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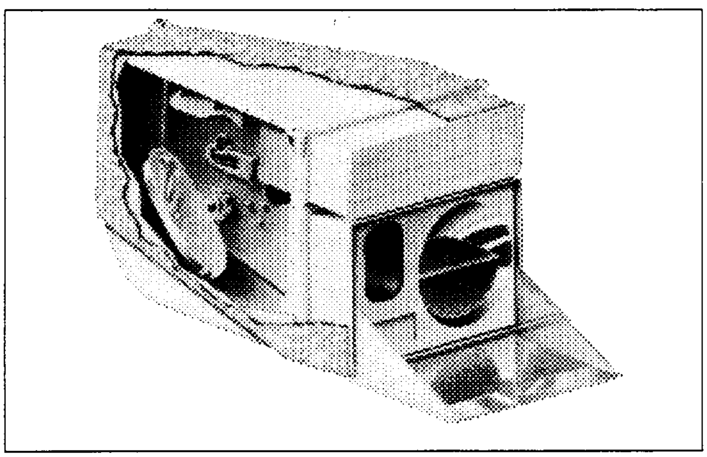
From Santa Barbara Research Center

# MODIS

## Moderate Resolution Imaging Spectroradiometer

With the inception of the U.S. Global Change Research Program, NASA, along with several other government agencies, has been charged with the task of developing a detailed understanding of Earth system processes and their contribution to global climate change. In response, NASA's Mission to Planet Earth consists of the Earth Observing System (EOS) and a variety of other mission elements, including Earth Probes and operational and research satellites. The EOS will combine the means for making observations and interpreting data with a scientific research effort to provide the geophysical, atmospheric, chemical, and biological information necessary for an intense, extended study of our planet. The EOS Data and Information System (EOSDIS), an electronically accessible global data base, will accumulate EOS information over the initial 10 years and then function for at least 15 years at full capacity to allow accurate modeling of the processes that control our environment.

MODIS is the key EOS facility instrument and is planned for launch in 1998. SBRC was awarded a contract by NASA in August 1991 to build three MODIS instruments with an option to build three more.



*The MODIS instrument will be mounted on a front corner of the EOS spacecraft, allowing solar calibration and a clear view of space for radiative cooling and dc restoration.*

The MODIS instrument will acquire data that will improve our understanding of global dynamics and processes occurring on the surface of Earth, in the oceans, and in the lower atmosphere. Specific global survey data products will include:

- Surface temperature with 1-km resolution, day and night, with absolute accuracy goals of 0.25% over oceans and 1% over land
- Ocean color, defined as ocean-leaving spectral radiance (within 5%) from the 415 to 653 nm spectral region, after correction for atmospheric effects, based on data acquired from the sensor's near-infrared channels
- Chlorophyll fluorescence (within 50%) at surface water concentrations of 0.5 mg/m$^3$ of chlorophyll-*a*
- Concentration of chlorophyll-*a* (within 35%)
- Vegetation and land-surface cover, conditions, and productivity, defined as:
  - Net primary productivity, leaf-area index, and intercepted photosynthetically active radiation
  - Land-cover type with identification and detection of change
  - Vegetation indices corrected for atmospheric effects, soil, polarization, and directional effects
  - Snow and sea-ice cover and reflectance
- Cloud and aerosol properties at 500m resolution during the day and 1000m resolution at night
- Total atmospheric water vapor
- Total ozone

The measurements listed above must be made with an extraordinary level of radiometric fidelity and stability over a broad spectral range so that we can be confident that we are measuring the properties of the earth system rather than imperfections in the instrument. Accordingly, a key feature that distinguishes MODIS from prior space sensors is the incorporation of extensive on-board calibration sources for comprehensive end-to-end verification of spatial (geometric), spectral, and radiometric calibration that includes:

- Spectral calibration of channel bandpasses
- Verification of spectral-band registration
- DC restoration on every scan using a direct view of space
- Lunar calibration via the space-view port
- Blackbody calibration of thermal bands on every scan
- Solar diffuser reference
- Solar diffuser stability monitor

These on-board calibration sources will be used in conjunction with pre- and post-launch ground-based references to provide an unprecedented degree of spectroradiometric accuracy. The current design goals are ≤ 3% absolute accuracy in the reflective bands and ≤ 1% in the emissive bands.

In addition to precise radiometry, MODIS' multiplicity of spectral bands represents another significant advance in spaceborne remote sensing. With 36 spectral bands from 0.405 to 14.385 µm, MODIS will provide the spectral detail that is vital to understanding the characteristics of and changes in land cover, the oceans and the atmosphere.

