

MODERATE RESOLUTION IMAGING SPECTRORADIOMETER - LITE

(MODIS - L)

DESIGN OVERVIEW

November 14, 15, 1995

Thomas S. Pagano



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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 background.

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

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REDUCE COSTS

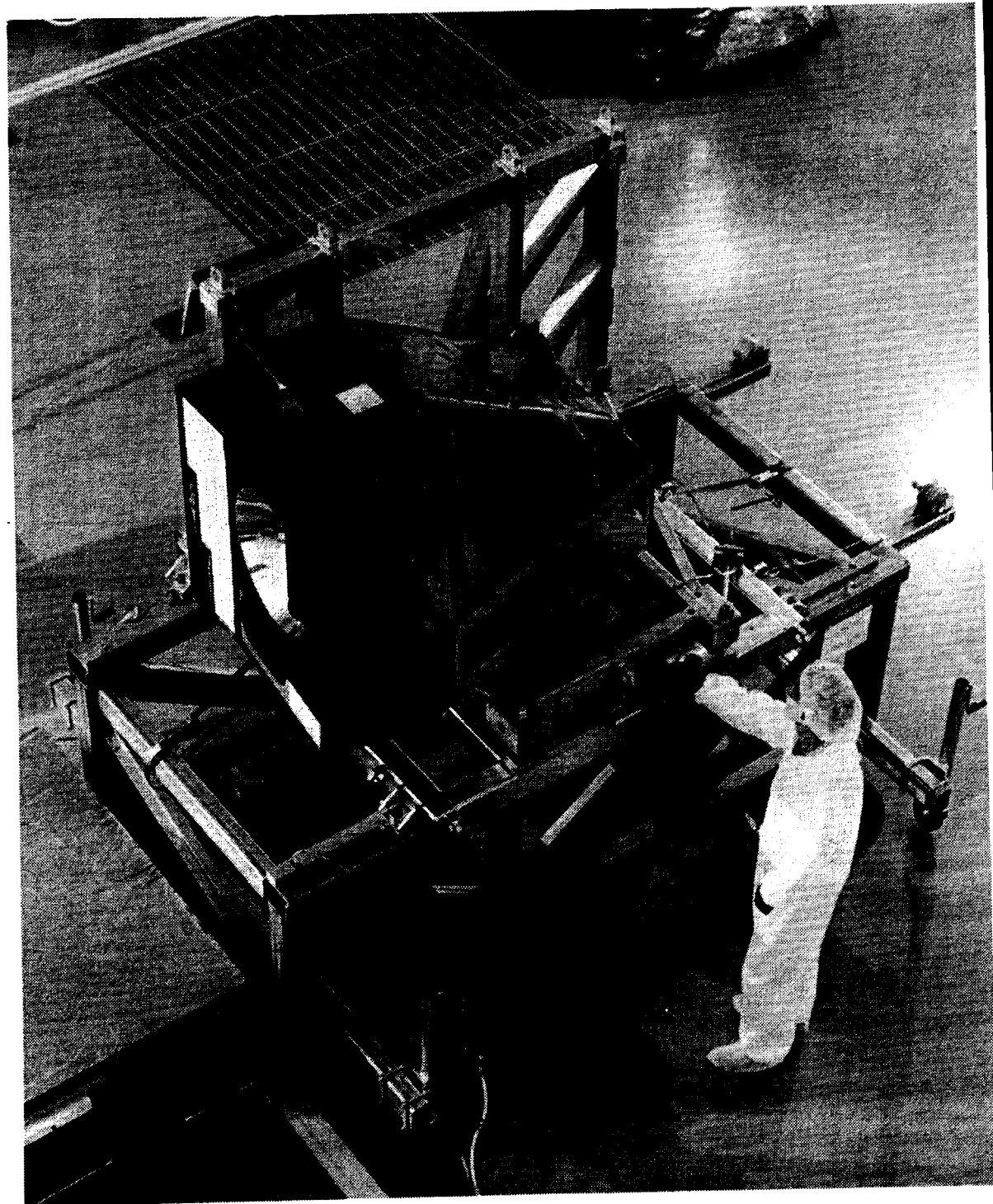
- **Exploit significant NASA investment in MODIS non-recurring design costs**
- **Preserve 6 year design life for low lifecycle costs**
- **Streamline development and documentation process**

