MODERATE RESOLUTION IMAGING SPECTRORADIOMETER - LITE

(MODIS - L)

DESIGN OVERVIEW

November 14, 15, 1995

Thomas S. Pagano

HUGHES AIRCRAFT

MODIS-L PROVIDES BASIS FOR LOW-COST SOLUTION TO AUSTERE EOS

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REDUCE COSTS

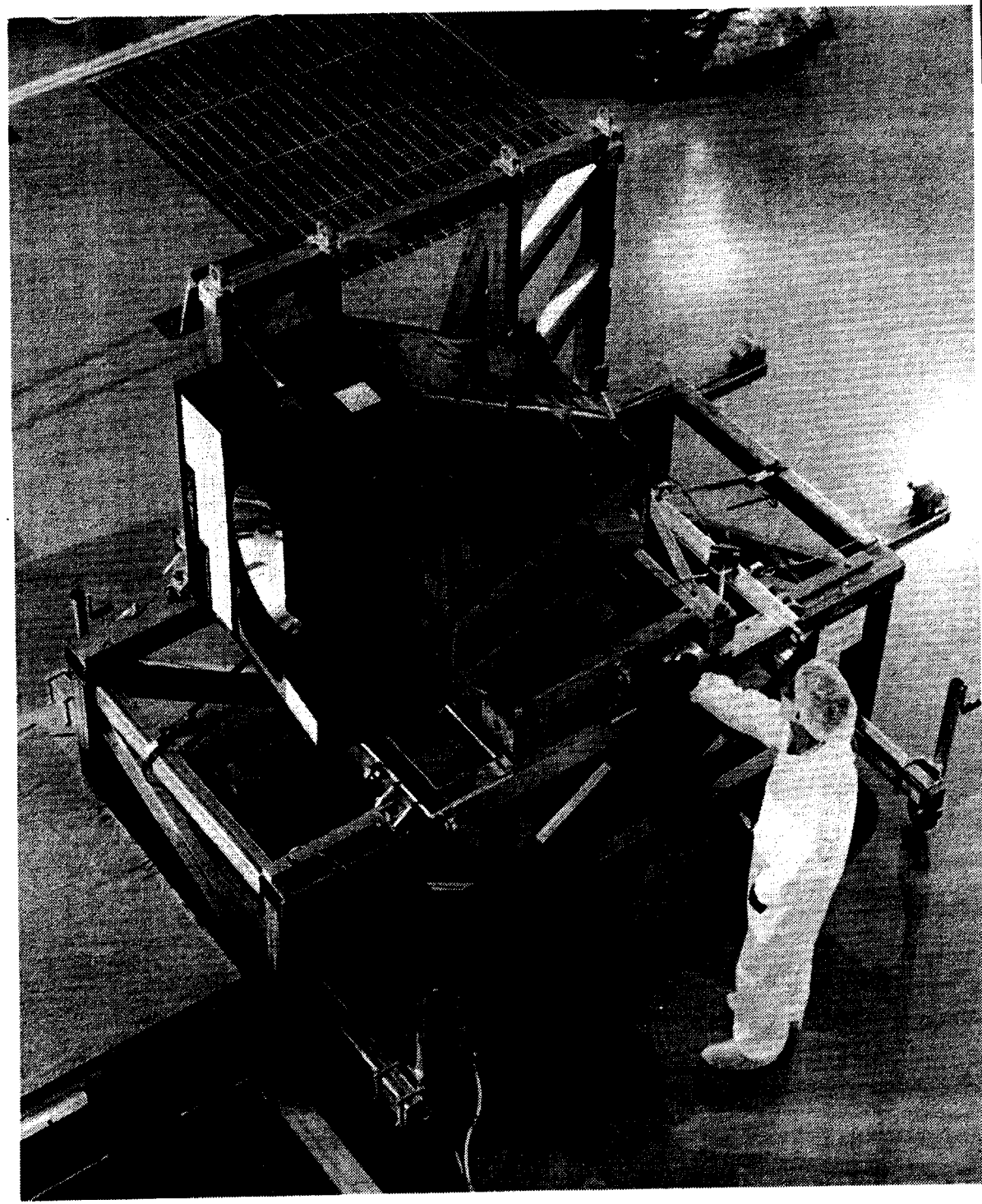
- Exploit significant NASA investment in MODIS non-recurring design costs
- Preserve 6 year design life for low lifecycle costs
- Streamline development and documentation process

REDUCE SPACECRAFT RESOURCE NEEDS

- Repackage subsystems for reduced volume
- Reduce power requirements, reduce redundancy
- Eliminate non-mission critical subsystems

PRESERVE SCIENCE/OPERATIONAL OBJECTIVES

- Maintain all 36 bands with same IFOVs
- Maintain high performance Optics, FPAs, Electronics
- Preserve essential calibration methodology



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95-4-75(10)

EM MODIS FULL BUILD-UP OF ESSENTIAL SUBSYSTEMS

MODIS

GSFC SBRC

MODIS-L BASIC DESIGN ASSUMPTIONS LEAD TO SMALLER PACKAGE

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- Remove SRCA and SDSM: Reduces viewfactor requirements
- Change scan approach: Tilted Paddle Wheel
- Repackage electronics: reduced capability, reduced redundancy, new technology employed
- Redesign mainframe: smaller structure possibly different material
- Moved solar diffuser to nadir aperture door
- Moved blackbody to end of scan position

