

MODERATE RESOLUTION IMAGING SPECTRORADIOMETER - LITE

(MODIS - L)

DESIGN OVERVIEW

November 14, 15, 1995

Thomas S. Pagano



HUGHES
AIRCRAFT

The logo consists of the word "HUGHES" in a large, bold, sans-serif font, with the word "AIRCRAFT" in a smaller, all-caps, sans-serif font directly below it. The text is white and is contained within a black rounded rectangular border.

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

SANTA BARBARA
RESEARCH
CENTER



REDUCE COSTS

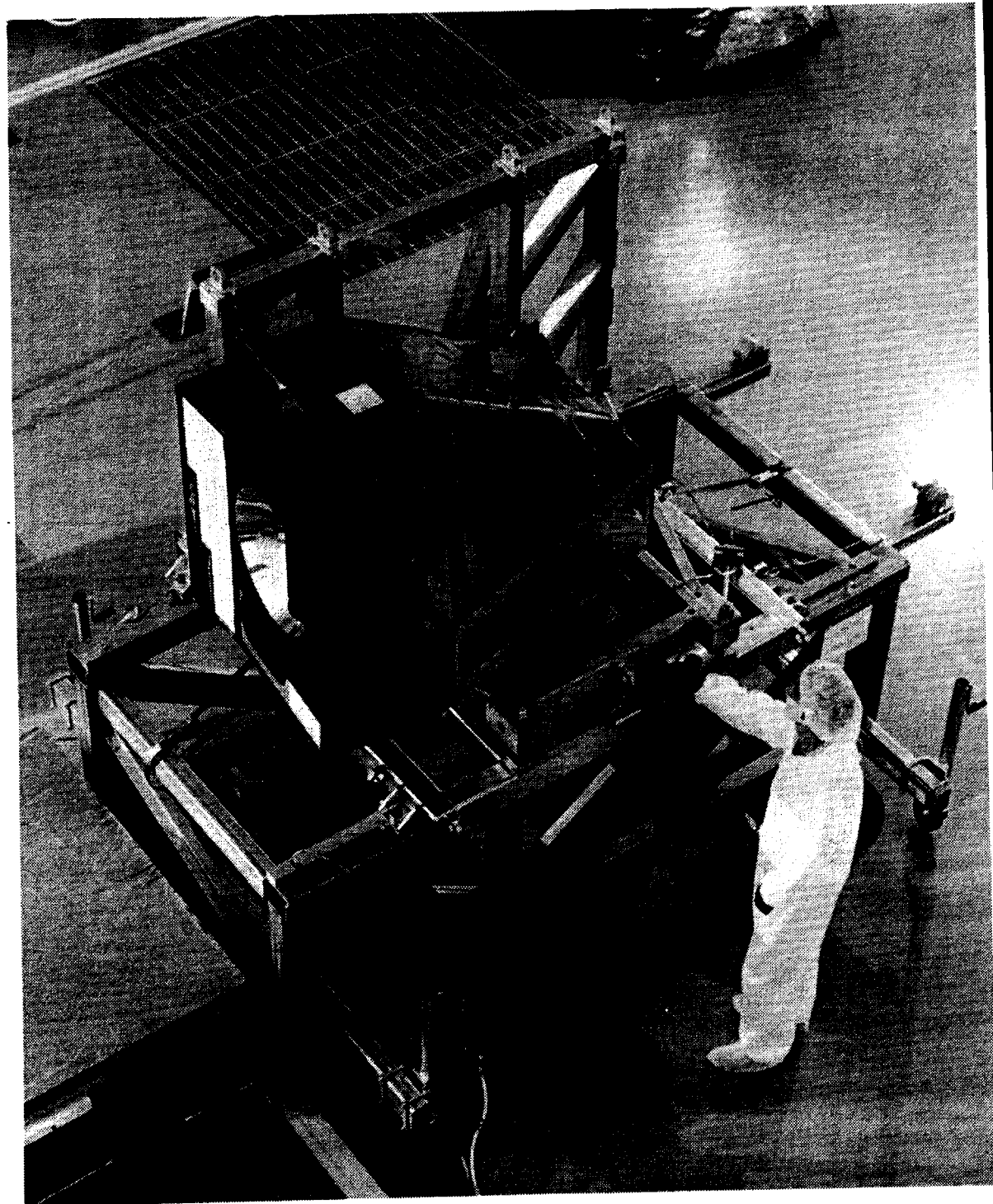
- **Exploit significant NASA investment in MODIS non-recurring design costs**
- **Preserve 6 year design life for low lifecycle costs**
- **Streamline development and documentation process**

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**



SANTA BARBARA
RESEARCH
CENTER

HUGHES
AIRCRAFT

A HUGHES ELECTRONICS COMPANY

95-4-75(10)