MODIS exploits a rich heritage of SBRC instrument designs including the Landsat Multispectral Scanners, Thematic Mappers and dozens of other space sensors that have accumulated over 250 instrument years of on-orbit performance. This experience provides the basis for achieving the reliability and design-life requirements for MODIS.

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# MODERATE RESOLUTION IMAGING SPECTRORADIOMETER (MODIS)

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## MODIS TECHNICAL SPECIFICATIONS

**Orbit:** 705 km, 10:30 a.m. descending node or 1:30 p.m. ascending node, sun-synchronous, near-polar, circular

**Scan:** 20.3 rpm, cross track

**Scan Width:** 2330 km (cross track) by 10 km (along track)

**Telescope:** 17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop

**Size:** 1.0 x 1.6 x 1.0 m

**Weight:** 250 kg

**Power:** 225 W (orbital average)

**Data Rate:** 11 Mbps (peak daytime)

**Quantization:** 12 bits

**Spatial Resolution: (at nadir)** 250 m (bands 1-2)
500 m (bands 3-7)
1000 m (bands 8-36)

| Primary Use | Band | Bandwidth[1] | Spectral Radiance[2] | Required SNR[3] |
|---|---|---|---|---|
| Land/Cloud Boundaries | 1 | 620 - 670 | 21.8 | 128 |
| | 2 | 841 - 876 | 24.7 | 201 |
| Land/Cloud Properties | 3 | 459 - 479 | 35.3 | 243 |
| | 4 | 545 - 565 | 29.0 | 228 |
| | 5 | 1230 -1250 | 5.4 | 74 |
| | 6 | 1628 -1652 | 7.3 | 275 |
| | 7 | 2105 -2155 | 1.0 | 110 |
| Ocean Color | 8 | 405 - 420 | 44.9 | 880 |
| | 9 | 438 - 448 | 41.9 | 838 |
| | 10 | 483 - 493 | 32.1 | 802 |
| | 11 | 526 - 536 | 27.9 | 754 |
| | 12 | 546 - 556 | 21.0 | 750 |
| | 13 | 662 - 672 | 9.5 | 910 |
| | 14 | 673 - 683 | 8.7 | 1087 |
| | 15 | 743 - 753 | 10.2 | 586 |
| | 16 | 862 - 877 | 6.2 | 516 |
| Atmospheric Water Vapor | 17 | 890 - 920 | 10.0 | 167 |
| | 18 | 931 - 941 | 3.6 | 57 |
| | 19 | 915 - 965 | 15.0 | 250 |

| Primary Use | Band | Bandwidth[1] | Spectral Radiance[2] | Required NEΔT(K)[3] |
|---|---|---|---|---|
| Surface/Cloud Temperature | 20 | 3.66 - 3.84 | 0.45 | 0.05 |
| | 21 | 3.93 - 3.99 | 2.38 | 2.00 |
| | 22 | 3.93 - 3.99 | 0.67 | 0.07 |
| | 23 | 4.02 - 4.08 | 0.79 | 0.07 |
| Atmospheric Temperature | 24 | 4.43 - 4.50 | 0.17 | 0.25 |
| | 25 | 4.48 - 4.55 | 0.59 | 0.25 |
| Cirrus Clouds | 26 | 1.36 - 1.39 | 6.00 | 150[4] |
| Water Vapor | 27 | 6.54 - 6.90 | 1.16 | 0.25 |
| | 28 | 7.18 - 7.48 | 2.18 | 0.25 |
| | 29 | 8.40 - 8.70 | 9.58 | 0.05 |
| Ozone | 30 | 9.58 - 9.88 | 3.69 | 0.25 |
| Surface/Cloud Temperature | 31 | 10.78 -11.28 | 9.55 | 0.05 |
| | 32 | 11.77 -12.27 | 8.94 | 0.05 |
| Cloud Top Altitude | 33 | 13.19 -13.49 | 4.52 | 0.25 |
| | 34 | 13.49 -13.79 | 3.76 | 0.25 |
| | 35 | 13.79 -14.09 | 3.11 | 0.25 |
| | 36 | 14.09 -14.39 | 2.08 | 0.35 |

[1] Bands 1 to 19, nm; Bands 20 to 36, µm [2] ($W/m^2$-µm-sr) [3] Performance goal is 30 to 40% better than required [4] SNR