MODIS-L REPRESENTS SMALLER PACKAGE OF MODIS ESSENTIALS

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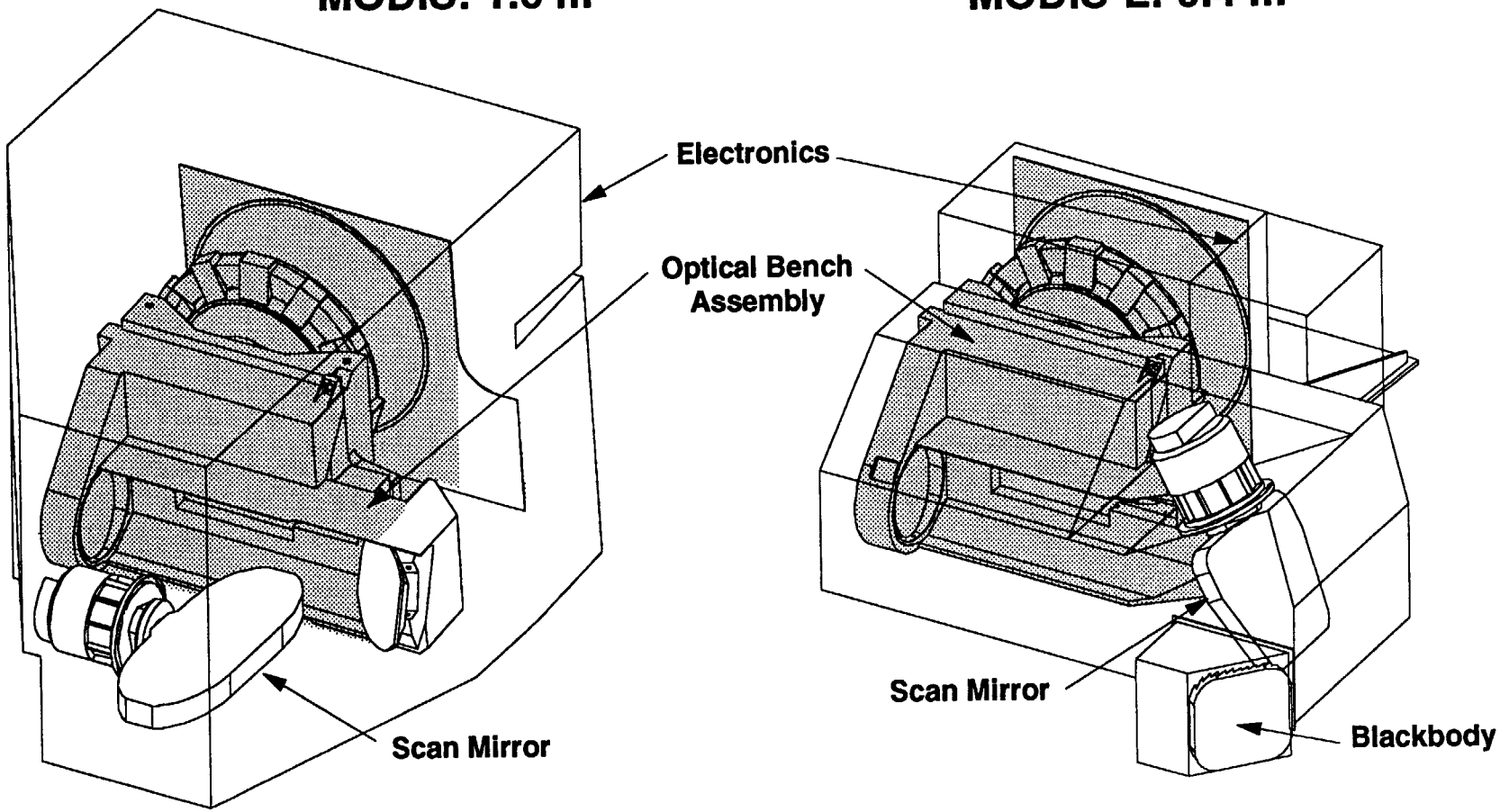
MODIS: 1.6 m^3

MODIS-L: 0.4 m^3



- **MODIS-L four times smaller than MODIS**

MODIS-L REDUCES RESOURCE REQUIREMENTS

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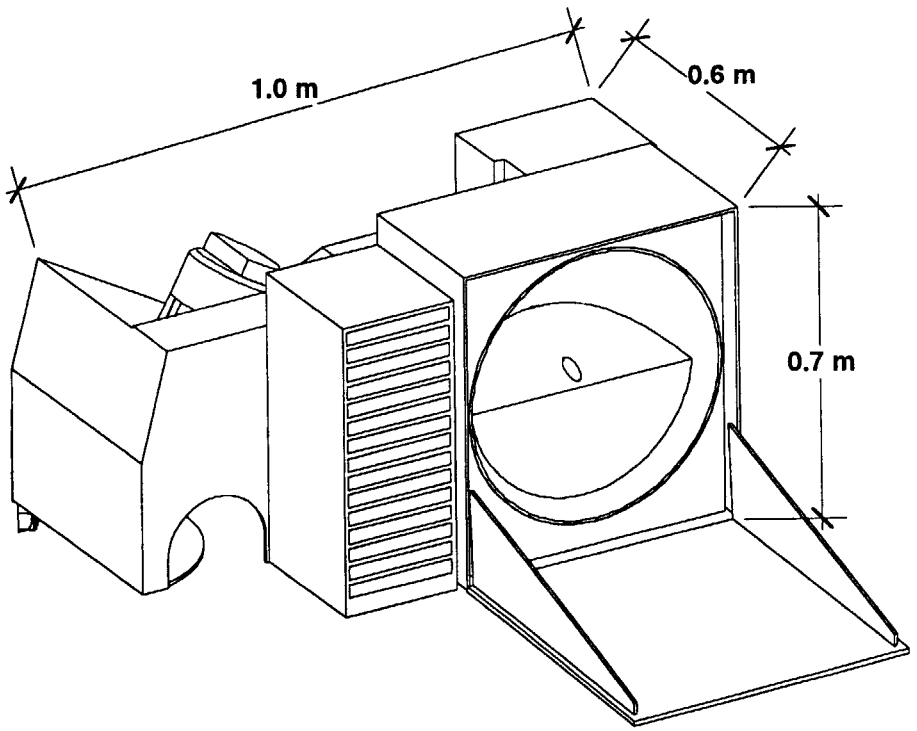