EM MODIS[®] FULL BUILD-UP OF ESSENTIAL SUBSYSTEMS



MODIS-L BASIC DESIGN ASSUMPTIONS LEAD TO SMALLER PACKAGE

SANTA BARBARA
RESEARCH
CENTER



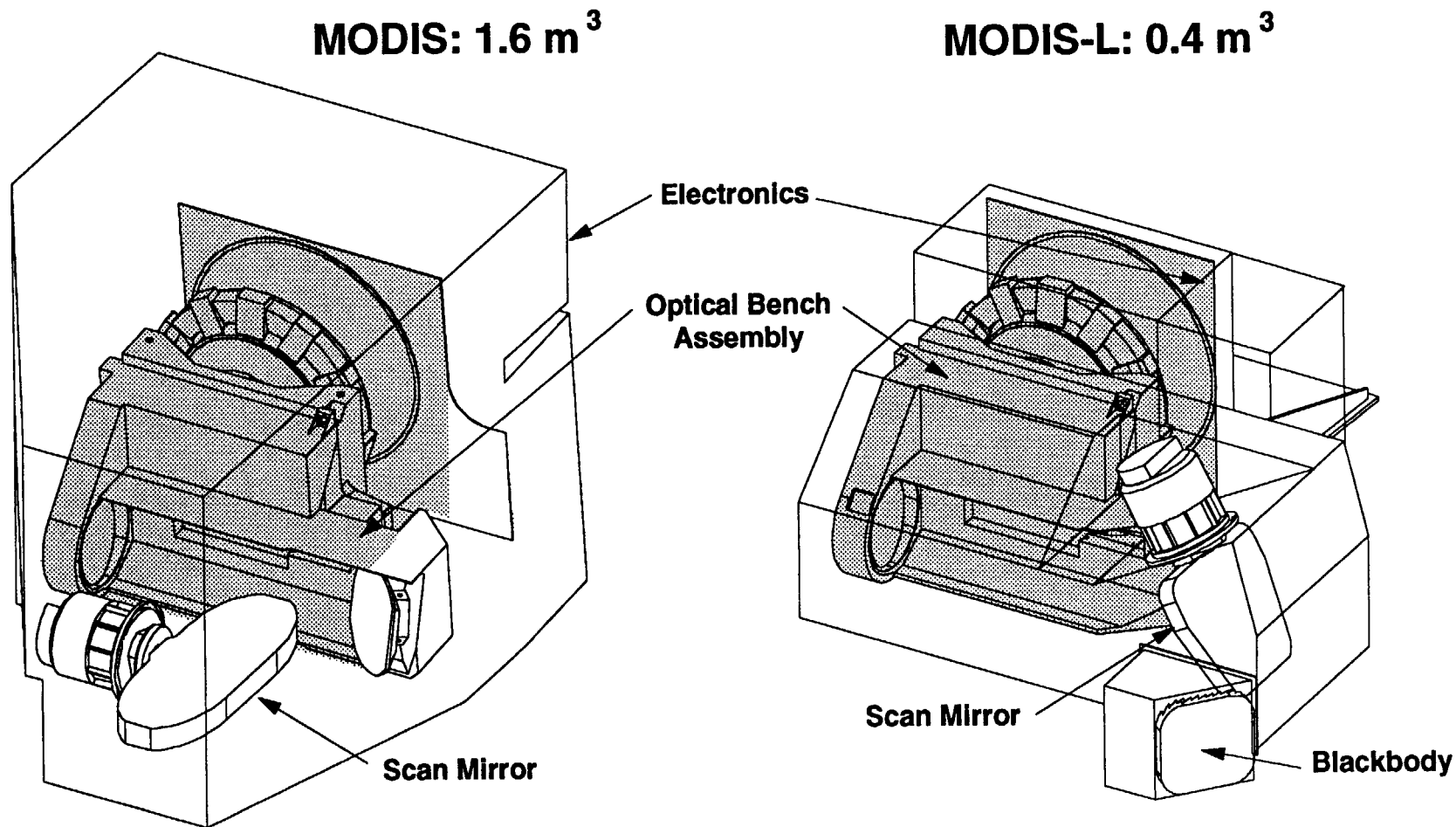
A HUGHES ELECTRONICS COMPANY

- **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

MODIS: 1.6 m³

MODIS-L: 0.4 m³



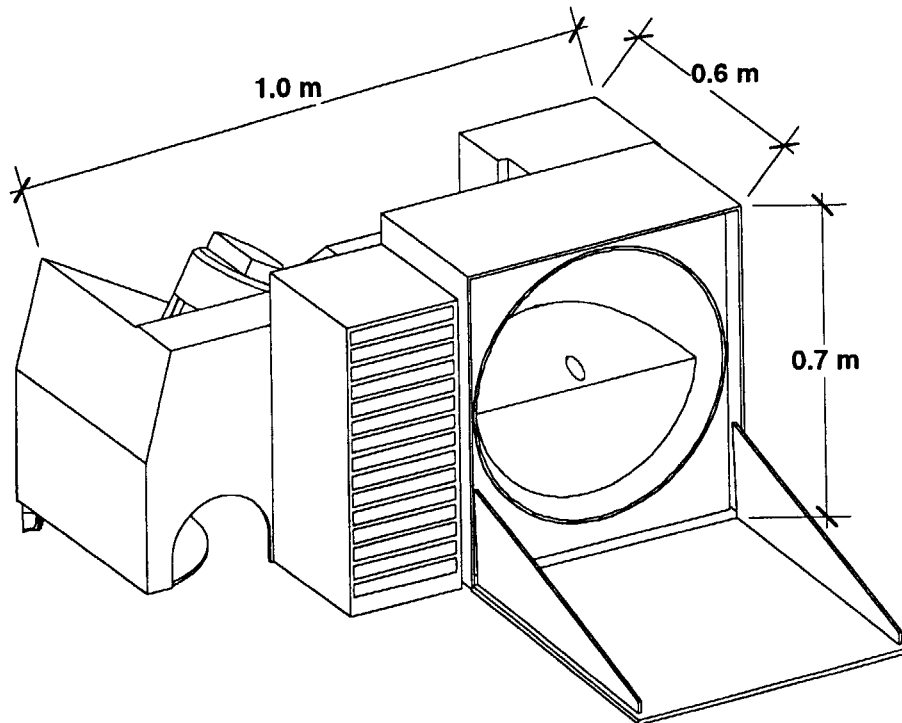
- MODIS-L four times smaller than MODIS

MODIS-L REDUCES RESOURCE REQUIREMENTS

SANTA BARBARA
RESEARCH
CENTER



A HUGHES ELECTRONICS COMPANY



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
Scan Mirror
Motor Encoder
Afocal Telescope
Aft Optics Assembly
Focal Plane Assemblies (4)
Radiative Cooler Assembly
Main Electronics Module
Forward Viewing Electronics
Space Viewing Electronics
Solar Diffuser Assembly
Blackbody
Covers and Doors
Actuators, Temp Sensors, Misc
SRCA
SDSM

GROUND SUPPORT EQUIPMENT

Fixturing
ScMA
PSA
SpMA
IAC
BCS
SVS
SIS
MCC
STE

SUPPORT AREAS

Specifications