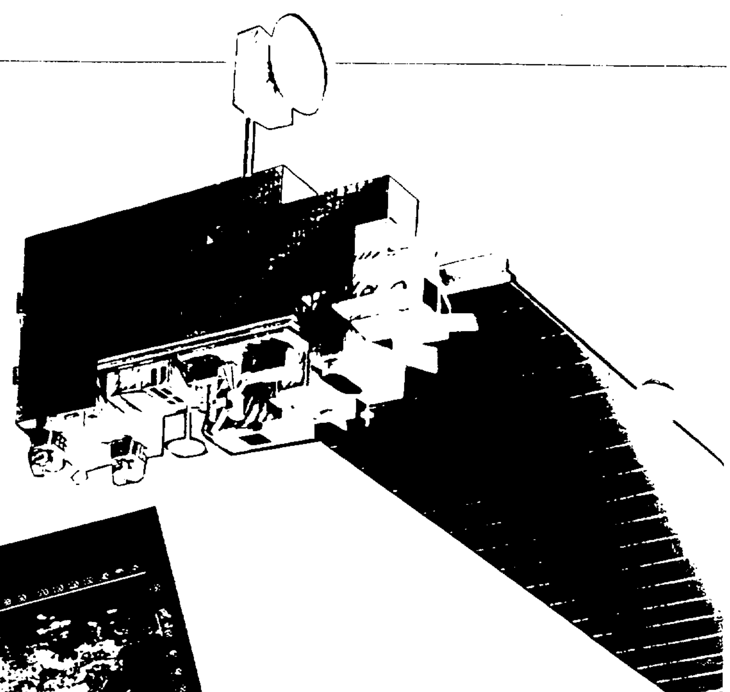
***For more information contact:***

CARL SCHUELER
(805) 562-7155
FAX: (805) 562-7767

# MODERATE RESOLUTION IMAGIN

## Keystone Instrument for the

EOS



# G SPECTRORADIOMETER (MODIS)
# Earth Observing System (EOS)


## MODIS SCIENCE OBJECTIVES

**Vincent V. Salomonson, NASA Goddard Space Flight Center (GSFC), MODIS Science Team Leader**

*The near-daily coverage of MODIS, combined with its continuous operation, broad spectral coverage, and relatively high spatial resolution, make the MODIS instrument central to the objective of EOS. MODIS data products will be provided by the MODIS Science Team members in support of the Earth science community at large and the interdisciplinary investigators, as well as the science team members' own investigations. MODIS observations and data products will be applied to many of the areas identified as EOS science topics, such as:*

- Land surface composition
- Land surface biological activity, phenology, and physical state
- Surface temperature
- Snow and sea-ice extent and character
- Ocean circulation
- Oceans and lakes biological activity
- Aerosol properties
- Cloud properties

### ATMOSPHERE DISCIPLINE GROUP

*There are many satellite systems that provide frequent, regular atmospheric observations. MODIS will also provide a daily survey of cloud cover and atmospheric aerosols, but in a broad set of unique spectral bands to provide additional information from which research can be conducted. This information will be used to identify trends in atmospheric contamination, as well as to provide models of radiative transfer that can be used to correct atmospheric signal corruption for land and ocean observations by MODIS and other instruments.*

**Yoram J. Kaufman, GSFC**
- Aerosol climatology
- Atmospheric corrections
- Aerosol effect of biomass burning
- Aerosol effect on clouds and radiation
- Fire properties/water vapor

**Michael D. King, GSFC**
- Cloud cover
- Cloud optical thickness
- Cloud droplet effective radius

**Paul Menzel, NOAA/NESDIS**
- Cloud cover
- Precipitable water
- Cloud-top pressure
- Water vapor
- Ozone

**Didier Tanre, Laboratoire d'Optique Atmospherique**
- Aerosol properties
- Atmosphere corrections
- Aerosols

### LAND DISCIPLINE GROUP

*MODIS will add to the regular observations provided by the NOAA AVHRR with a large set of additional spectral bands and improved spatial resolution and radiometric accuracy to enable scientific observations of long-term environmental trends associated with land surface change.*

**Alfredo Huete, Univ. of Arizona**
- Vegetation-soil-detritus interactions
- Soil and vegetation indices
- Spectral/temporal mixture modeling

**Christopher O. Justice, Univ. of Maryland**
- Vegetation indices
- Land cover
- Fire properties

**Jan-Peter Muller, Univ. College London**
- Composition of terrestrial surfaces
- 3D structure of terrestrial surfaces
- Simulation modeling