MODIS - L
Size: 1.0 x 0.6 x 0.7 m
Mass: 100 kg
Power: 100 W
Data Rate: 10.8 Mbps

MODIS
Size: 1.0 x 1.6 x 1.0 m
Mass: 220 kg
Power: 225 W
Data Rate: 10.8 Mbps

- Design builds on compact MODIS optical bench with advanced new scan approach

INSTRUMENT	
Mainframe	Redesign
Scan Mirror	Redesign
Motor Encoder	Existing
Afocal Telescope	Existing
Aft Optics Assembly	Existing
Focal Plane Assemblies (4)	Existing
Radiative Cooler Assembly	Existing
Main Electronics Module	Repackage
Forward Viewing Electronics	Repackage
Space Viewing Electronics	Repackage
Solar Diffuser Assembly	Deployable
Blackbody	Relocate
Covers and Doors	Redesign
Actuators, Temp Sensors, Misc	Existing
SRCA	Deleted
SDSM	Deleted
GROUND SUPPORT EQUIPMENT	
Fixturing	Existing
ScMA	Existing
PSA	Existing
SpMA	Existing
IAC	Existing
BCS	Existing
SVS	Existing
SIS	Existing
MCC	Existing
STE	Existing
SUPPORT AREAS	
Specifications	Minor Revs
Drawings	Minor Revs
Procedures	Existing
Parts and Reliability	Minor Revs
Subsystem Test Verifications	Existing
Quality Control	Existing
Configuration Management	Existing

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MODIS-L BUILDS UPON EXISTING MODIS SUBSYSTEMS GSE AND SUPPORT AREAS

MODIS OPTICAL BENCH ASSY TRANSFORMED INTO MODIS-L

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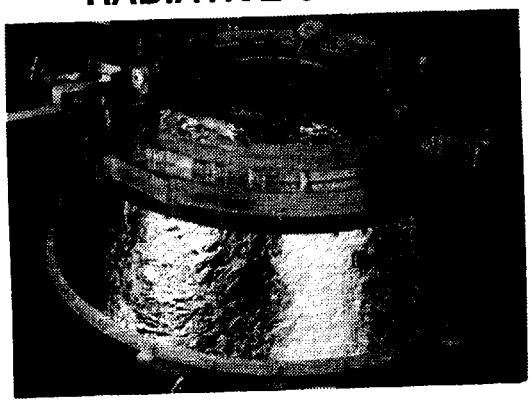
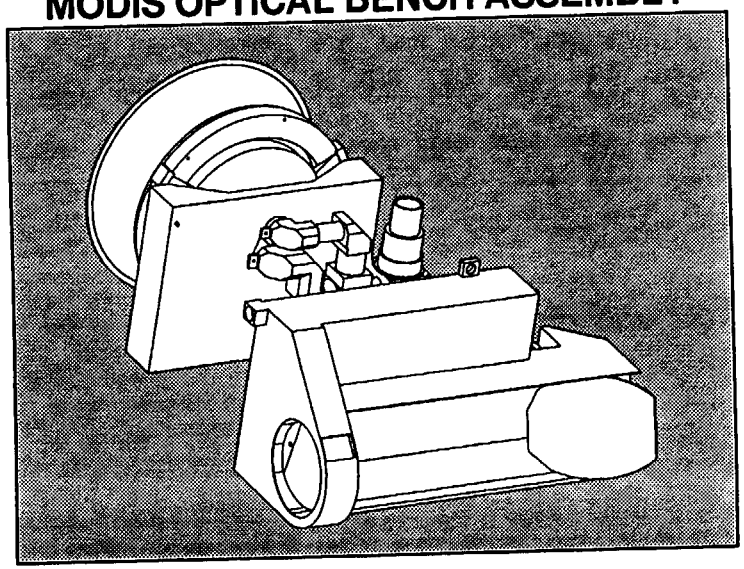
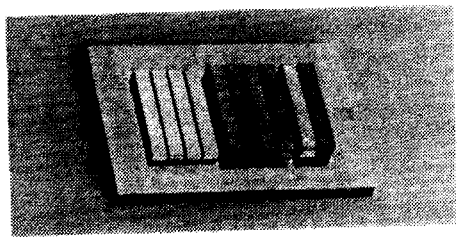
RADIATIVE COOLER



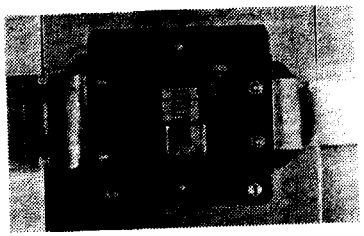
MODIS OPTICAL BENCH ASSEMBLY



FILTERS / DICHROICS



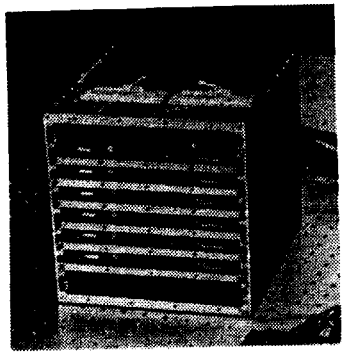
FOCAL PLANES



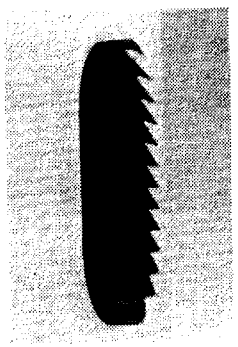
AFOCAL TELESCOPE

OTHER KEY SUBSYSTEMS USED:

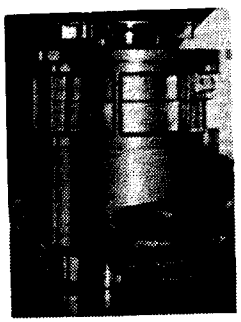
ANALOG ELECTRONICS



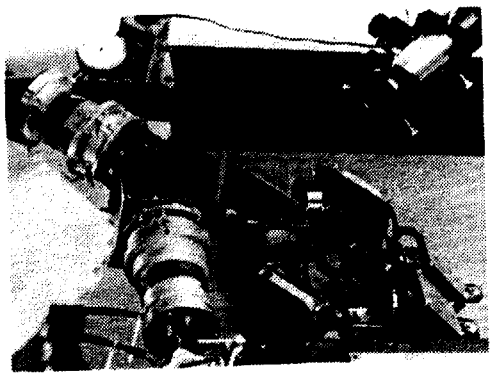
BB/SD



SCAN MOTOR



RE-IMAGING OPTICS



MODIS GROUND SUPPORT EQUIPMENT IN-PLACE

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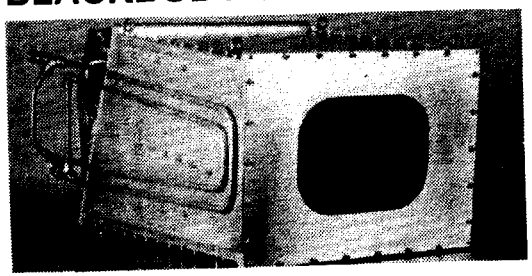
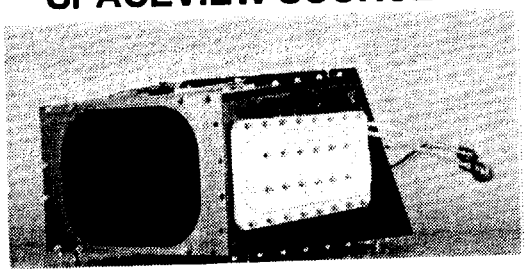
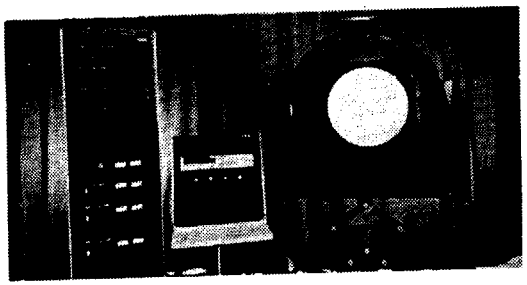
BLACKBODY CAL SOURCE