Drawings
Procedures
Parts and Reliability
Subsystem Test Verifications
Quality Control
Configuration Management

Redesign
Redesign
Existing
Existing
Existing
Existing
Existing
Repackage
Repackage
Repackage
Deployable
Relocate
Redesign
Existing
Deleted
Deleted

Existing
Existing
Existing
Existing
Existing
Existing
Existing
Existing
Existing
Existing

Minor Revs
Minor Revs
Existing
Minor Revs
Existing
Existing
Existing

SANTA BARBARA
RESEARCH
CENTER



A HUGHES ELECTRONICS COMPANY

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

MODIS OPTICAL BENCH ASSY TRANSFORMED INTO MODIS-L

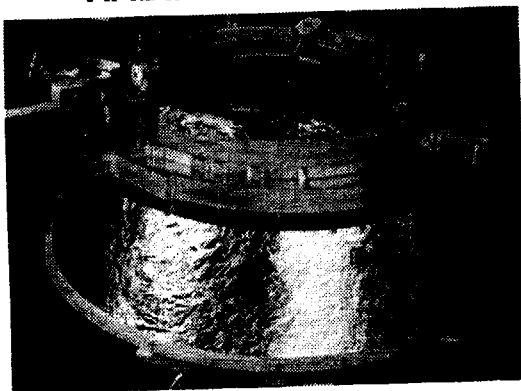
95-6-46

SANTA BARBARA
RESEARCH
CENTER

HUGHES
AIRCRAFT

A HUGHES ELECTRONICS COMPANY

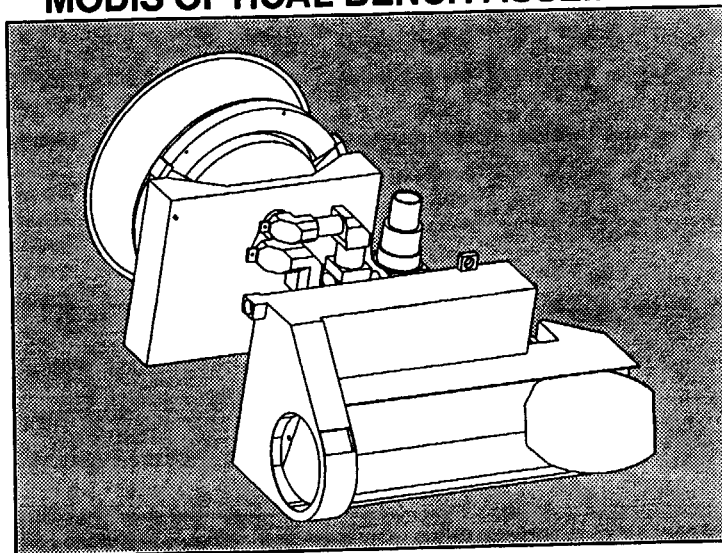
RADIATIVE COOLER



AFOCAL TELESCOPE

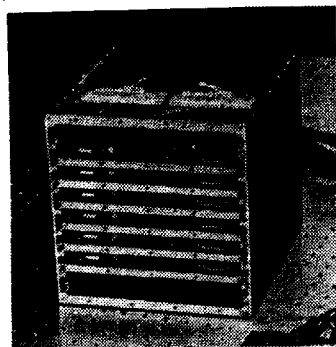


MODIS OPTICAL BENCH ASSEMBLY

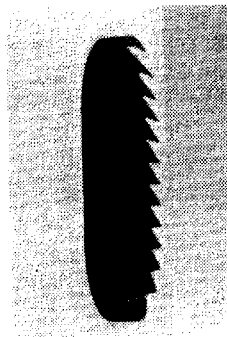


OTHER KEY SUBSYSTEMS USED:

ANALOG ELECTRONICS



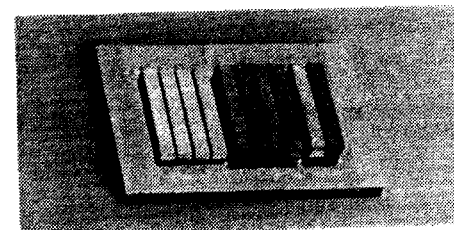
BB/SD



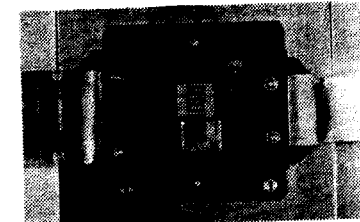
SCAN MOTOR



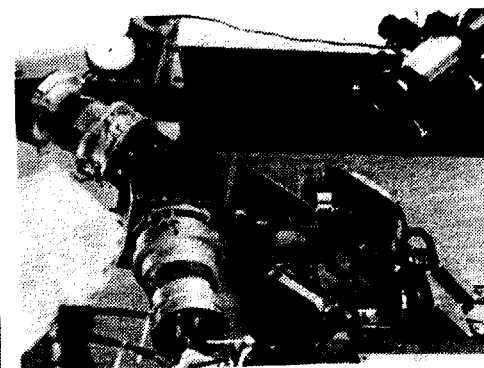
FILTERS / DICHOIRCS



FOCAL PLANES



RE-IMAGING OPTICS





MODIS GROUND SUPPORT EQUIPMENT IN-PLACE

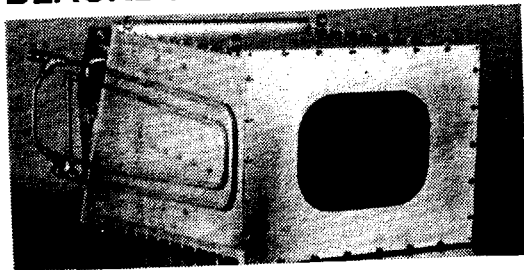
SANTA BARBARA
RESEARCH
CENTER



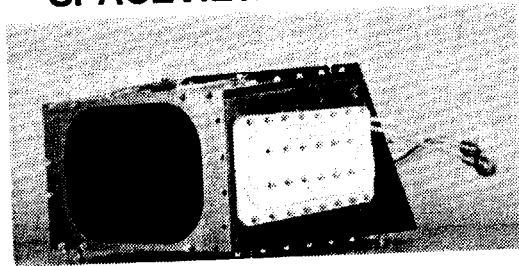
A HUGHES ELECTRONICS COMPANY

95-6-47

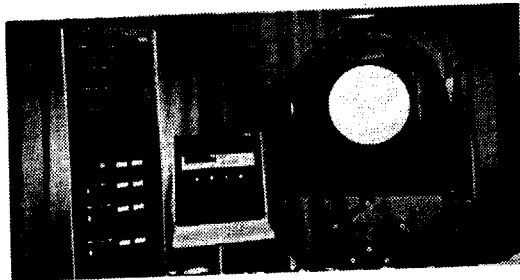
BLACKBODY CAL SOURCE