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-L BASIC DESIGN ASSUMPTIONS LEAD TO SMALLER PACKAGE

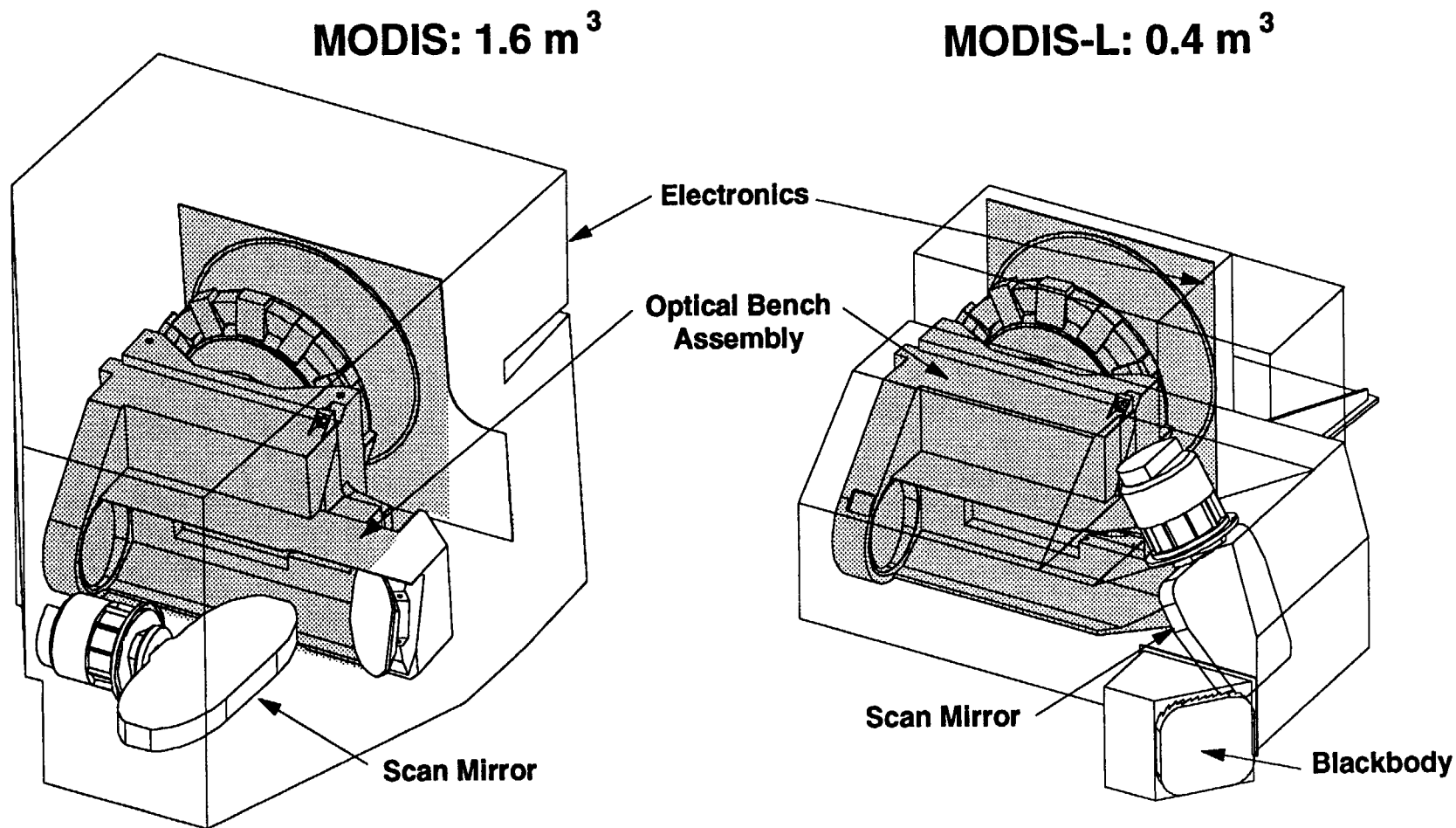
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- **Remove SRCA and SDSM: Reduces viewfactor requirements**
- **Change scan approach: Tilted Paddle Wheel**
- **Repackage electronics: reduced capability, reduced redundancy, new technology employed**
- **Redesign mainframe: smaller structure possibly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