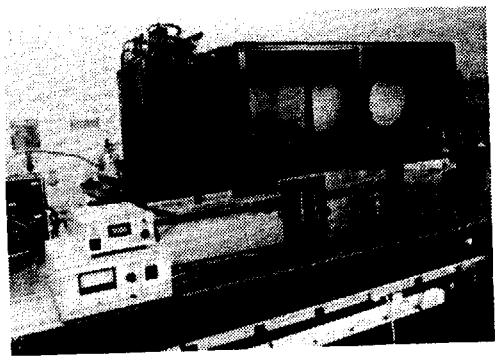
SPACEVIEW SOURCE



SPHERICAL INTEGRATOR SOURCE



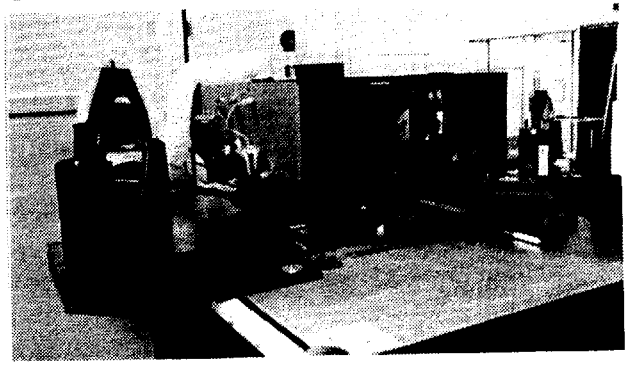
POLARIZED SOURCE ASSY



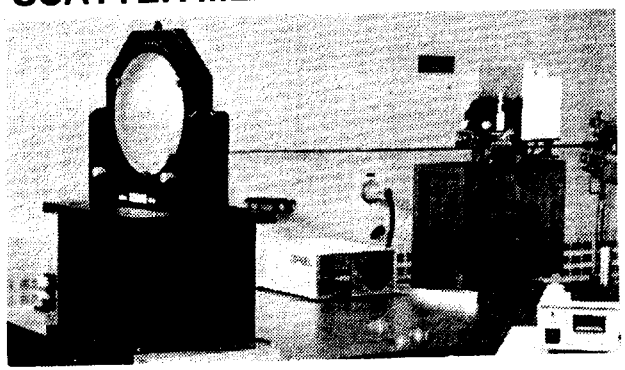
INTEGRATION AND ALIGNMENT COLLIMATOR

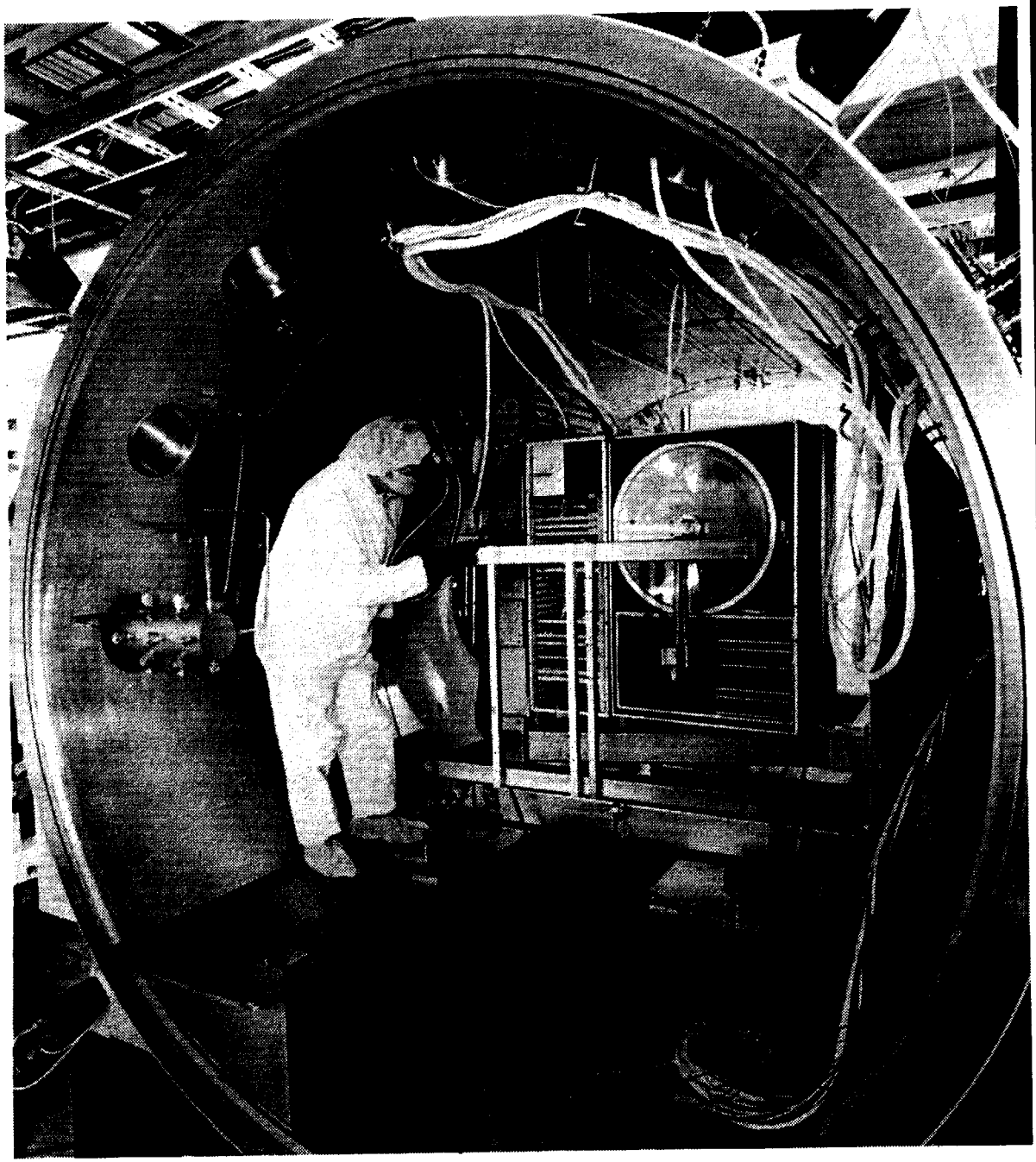
BENCHTEST COOLER SYSTEM TEST COMPUTERS

SPECTRAL MEASUREMENT ASSY



SCATTER MEASUREMENT ASSY





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MODIS CALIBRATION CHAMBER DEMONSTRATED ON MODIS EM

MODIS

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MODIS-L PRESERVES HIGH PERFORMANCE

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- All 36 bands with good in-band and low out-of-band spectral response
- Same MODIS FPAs with wide dynamic range and low noise
- Radiative cooling gives 85K FPA operation with long life, high reliability
- Low noise analog electronics, 12 bit radiometetry, high stability
- Excellent pre-flight calibration and characterization
- MODIS full-aperture blackbody and solar diffuser for in-flight cal

Spectral

- 2 NIR @ 250 m
- 2 VIS @ 500 m
- 12 VIS/NIR @ 1 km
- 3 SW @ 500 m
- 7 MW @ 1 km
- 10 LWIR @ 1 km

Spatial

- GSD: 1 km, 0.5 km, 0.25 km
- FOV: $\pm 64°$ (Full Disk)
- Registration: $< \pm 0.2$ IFOV
- MTF > 0.3 @ Nyquist

Radiometric

- 12 Bit Dynamic Range
- Polarization < 3%
- SNR: > 300:1 @ 1% albedo
- NEΔT: 0.05K @ 12 μm, 300K

LITE ELECTRONICS ACHIEVE SIGNIFICANT WEIGHT REDUCTION RETAIN IMPORTANT CAPABILITIES

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New Features

- Miniature synchronized power supply converter modules
- Net decrease of 17 PWB's:
  - Format Proc./Engine
  - FIFO's
  - FDDI's
  - Cal controllers
  - FAM, SAM redundancy
- Hardware multiplexer and formatter

Performance Impact

- Output data format changed
- Hardware controlled offsets
- Fixed (not prog.) gains
- Bursted (unbuffered) data
- FDDI coding eliminated (simple format in CCSDS)
- Floating temp blackbody
- Reduced redundancy

MODIS-L OFFERS SIGNIFICANTLY REDUCED ELECTRONICS VOLUME

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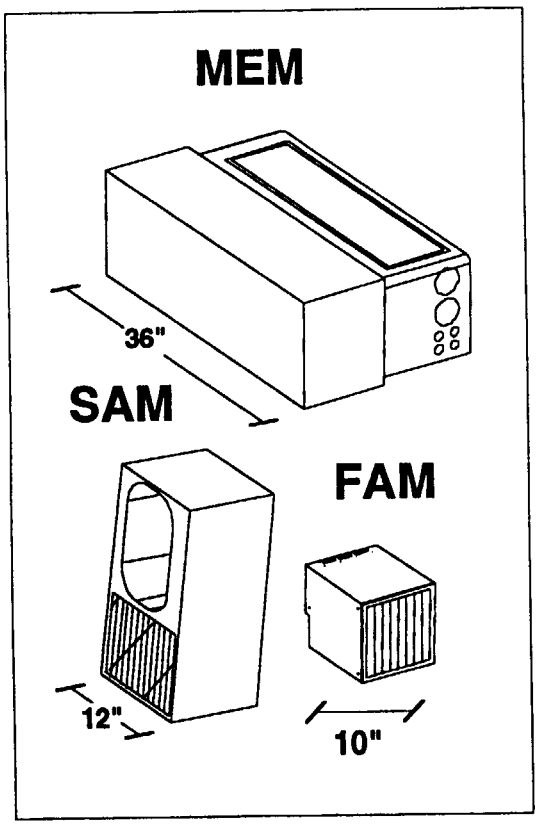
Current Approach



Critical Circuits Redundant

PS1	PS2
C/B ACE 1	
C/B ACE 2	
C/B ACE 3	
ACE/ACE 1	
ACE/ACE 2	
C/B/TLMY	
FAM POSTAMPS 1	
FAM POSTAMPS 2	
FAM POSTAMPS 3	
FAM POSTAMPS 4	
FAM POSTAMPS 5	
FAM POSTAMPS 6	
FAM TIMING 1&2	
SBC/TLMY 1	
SBC/TLMY 2	
FORMATTER 1	
FORMATTER 2	
TIMING 1&2	
SERVO CTRL 1	
SERVO CTRL 2	
MECH. CTRL	
TEMP. CTRL	

27"