**Steven W. Running, Univ. of Montana**
- Vegetation leaf area index
- Vegetation primary productivity
- Vegetation stress
- Evapotranspiration

**Vincent V. Salomonson, GSFC**
- Snow and ice cover
- Surface radiation budget components
- Dynamics of snow cover
- MODIS calibration

**Alan H. Strahler, Boston Univ.**
- Land cover types and changes
- Land surface reflective characteristics

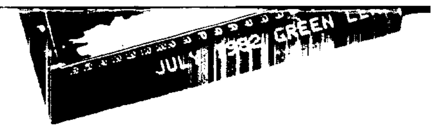
**Vern Vanderbilt, NASA Ames Research Center**
- Polarization vegetation index
- Land surface BRDF

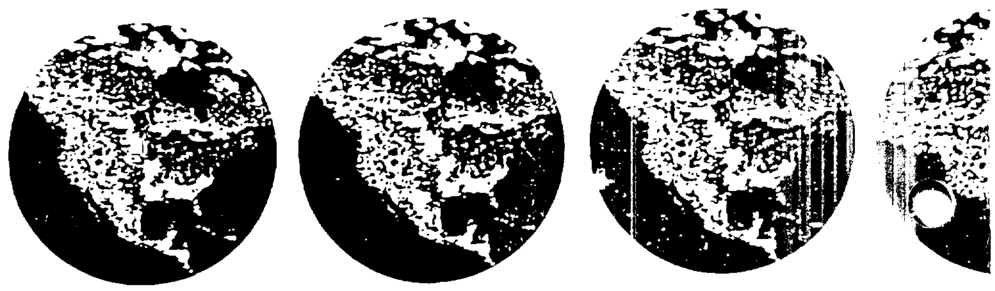
**Zhengming Wan, Univ. of California, Santa Barbara**
- Land surface temperature
- Land surface emissivity

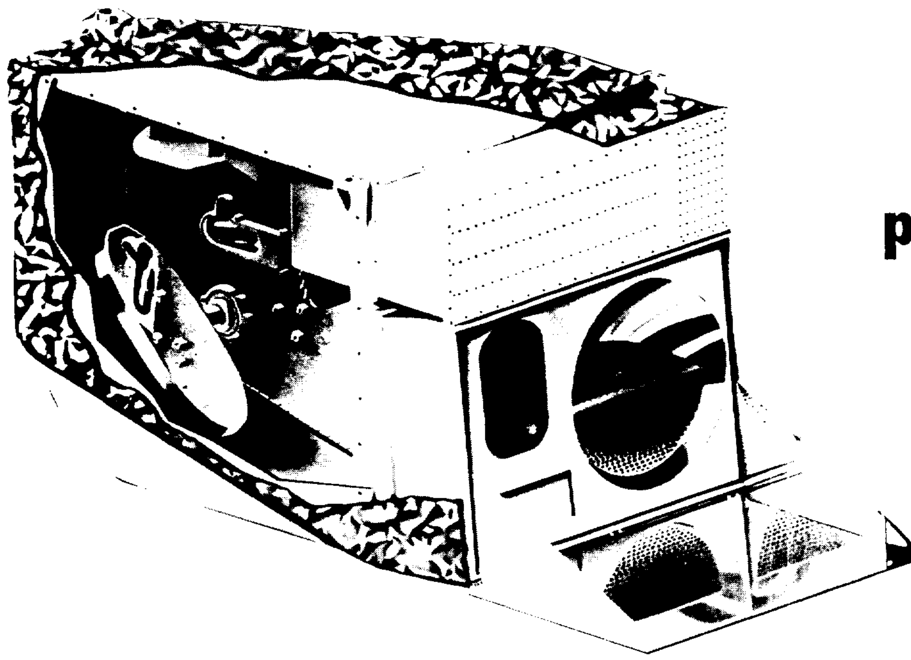
Tech. Team mtg 2/25/93
Attach. #2

### OCEANS DISCIPLINE GROUP

*MODIS will add to the on-going SeaWiFS and EOS-color data sets to be obtained by EOS with a*