MODIS-L REPRESENTS SMALLER PACKAGE OF MODIS ESSENTIALS



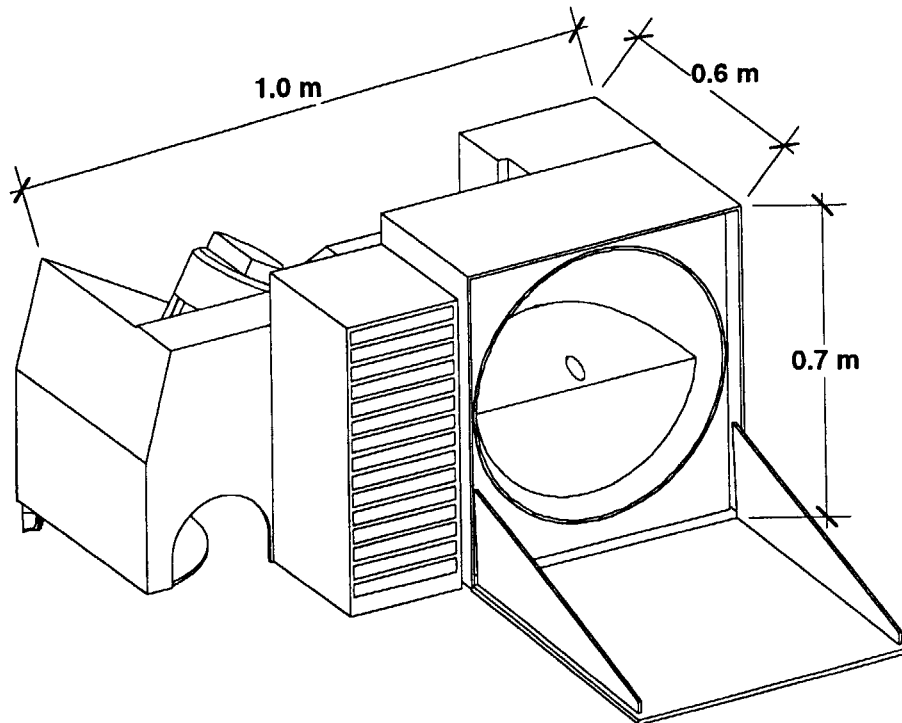
- MODIS-L four times smaller than MODIS

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
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

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

GROUND SUPPORT EQUIPMENT

Fixturing
ScMA
PSA
SpMA
IAC
BCS
SVS
SIS
MCC
STE

Existing
Existing
Existing
Existing
Existing
Existing
Existing
Existing
Existing
Existing

SUPPORT AREAS

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

Minor Revs
Minor Revs
Existing
Minor Revs
Existing
Existing
Existing

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

MODIS OPTICAL BENCH ASSY TRANSFORMED INTO MODIS-L

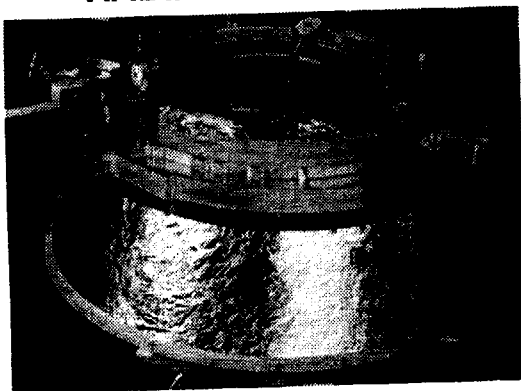
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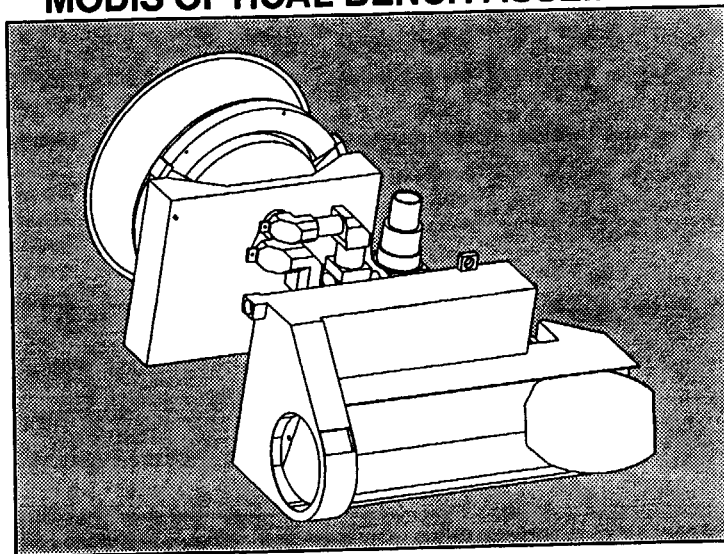
RADIATIVE COOLER



AFOCAL TELESCOPE

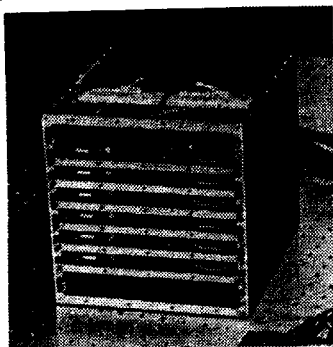


MODIS OPTICAL BENCH ASSEMBLY

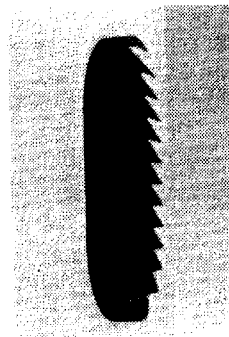


OTHER KEY SUBSYSTEMS USED:

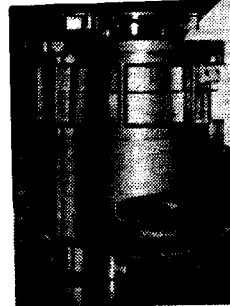
ANALOG ELECTRONICS



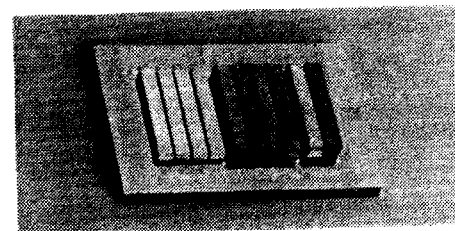
BB/SD



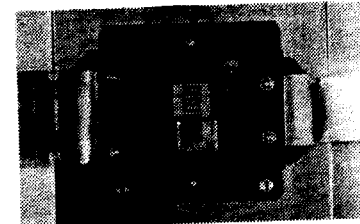
SCAN MOTOR



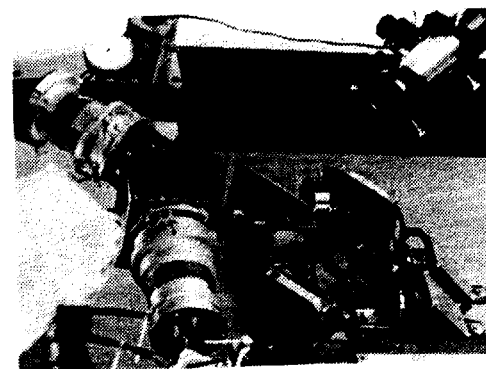
FILTERS / DICHROICS



FOCAL PLANES



RE-IMAGING OPTICS





MODIS GROUND SUPPORT EQUIPMENT IN-PLACE

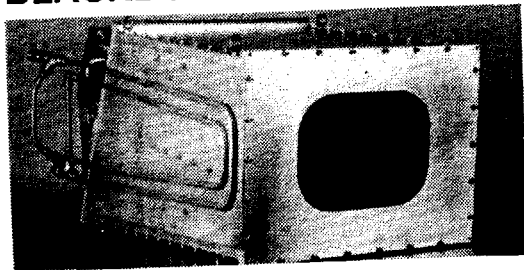
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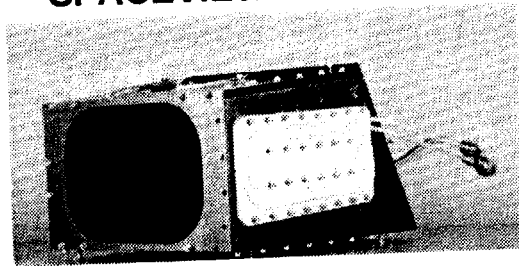
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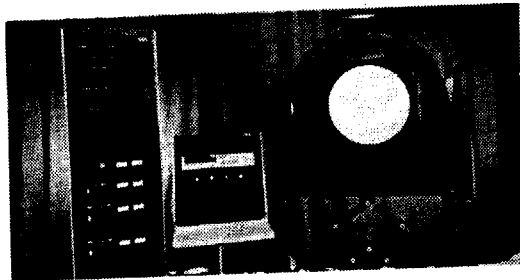
BLACKBODY CAL SOURCE