Limited Redundant

PS1	PS2
C/B ACE 1	
C/B ACE 2	
C/B ACE 3	
ACE/ACE 1	
ACE/ACE 2	
C/B/TLMY	
FAM POSTAMPS 1	
FAM POSTAMPS 2	
FAM POSTAMPS 3	
FAM POSTAMPS 4	
FAM POSTAMPS 5	
FAM POSTAMPS 6	
FAM TIMING 1&2	
SBC/TLMY	
FOMATTER	
TIMING 1&2	
SERVO CTRL	
MECH CTRL	
TEMP CTRL	

22"

MODIS-L INCORPORATES ADVANCED TECHNOLOGY ALREADY PROVEN IN MODIS

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MECHANICS

- Latest Graphite-Epoxy techniques employed in lightweight structures
- Advanced radiative cooling technology, improved capacity, reduced mass
- Robust, lightweight beryllium structures

OPTICS

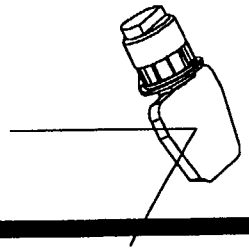
- Latest IAD multi-layer stripe filter technology
- Unprecedented dichroic beamsplitter coatings covering 0.4 - 14.4 μm
- Advanced out-of-band blocking coatings
- Advanced surface treatments for low scatter

FOCAL PLANE ASSEMBLIES

- Direct-hybrid detector/readout monolithic Focal Plane Assemblies
- Proprietary on-chip preamplification and signal processing
- High QE PV silicon and PV HgCdTe detectors from 0.4 - 10 μm
- High resistance PC HgCdTe to 14.4 μm

ELECTRONICS

- Low power, low noise flight 12 bit analog-to-digital electronics
- High speed multiplexing circuits with low crosstalk for flight use



TILTED PADDLE-WHEEL SCAN PRESERVES COREGISTRATION

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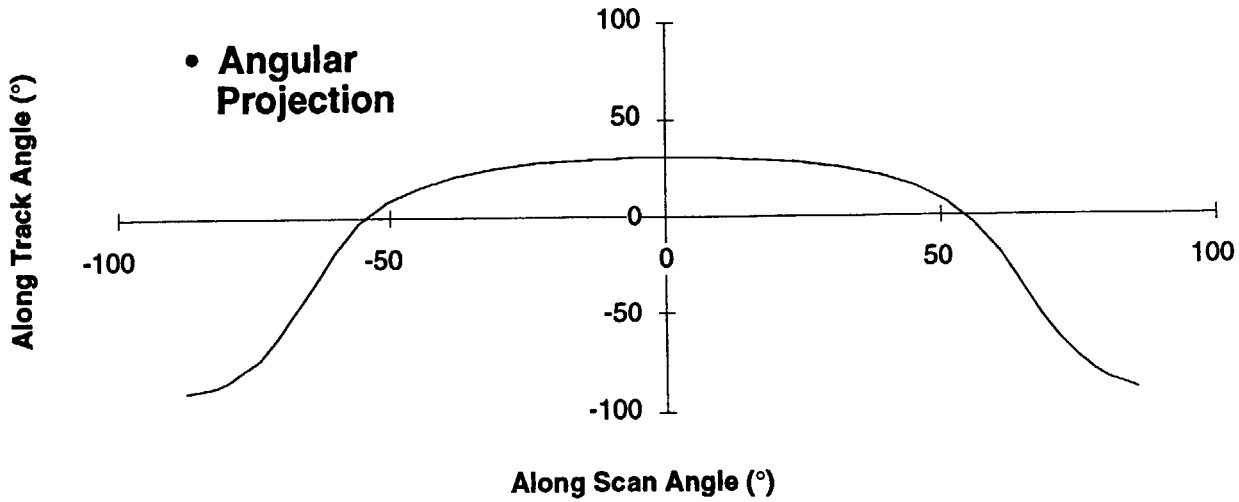
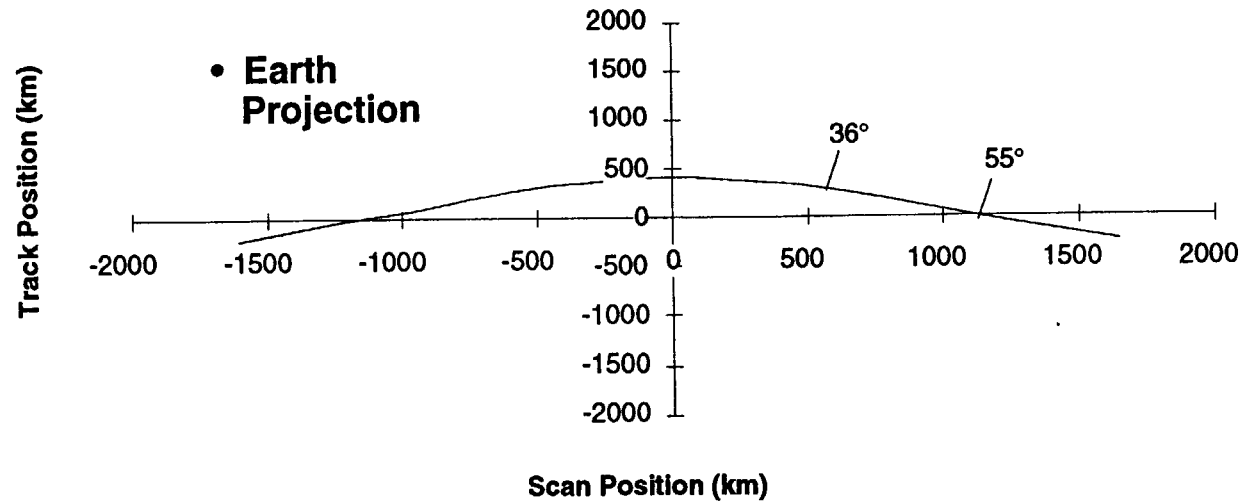
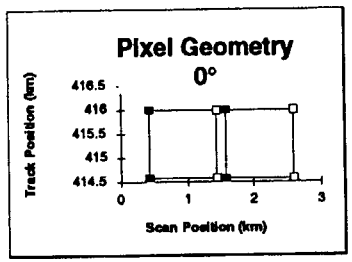
- **Angular Projection**

