approx. 59	Single Pixel Injection 60	Gaussian Approx. 61	Single Pixel Injection 62	Gaussian Approx. 63	Single Pixel Injection 64

☐ = TBD / Unknown ▨ = In Progress ▩ = Complete / Evolving

ScMA = Scatter Measurement Apparatus SIS = Spherical Integrating Source

Qualitative Comparisons of Optical and Electronic Artifacts With Predecessor Instruments

Key Features	MODIS	GOES-8	AVHRR/3	HIRS/3	TM	Comments/Effects
Spectral Bands	36	5	6	20	7	•Aft-Optics and FPA Complexity Increases Potential for Scatter, Ghosting and Crosstalk
Dynamic Range (Bits)	12	10	10	13	8	•Increases Susceptibility to Residual Effects
Optical System Configuration	•Off-Axis Afocal w/inter. Field Stop(Sized for LWIR) •4 Channel Aft-Optics •No Lyot Stop(s)	•Cassegrain with SM Support Spider •5 Channel Aft-Optics •Lyot Stops Near Detectors	•Cassegrain with SM Support Spider •6 Channel Aft-Optics •Field Stops Near Detectors	•Cassegrain with SM Support Spider •Filter Wheel and 3 Channel Aft-Optics •Lyot Stops Near Det.'s	•Ritchey-Chretein with/SM Support Spider •Reflective 2 Channel Aft-Optics •No Lyot Stops	•SM Support Spider Contributes to Scatter •Lyot Stop(s) Optimally Reduce Scatter •Field Stops Help Reduce Scatter
No. of Scattering Surfaces and Bulk Media	21 23 40 40	15 30 29 28, 27	20 23 21 20, 23, 24	23 24 25	10 10	•Contribute to In-Field/Near-Field Scatter •Sources for Ghosting
Detectors/FPA (Bands/FPA)	100 (7) 170 (9) 130 (10) 100 (10)	8 (1) 4 (1) 2 (1) 4 (1) 4 (1)	1 1 1 1 1	1 1 1	48 (3) 36 (3)	•Multiple Detectors per Band/FP Introduce Potential for Scatter, Ghosting and Crosstalk Effects

Qualitative Comparisons of Optical and Electronic Artifacts With Predecessor Instruments (Continued)

Optical/Electronic Effect	MODIS	GOES-8/I	AVHRR/3	HIRS/3	TM
Far-Field Scatter	•TBD •Off-Axis Telescope •Limited by Field Stop •No Lyot Stop	•Probably Not Within 10 BIT DNR •Secondary Mirror Support Spider Scatter •Effective Use of Lyot Stops	•Probably Not Within 10 BIT DNR (Observed Problems Near S/C Sunrise for 3-5 Minutes) •Secondary Mirror Support Spider Scatter •Effective Use of Lyot Stops Near Detectors	•Potentially Within 13 BIT DNR Depending on Source and Source Position •Secondary Mirror Support Spider Scatter •Effective Use of Lyot Stops	•Masked by Electronics Memory Effect •Secondary Mirror Support Spider Scatter •No Lyot Stop •Edge Scatter Off Primary FPA TBD •Predicted Noise to Signal <1.5% Based on Optical Elements TIS (Within 8 Bit DNR)
In-Field Scatter	•TBD •Expected Contributor to Transient Response at Cloud Edges	•Far-Field Scatter Factors Apply	•Far-Field Scatter Factors Apply	•Far-Field Scatter Factors Apply	•Far-Field Scatter Factors Apply

Qualitative Comparisons of Optical and Electronic Artifacts With Predecessor Instruments (Continued)

Ghosting	Scan & Track Residuals Expected.	•Within-Band Only/Pixel-to-Pixel •8 Plano Surfaces Face Detector Arrays	•None - Single Detector Channels	•None - Single Detector Channels	Nil-Small Amount of Axial Narcissus Viewed Thru Telescope and Relay Primary's
Optical Crosstalk	•Scan &Track Residuals Expected	•Within-Band Only/Pixel-to-Pixel •Contiguous Aplanat Lens Residual Reflections	•None - Single Detector Channels	•None - Single Detector Channels	Unknown-Probably Within Electronic Memory Effect •Limited to Within Bands •Monolithic Arrays With Contiguous Spectral Filter •Effect Reduced by Staggered Arrays
Electronic Crosstalk	•FPAs CCD Bump Bonded Config.	•Some Overshoot Observed	•Nil-Single Detector Discrete Electronics	•None - Single Detector Channels	•Electronic Crosstalk Unknown-Special Shields Provided •~1% Electronic Memory Effect Observed

Highlights of MCST Scattered Light/Stray Light Analysis

- An End-to-End High Fidelity Scattered Light Computer Model
  - Using APART and/or ASAP Models
  - Covers VIS, NIR, SWMIR and LWIR Channels (34 Distinct Bands)

- Model Features:
  - Includes All Reflective and Transmissive Optical Elements In MODIS Fore-Optics and Aft-Optics
  - Models the SWMIR and LWIR Intermediate Focus Scan Direction Ghosting Reduction Filter/Dichroic Assemblies
  - Estimates Scattered Light Across Entire MODIS Field-of-Regard Including Five Scan Mirror Positions
  - Assesses System Level Scattered Light Effects Due to Two Instrument Particulate Contamination Levels

- Model Products:
  - Most Significant Scattered Light Propagation Paths (Top Ten Scattering Elements/Surfaces
  - Response of MODIS to "Bright Target Within-Field Stray Light", "Dark Target Within-Field Stray Light" and "Warm Target Within-Field Diffracted Light"
  - Scan and Track Distances From Cloud Top Edges for Measured Radiometric Values to be Within 0.25% of the Specified Cloud Top Radiance for a Selected Wavelength/Channel and 7 Cloud Sizes/ Geometries