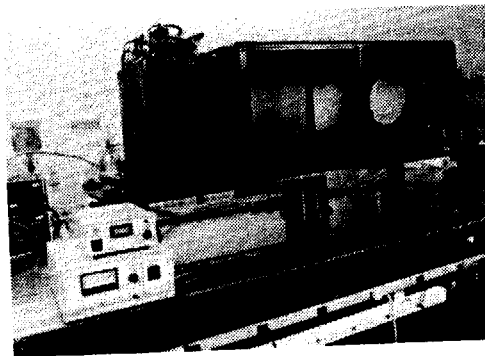
SPACEVIEW SOURCE



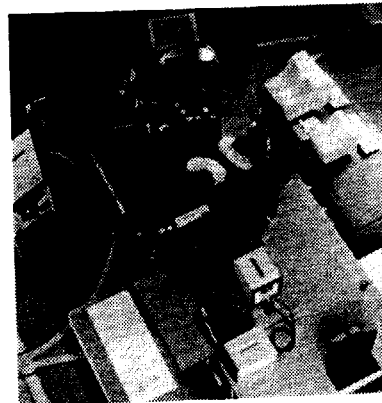
SPHERICAL INTEGRATOR SOURCE



POLARIZED SOURCE ASSY

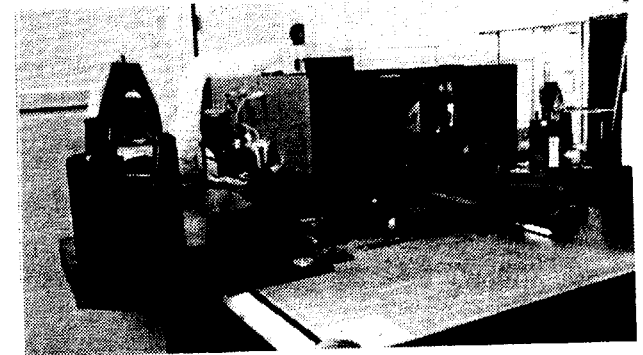


**INTEGRATION AND
ALIGNMENT COLLIMATOR**

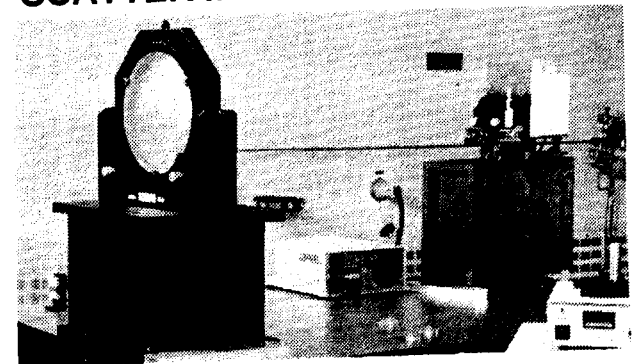


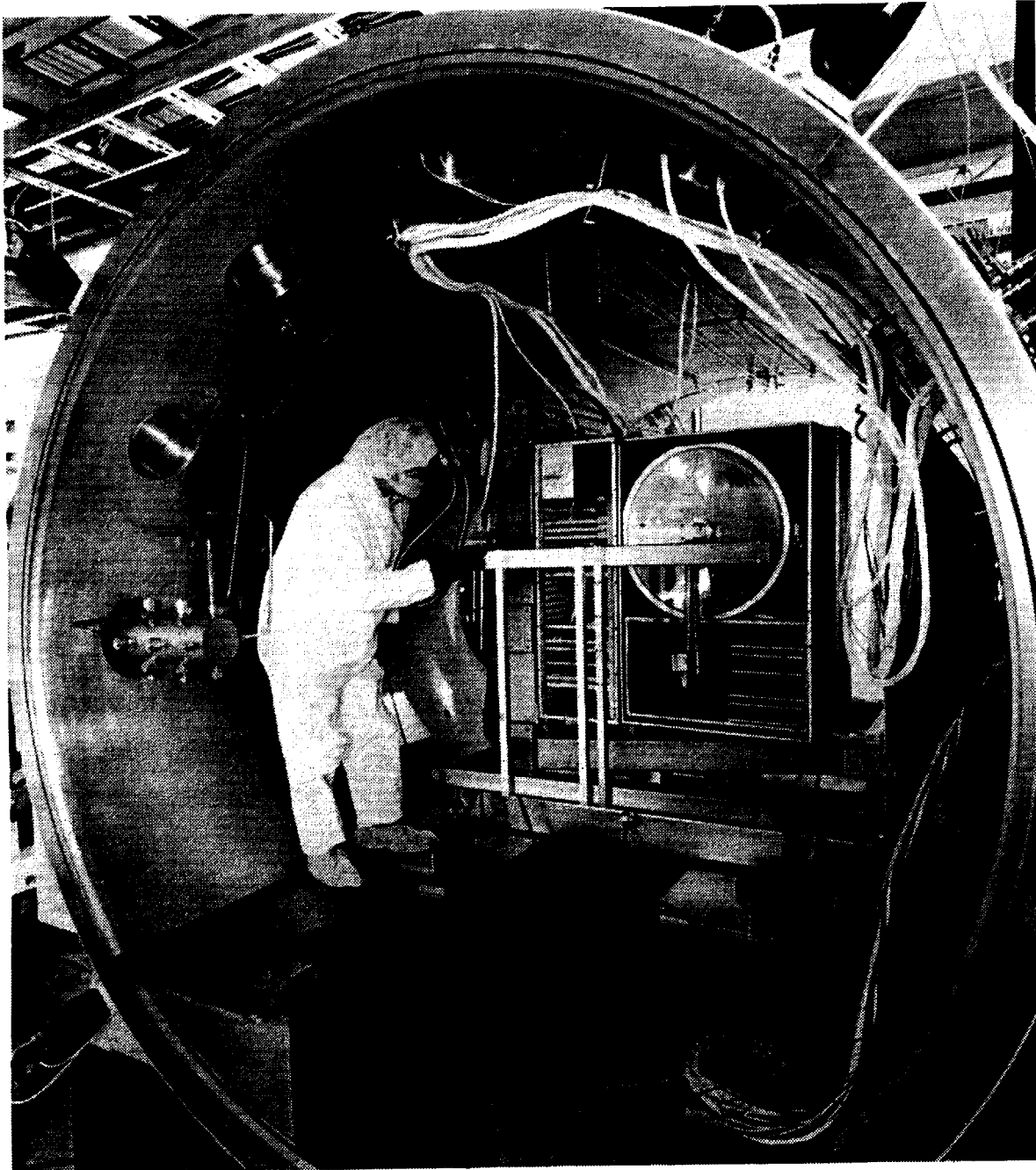
**BENCHTEST COOLER
SYSTEM TEST COMPUTERS**