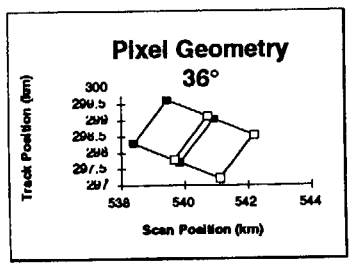


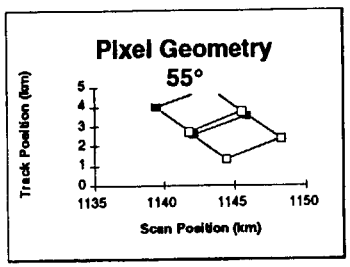
- **Earth Projection**



GIFOVs







ESSENTIAL FULL-APERTURE RADIMETRIC CALIBRATION PRESERVED

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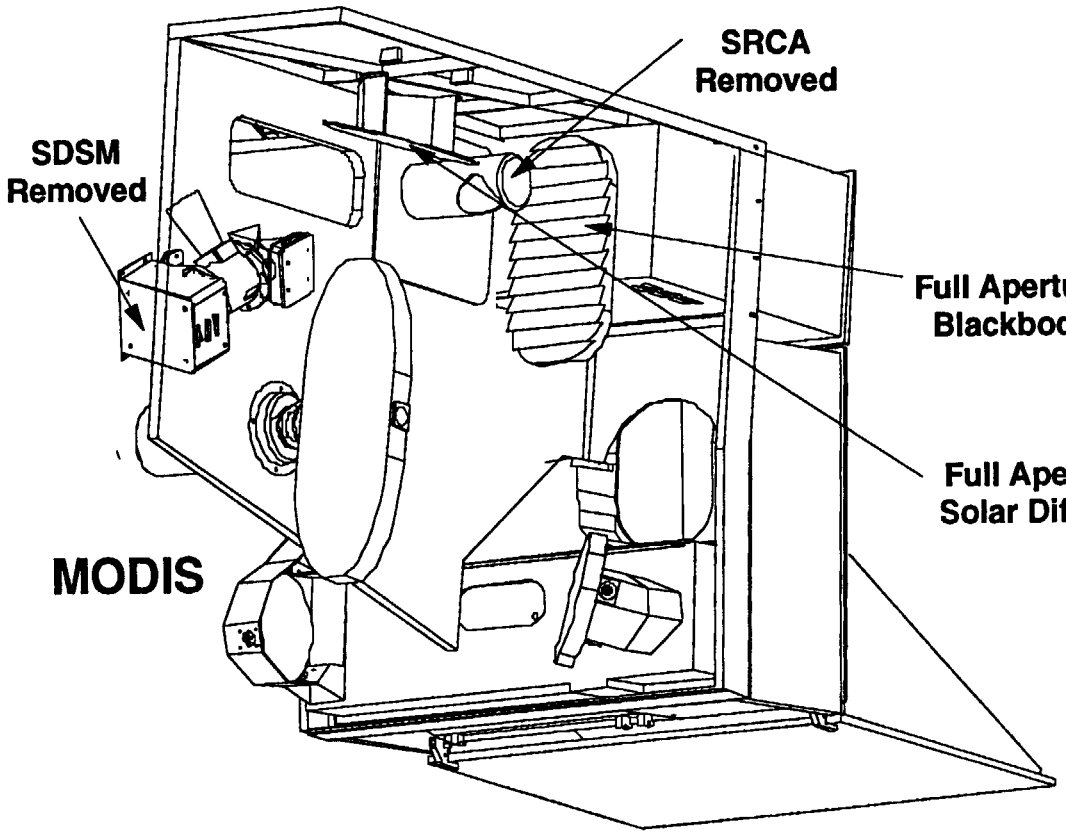
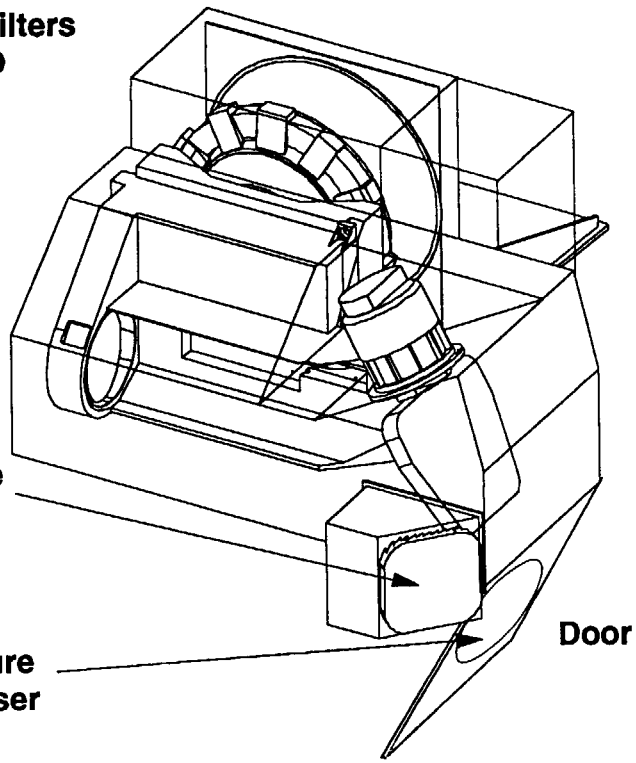
- SDSM: Solar Diffuser Stability Monitor; Use ground truth and lunar cal.
- SRCA: Spectroradiometric Calibration Assembly: Mitigated by IAD filters
- FULL APERTURE SOLAR DIFFUSER AND BLACKBODY PRESERVED