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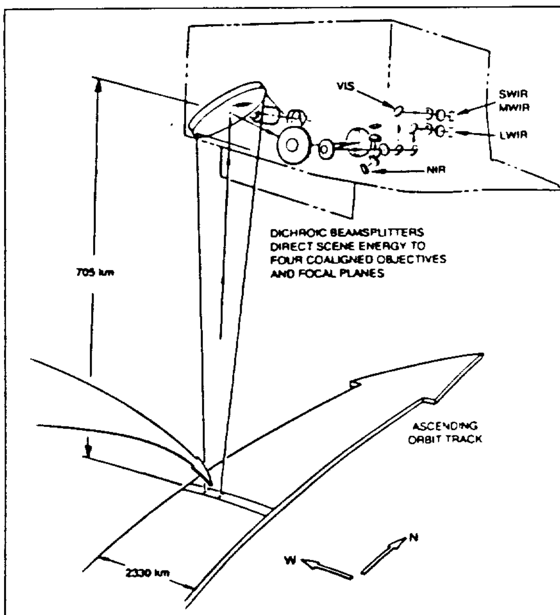


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[1] Bands 1 to 19, nm; Bands 20 to 36, µm    ... µm ...    [3] Performanc

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# l coverage
# by AVHRR,
# and HIRS,
# exploring
# mosphere,
# ›here, and
# oceans

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...top

| ...nd | Bandwidth[1] | Spectral Radiance[2] | Required NEΔT(K)[3] |
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... goal is 30 to 40% better than required   [4] SNR

01592-0730 REV 2/18/93

*substantial ocean spectral sensing capability across the visible to thermal infrared for biomass measurements and sea-surface temperature assessment. These data will be correlated with available ocean ship and data buoy information to obtain improved and calibrated long-term measurements of the ocean surface.*

**Mark R. Abbot, Oregon State Univ.**
- Chlorophyll-a concentration (via fluorescence)
- Near-surface primary ocean productivity via fluorescence

**Ian Barton, CSIRO**
- Land surface emissivity
- Sea surface temperature

**Otis B. Brown, Univ. of Miami**
- Sea-surface temperature

**Kendall L. Carder, Univ. of S. Florida**
- Chlorophyll-a concentration
- Dissolved organic matter concentration

**Dennis K. Clark, NOAA/NESDIS**
- Chlorophyll-a concentration
- Ocean water attenuation coefficients
- Detached coccolith concentration
- Pigment concentration
- Particulate organic matter concentration
- Ocean water suspended solids concentration

**Wayne Esaias, GSFC**
- Primary ocean productivity
- Pigment concentration
- Photosynthetically active radiation

**Robert H. Evans, Univ. of Miami**
- Calibration data

**Howard R. Gordon, Univ. of Miami**
- Sea surface wind velocity
- Sea surface glint pattern, glint field
- Surface photosynthetically active radiation PAR (IPAR)
- Aerosol angstrom exponent
- Aerosol radiance
- Water leaving Level-2 radiance
- Phytoplankton backscatter coefficient
- Coccolith backscatter coefficient
- Ocean water backscatter coefficient
- Detached coccolith concentration
- Ocean water attenuation coefficient (490 nm)

**Frank E. Hoge, Wallops Flight Center**
- Chlorophyll fluorescence line curve
- Pigment concentration via spectral curve
- Colored dissolved organic matter fluorescence efficiency, (CDOM = Gelbstoff)
- Phycobillin pigment concentration

**John Parslow**

## CALIBRATION DISCIPLINE GROUP

*A key feature of MODIS is the incorporation of extensive on-board calibration sources for verifying the accuracy and stability of the instrument. These, as well as pre-launch instrument calibration are required, since data will be collected over the lifetimes of several MODIS instruments necessitating accurate instrument-to-instrument calibration. The calibration discipline group will coordinate the development of instrument calibration with the data requirements of the science data discipline groups to ensure optimum MODIS calibration performance.*