SPECTRAL MEASUREMENT ASSY



SCATTER MEASUREMENT ASSY





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MODIS CALIBRATION CHAMBER DEMONSTRATED ON MODIS EM



MODIS-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

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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

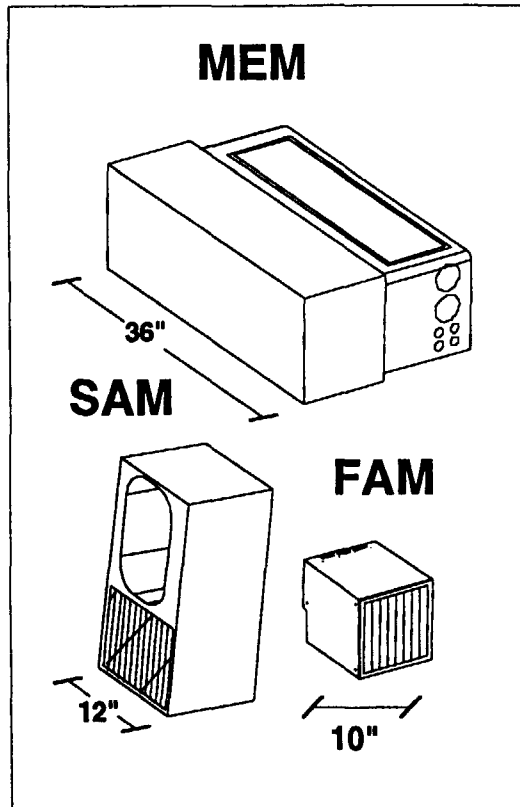
MODIS-L OFFERS SIGNIFICANTLY REDUCED ELECTRONICS VOLUME

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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

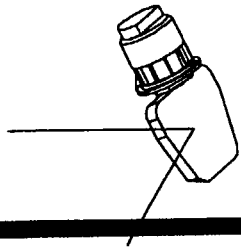
- Latest IAD multi-layer stripe filter technology
- Unprecedented dichroic beamsplitter coatings covering 0.4 - 14.4 μm
- Advanced out-of-band blocking coatings
- Advanced surface treatments for low scatter