POLAR ENVIRONMENTAL IMAGER PERFORMANCE COMPARISON

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Parameter	MODIS	TRMM/VIRS	AVHRR - 2	CZCS	SeaWiFS	OLS	MODIS-L (Concept)	MODIS-AT (Concept)
Interface								
Size	1.0m x 1.6m x 1.0m	0.4m x 0.8m x 0.4 m	0.3m x0.4m x 0.8m	0.4m x 0.8m x 0.6m	0.5m x 0.6m x 0.5m 0.6m x 0.3m x 0.3m elect	0.8m x 0.3m x 0.3m + 0.3m x 0.3m x 0.2m elect	1.0m x 0.6m x 0.7m	0.4m x 0.4m x 0.3 m
Volume	1.60 m^3	0.13 m^3	0.10 m^3	0.17 m^3	0.19 m^3	0.09 m^3	0.42 m^3	0.05 m^3
Sensor Mass	140 kg	29 kg	19 kg	42 kg	27 kg	22 kg	75 kg	45 kg
Electronics Mass	80 kg	19 kg	10 kg		24 kg	21 kg	25 kg	15 kg
Density	137.5 kg/m^3	377.3 kg/m^3	302.1 kg/m^3	243.7 kg/m^3	267.7 kg/m^3	477.8 kg/m^3	238.1 kg/m^3	1143.3 kg/m^3
Power	160 W	40 W	29 W	50 W	61 W	170 W	100 W	60 W
Data Rate	10.8 Mbps	< 50 kbps	665.4 Kbps	800 kbps	1.885 Mbps	1.024 Mbps	10.8 Mbps	8.8 Mbps
Spatial								
FOV	±58°	±45°	±55.4°	±39.2°	±55.4°	±57.85°	±58°	±55°
IFOV @ Nadir	0.35, 0.71, 1.42 mr 250, 500, 1000 m	6 mr, 2.11 km	1.3 mr, 1.08 km	0.865 mr, 0.826 km	1.6 mr, 1.13 km	0.67 mr, 0.3 nmi	0.35, 0.71, 1.42 mr 250, 500, 1000 m	1.42 mr, 1 km
Spectral								
Number of Bands	36	5	5	6	8	2 + LLL	36	80
Coverage	0.4 - 14.4 µm	0.6 - 12 µm	0.6 - 12 µm	0.44 - 0.75, 11.5 µm	0.4 - 0.9 µm	0.4 - 12.8 µm	0.4 - 14.4 µm	0.4 - 12 µm
Bandwidth	10 nm - 500 nm	60 nm - 12 µm	100 nm - 1.0 µm	20 nm - 2.0 µm	20 nm - 40 nm	700 nm - 2.6 µm	10 nm - 500 nm	10 nm - 300 nm
Edge Range	≤2% cwl	< 5% cwl	≤6% cwl	> 2% cwl	≤2% cwl		≤3% cwl	≤2% cwl
Peak Out-of-Band	≤ 0.01%	< 1.2%	≤7%		<3.2%		≤ 0.01%	< 0.1%
Radiometric								
Dynamic Range	100% Albedo, 500K	100% Albedo, 320K	0 - 100%	100% Albedo, 320K	0 - 100%	1/4 moon -100% Albedo, 310K	100% Albedo, 500K	100% Albedo, 320K
Sensitivity VNIR	1389:1 at 443 nm L=40.6	> 100:1 @ 1% Albedo	>3:1 @ 0.5% Albedo	211:1 at 443 nm L=40.6	640:1 at 443 nm L=40.6	10:1 - 200:1	1389:1 at 443 nm L=40.6	1389:1 at 443 nm L=40.6
Sensitivity IR	0.05K at 300K, 12 µm	< 0.6K @ 300K	0.12 at 300 K	0.25K @ 270K		1K @ 210K to 310K	0.05K at 300K, 12 µm	0.05K at 300K, 12 µm
Quantizing Resolution	12 Bits		10 Bits	8 Bits	10 Bits	6 - 7 Bits	12 Bits	12 Bits
Polarization	< 2%	< 6%	< 5.3%	< 2.7%	< 2%		< 3%	< 2%
Calibration								
Absolute Accuracy	5% VNIR, <0.5% IR	10% VNIR, 5% IR	< 0.5K (≈0.7% at 12 µm)			8% VNIR, 1.5K IR	5% VNIR, < 0.5% at 12 µm	5% VNIR, < 0.5% at 12 µm
On-Orbit Calibration	Spectral, Spatial Solar Diffuser + Monitor Lamps, Blackbody Space View	Blackbody Solar Diffuser Space View	Blackbody Space View	Blackbody Space View	Solar Diffuser Space View	LED T-Cal Blackbody Space View	Lamps Solar Diffuser Blackbody Space View	Lamps Blackbody Space View
Sources								
AVHRR: ITT AVHRR Brochure, Rev 5/90, Final Engineering Report: 2/79								
OLS: Block 5D Compilation, Air Force Systems Command, July 1975								
MODIS: Protoflight Model: SBRC								
CZCS: Ball Aerospace Final Report F78-11, Rev.A, 5/79								
SeaWiFS: Pre-Ship Review, SBRC, 4/27/93								
TRMM/VIRS: Pre-Environmental Test Review: CDRL 021, 10/96								

SUMMARY AND CONCLUSIONS

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- Substantial amount of NASA investment in the MODIS program directly applicable to MODIS-L
- Built around existing subsystems, non-mission critical subsystems removed
- Significant reduction in cost achieved
- Significant reduction in instrument size, mass, power and data rate achieved
- MODIS-L fully exploits calibration hardware and techniques developed for MODIS
- Science performance objectives preserved
- Smooth transition from current design to modified approach

MODIS Lite

Requirements should be driven by radiometric stability:

1) stable detectors
   linear
   insensitive to temperature

2) spectral purity
   high spectral out-of-band rejection

3) well defined, stable passbands
   rectangular
   without crosstalk

4) well defined IFOV
   no "skirt" from aberrations and/or scattered light
   well understood size-of-source response

MODIS Lite

Calibration "methodologies"
- Preflight
- On-board
- "Vicarious"
- Cross-calibration with other sensors

Calibration "sources"
- Lamp(s)
- Sun
  - diffuser
  - moon
- Earth/atmosphere scenes

MODIS Lite

Recommendations

- Solar calibrator in solar reflective region
  - Preflight
  - On-board (solar diffuser)
  - Use preflight methodology for cal/val instrumentation
- Blackbody in TIR
  - multiple temperatures within single scan
- No "generic calibrator" that is external to MODIS
  - It must be "better" than MODIS
    - Stability
    - Spectral out-of-band
    - Well defined IFOV that is smaller than MODIS Lite