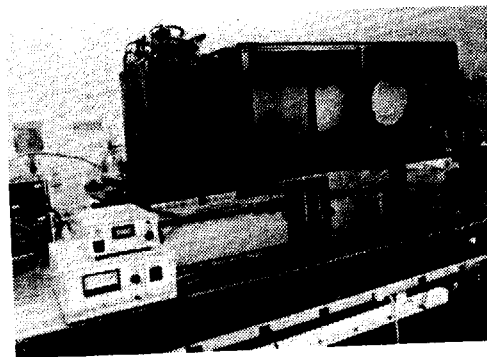
SPACEVIEW SOURCE



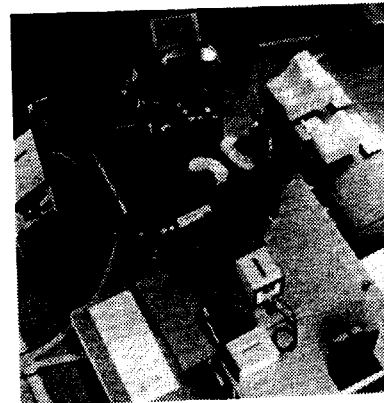
SPHERICAL INTEGRATOR SOURCE



POLARIZED SOURCE ASSY

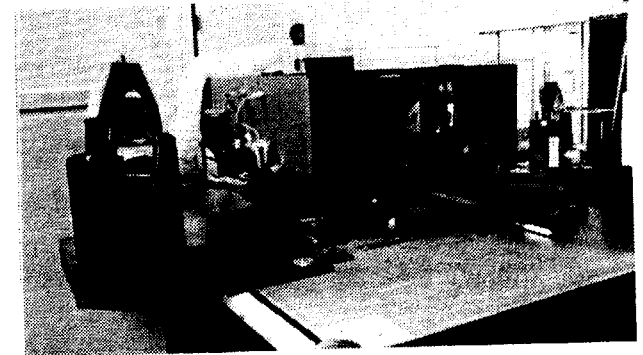


**INTEGRATION AND
ALIGNMENT COLLIMATOR**

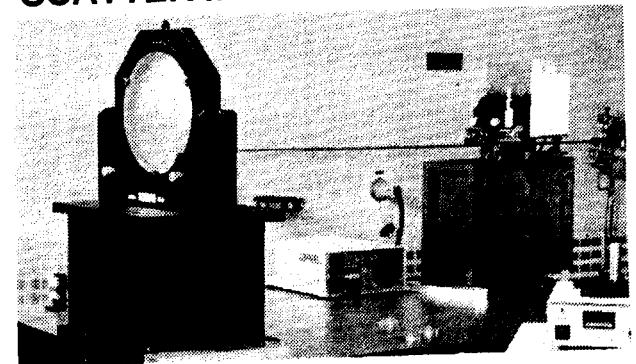


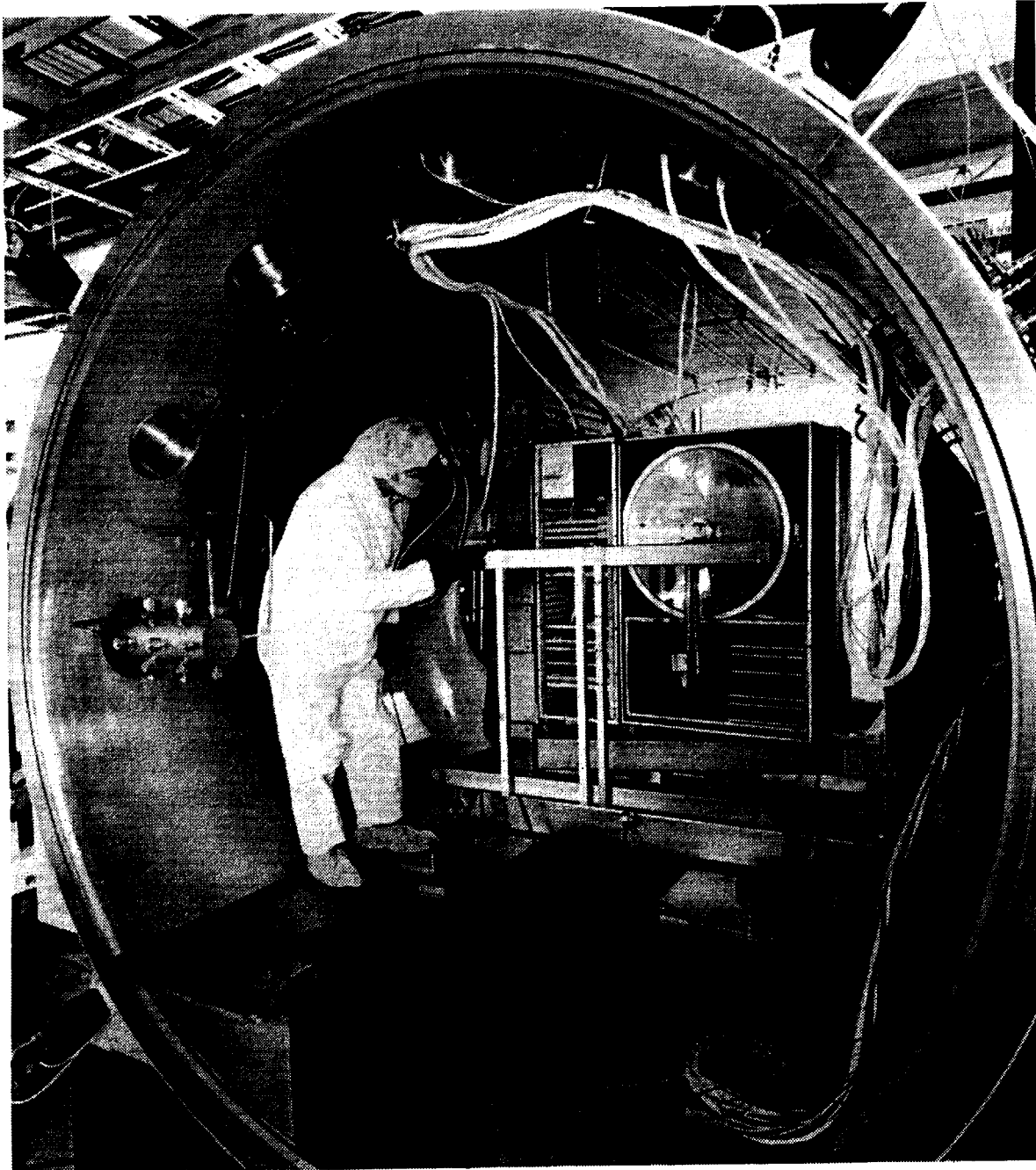
**BENCHTEST COOLER
SYSTEM TEST COMPUTERS**

SPECTRAL MEASUREMENT ASSY



SCATTER MEASUREMENT ASSY





SANTA BARBARA
RESEARCH
CENTER

HUGHES
AIRCRAFT

A HUGHES ELECTRONICS COMPANY

95-3-79(8)