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

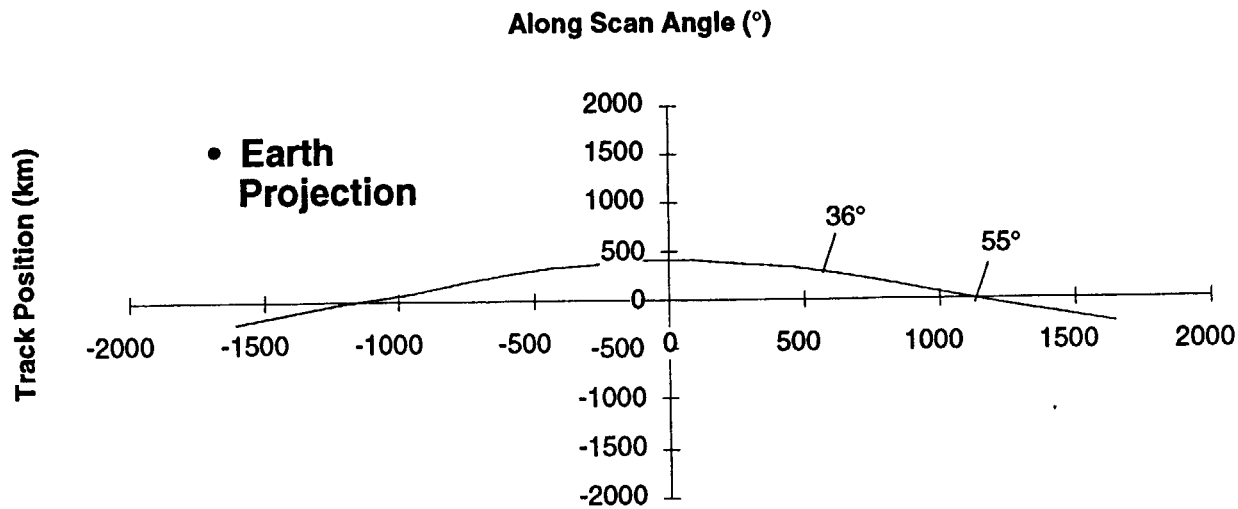
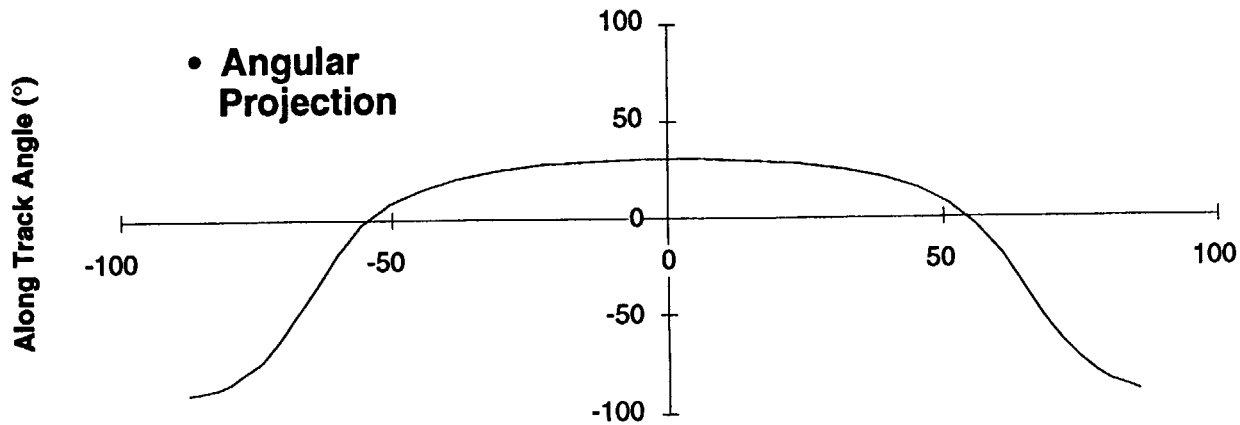


TILTED PADDLE-WHEEL SCAN PRESERVES COREGISTRATION

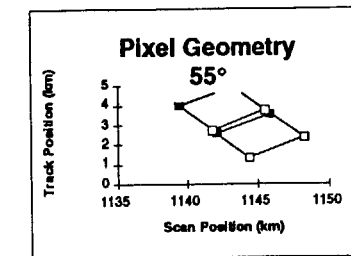
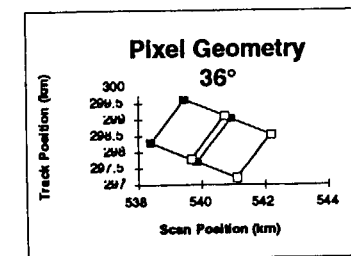
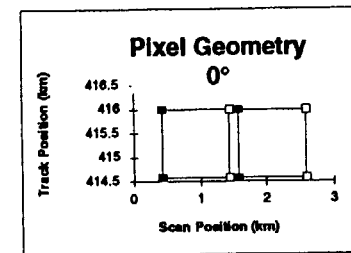
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GIFOVs