MODIS CALIBRATION CHAMBER DEMONSTRATED ON MODIS EM



MODIS-L PRESERVES HIGH PERFORMANCE



- 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 radiometry, 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: $\pm 64^\circ$ (Full Disk)
- Registration: $< \pm 0.2$ IFOV
- MTF > 0.3 @ Nyquist

Radiometric

- 12 Bit Dynamic Range
- Polarization $< 3\%$
- SNR: $> 300:1$ @ 1% albedo
- $NE\Delta T$: 0.05K @ 12 μm , 300K

LITE ELECTRONICS ACHIEVE SIGNIFICANT WEIGHT REDUCTION RETAIN IMPORTANT CAPABILITIES

SANTA BARBARA
RESEARCH
CENTER



A HUGHES ELECTRONICS COMPANY

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

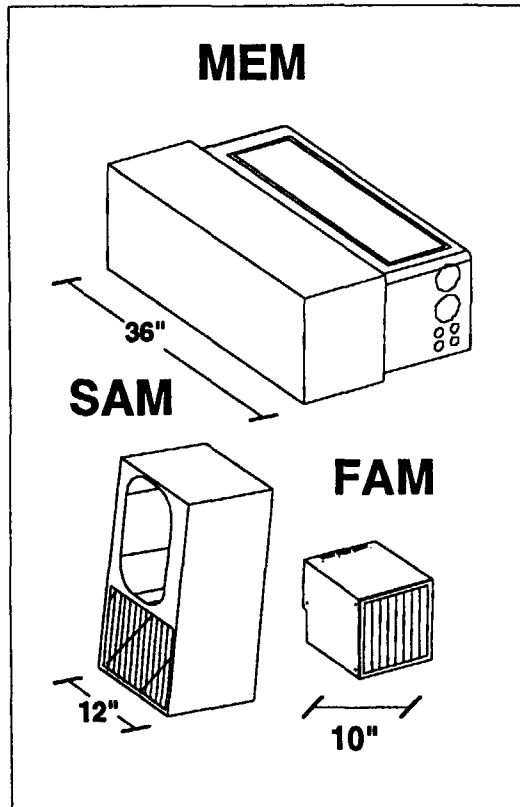
MODIS-L OFFERS SIGNIFICANTLY REDUCED ELECTRONICS VOLUME

SANTA BARBARA
RESEARCH
CENTER



A HUGHES ELECTRONICS COMPANY

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

SANTA BARBARA
RESEARCH
CENTER



A HUGHES ELECTRONICS COMPANY

MECHANICS

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

OPTICS

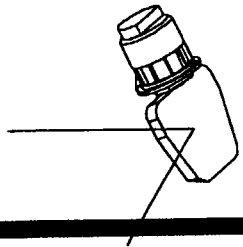
- Latest IAD multi-layer stripe filter technology
- Unprecedented dichroic beamsplitter coatings covering 0.4 - 14.4 μm
- Advanced out-of-band blocking coatings
- Advanced surface treatments for low scatter

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

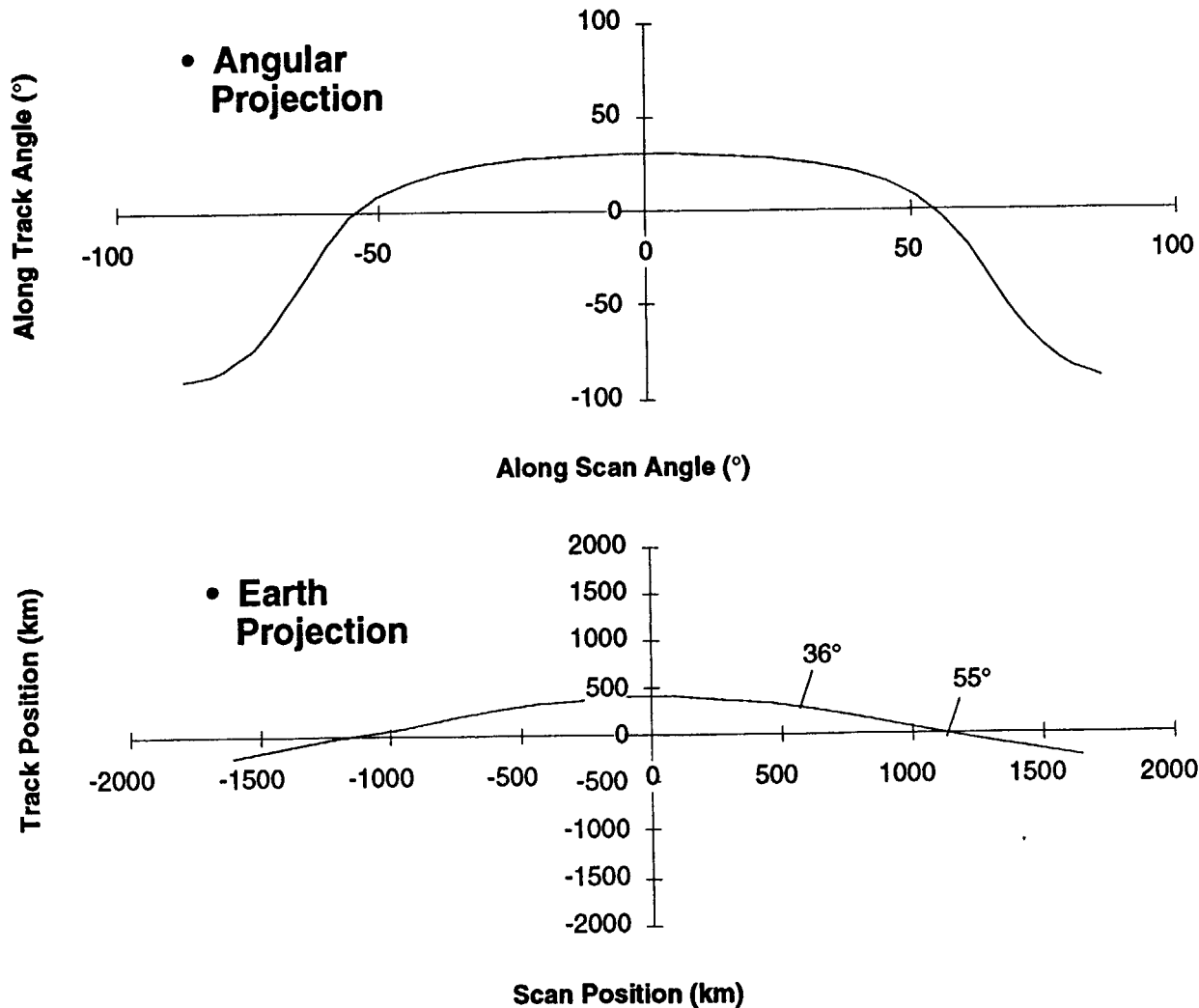


TILTED PADDLE-WHEEL SCAN PRESERVES COREGISTRATION

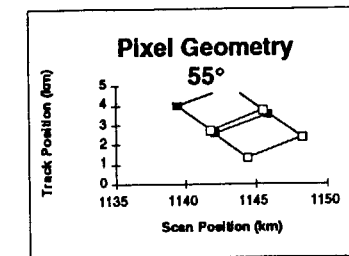
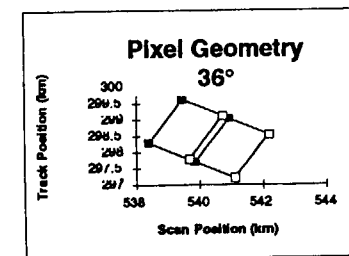
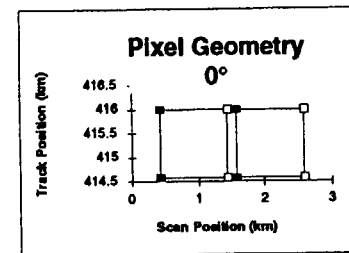
SANTA BARBARA
RESEARCH
CENTER