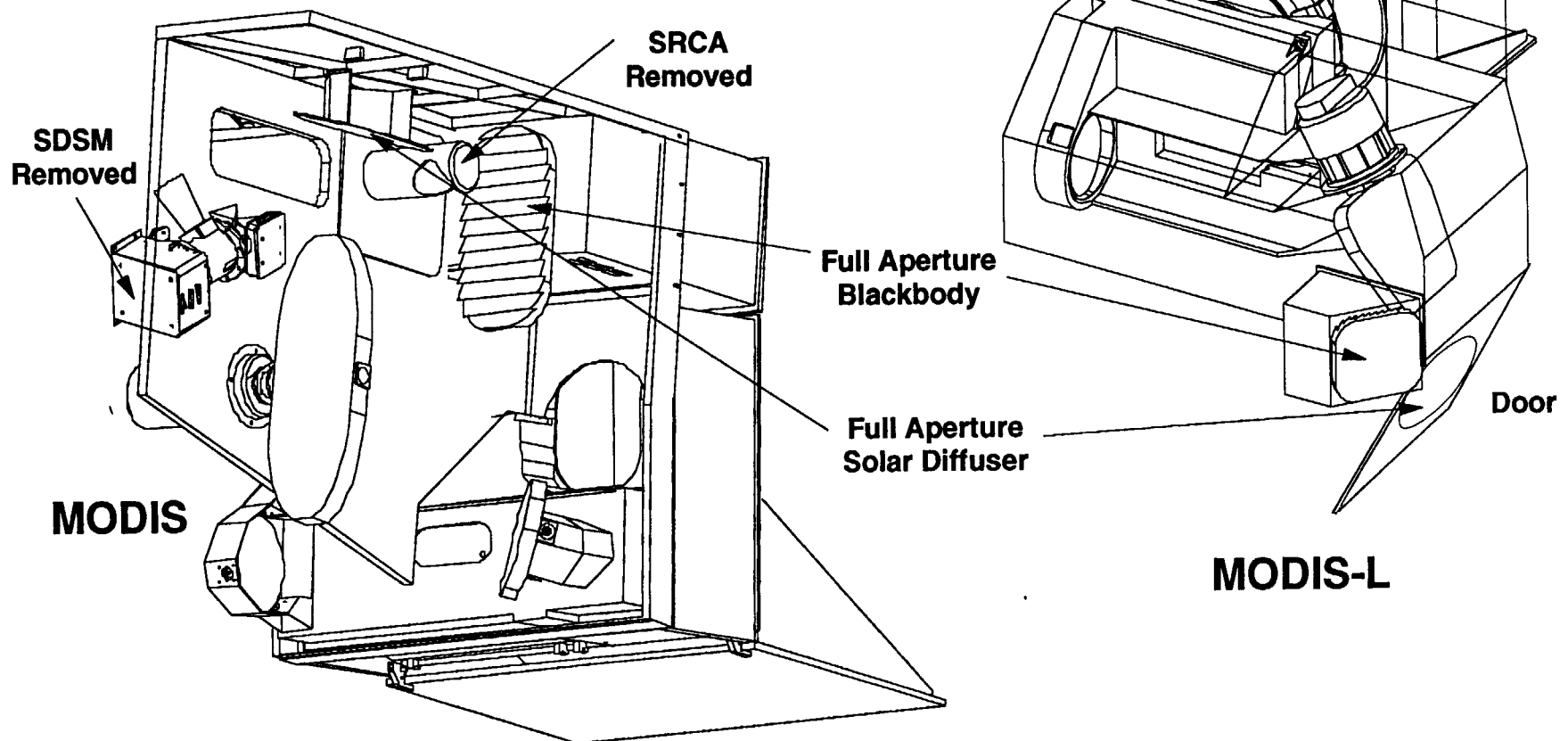
ESSENTIAL FULL-APERTURE RADIMETRIC CALIBRATION PRESERVED

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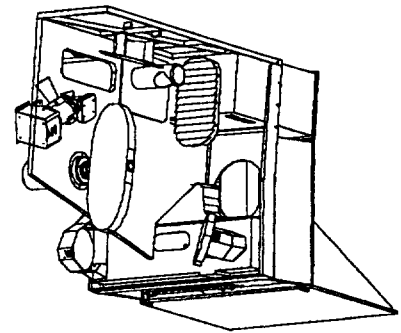
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- **SDSM: Solar Diffuser Stability Monitor; Use ground truth and lunar cal.**
- **SRCA: Spectroradiometric Calibration Assembly: Mitigated by IAD filters**
- **FULL APERTURE SOLAR DIFFUSER AND BLACKBODY PRESERVED**



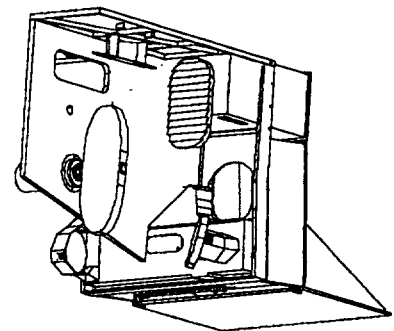
Baseline

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



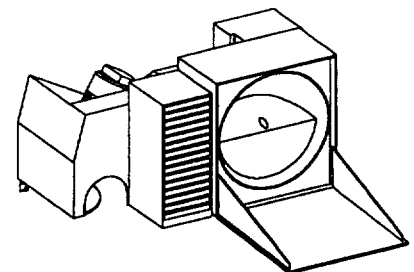
Reduced Calibration Reduced Electronics Redundancy

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



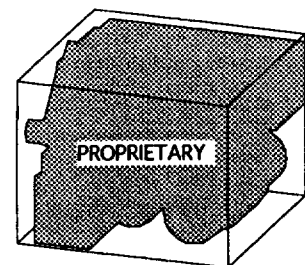
Smaller Scanner Enhanced Electronics

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



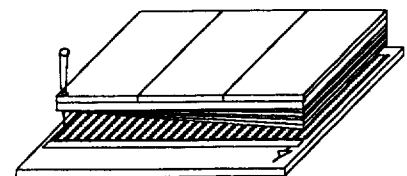
Pushbroom Sensor

- 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

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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 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: Protolight 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