HUGHES
AIRCRAFT

A HUGHES ELECTRONICS COMPANY



GIFOVs



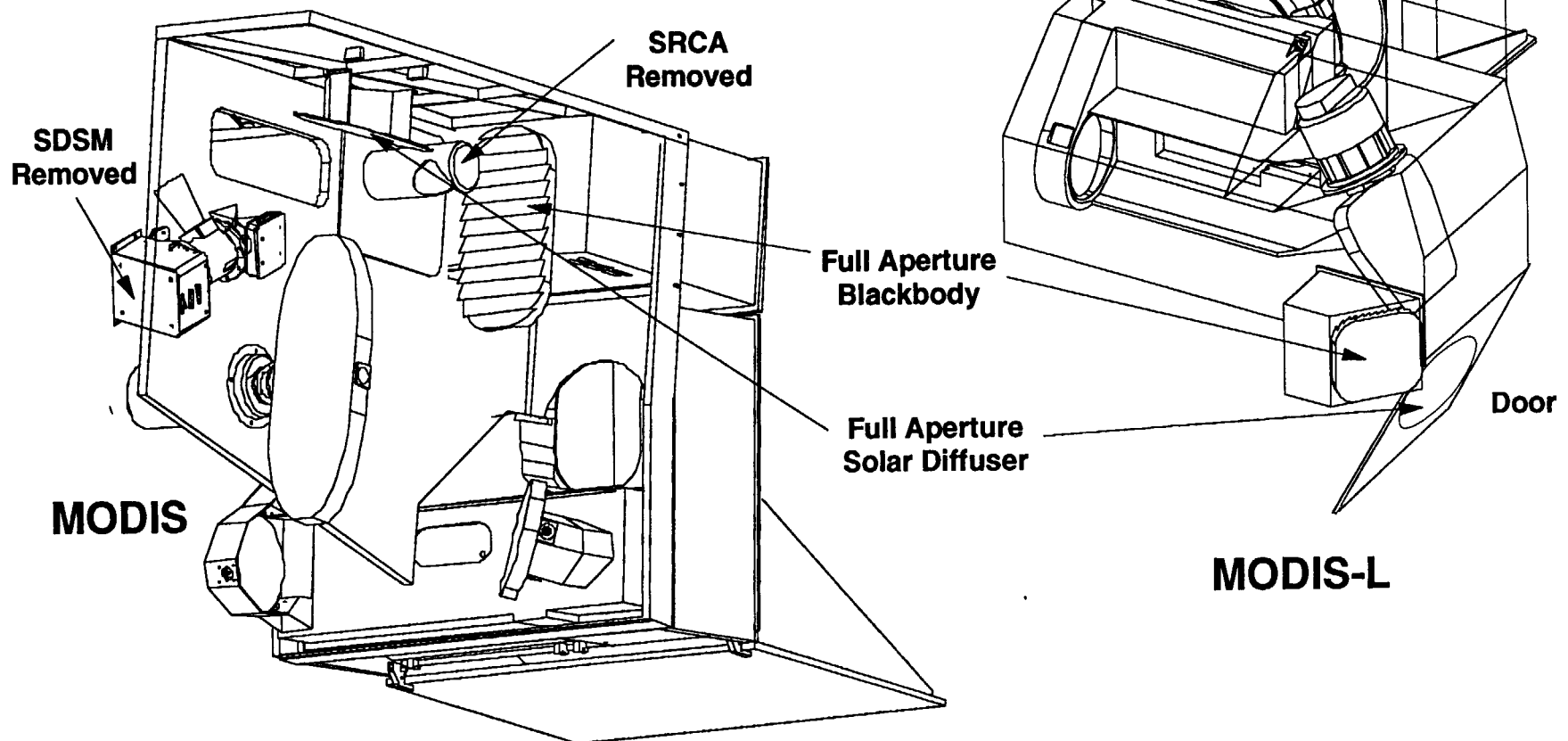
ESSENTIAL FULL-APERTURE RADIMETRIC CALIBRATION PRESERVED

SANTA BARBARA
RESEARCH
CENTER



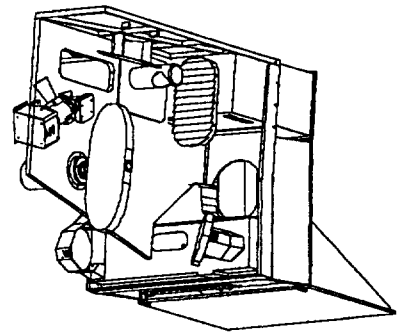
A HUGHES ELECTRONICS COMPANY

- **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**



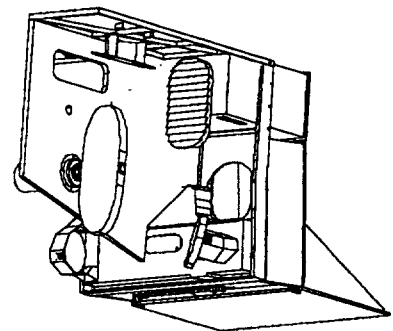
Baseline

- Mass 220 kg
 - Size 1x1x1.6m
 - Power 160W
 - Cost No NRE
 - Bands 36
- Calibration
 - SRCA
 - SDSM
 - SD
 - BB



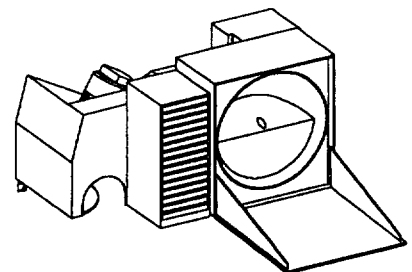
Reduced Calibration Reduced Electronics Redundancy

- Mass 180 kg
 - Volume 1x1x1.6m
 - Power 159W
 - Cost Very Low NRE
 - Bands 36
- Calibration
 - SD
 - BB



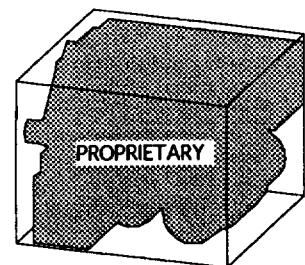
Smaller Scanner Enhanced Electronics

- Mass 100 kg
 - Volume 1x.6x.7m
 - Power 100W
 - Cost Low NRE
 - Bands 36
- Calibration
 - SD
 - BB



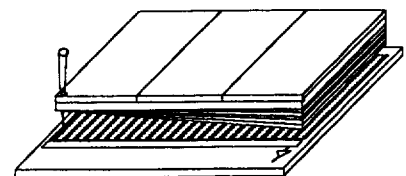
Pushbroom Sensor

- Mass <60 kg
 - Volume .4x.4x.3m
 - Power 60W
 - Cost Med NRE
 - Bands 80
- Calibration
 - SD
 - BB



Hyperspectral Capability

- Mass No Change
 - Volume No Change
 - Power No Change
 - Cost Med NRE
 - Bands As Desired
- Hydice
 - WIS



POLAR ENVIRONMENTAL IMAGER PERFORMANCE COMPARISON

SANTA BARBARA
RESEARCH
CENTER



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 x 0.4m 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 6/90, Final Engineering Report: 2/79								
OLS: Block 5D Compilation, Air Force Systems Command, July 1975								
MODIS: Protflight 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

SANTA BARBARA
RESEARCH
CENTER



A HUGHES ELECTRONICS COMPANY

- **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