**William L. Barnes, GSFC**
- Instrument calibration

**Philip N. Slater, Univ. of Arizona**
- Absolute radiometric calibration of MODIS

## MODIS SCIENCE DATA PRODUCTS

| | AEROSOL PROPERTIES | CLOUD COVER | CLOUD OPTICAL THICKNESS | CLOUD EFFECTIVE RADIUS | CLOUD TOP PRESSURE | PRECIPITABLE WATER | VEGETATIVE INDICES | VEGETATION LEAF AREA INDEX | VEGETATION GROWING SEASON DURATION | PRIMARY VEGETATION PRODUCTIVITY | VEGETATION STRESS | LAND COVER TYPE/CHANGE | LAND SURFACE CHARACTERISTICS | FIRE PRODUCTS | SNOW COVER | SEA ICE EXTENT | SEA SURFACE TEMPERATURE | PRIMARY OCEAN PRODUCTIVITY | OCEAN SURFACE WIND SPEED | CALIBRATION DATA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABBOTT, M. | | | | | | | | | | | | | | | | | | O | | |
| BARNES, W. | | | | | | | | | | | | | | | | | | | | Δ |
| BARTON, I. | | | | | | | | | | | | | | | | | O | | | |
| BROWN, O. | | | | | | | | | | | | | | | | | O | | | |
| CARDER, K. | | | | | | | | | | | | | | | | | | Δ | | |
| CLARK, D. | | | | | | | | | | | | | | | | | | Δ | | |
| ESAIAS, W. | | | | | | | | | | | | | | | | | | O | | |
| EVANS, R. | | | | | | | | | | | | | | | | | | | | O |
| GORDON, H. | Δ | | | | | | | | | | | | | | | | | Δ | O | |
| HOGE, F. | | | | | | | | | | | | | | | | | | Δ | | |
| HUETE, A. | | | | | | | O | O | | O | O | O | | | | | | | | |
| JUSTICE, C. | | | | | | | O | | O | | | O | | O | | | | | | |
| KAUFMAN, Y. | O | | | | | O | O | | | | | | | O | | | | | | |
| KING, M. | | O | O | O | | | | | | | | | | | | | | | | |
| MENZEL, P. | | Δ | Δ | Δ | O | O | | | | | | | | | | | | | | |
| MULLER, J. | | Δ | | | | | Δ | Δ | Δ | Δ | Δ | Δ | O | | | | | | | |
| PARSLOW, J. | | | | | | | | | | | | | | | | | | Δ | | |
| RUNNING, S. | | | | | | | | O | | O | O | | | | | | | | | |
| SALOMONSON, V. | | | | | | | | | | | | | O | | O | O | | | | O |
| SLATER, P. | | | | | | | | | | | | | | | | | | | | O |
| STRAHLER, A. | | | | | | | | | | | | O | | | | | | | | |
| TANRE, D. | O | | | | | O | O | | | | | | | | | | | | | |
| VANDERBILT, V. | | | | | | | O | | | | | | O | | | | | | | |
| WAN, Z. | | | | | | | | | | | | | O | | | | | | | |

O FINAL DATA PRODUCT   Δ INTERIM DATA PRODUCTS

ART92-0670 FIG 4

# Overview of the MODIS Instrument's On-board Calibration Systems

MODIS is a demanding and challenging instrument. The instrument performance and data products derived from MODIS must be carefully verified if those products are to be useful to the EOS program for detecting global climate change. Consequently, the on-board calibrator systems for MODIS are equal partners to the instrument performance for meeting the mission objectives. Mulptiple calibrators are required to provide adequate calibration/characterization of the instrument's radiometric, geometric and spectral performance over time frames from seconds to years. This note includes several paragraphs about the on-board calibrators to highlight their usefulness to the program. The cooled portion of the SDSM has been deleted because the proposed complexity was not justified. Tables describing these on-board calibrators and how they function are included at the end of the text. The calibration (including the verification of that calibration) required for MODIS is significantly more demanding than for any previously built earth imager.

The blackbody and space view port are essential for calibration of the MODIS emissive bands. Questions remain about the detailed design of the blackbody front surface. The baseline design may be too sensitive to temperature gradients within the scan cavity. SBRC will look at this design in detail in Spring, 1993, and GSFC is undertaking an in-house blackbody testing program for the baseline design and at least two alternative designs. The alternative designs would be somewhat heavier, and thicker, but no significant disruption of the interface between the blackbody and the scan cavity walls is expected. We have good confidence that the enhanced blackbody designs will be adequate for the MODIS measurement accuracy needs.

For wavelengths below 2.5 micrometers the Level-2 data products will be developed from reflectance rather than radiance data. The use of a diffuser is essential to providing accurate reflectance quantities. The use of a diffuser for reflected solar energy also allows for less strict performance requirements for the measurement of radiance. The diffuser and the scattering screen are not particularly demanding engineering systems. The quality of the reflected solar data sets is strongly controlled by our long-term understanding of the characteristics of the diffuser scattering surface. Consequently, a system to track the diffuser behavior (over periods up to a few months) is required.

This requirement is met by the Solar Diffuser Stability Monitor (SDSM), which includes a three position mirror mechanism, an integrator and a set of filter-diode radiometers. (This system could be equally well named the Solar Diffuser Degradation Monitor, since we expect the diffuser will degrade with time in orbit.) Contamination is expected to be the greatest at the beginning of the mission, so reliance on the diffuser-checking performance of the SDSM is expected to decrease during the lifetime of the mission. The SDSM is very important to the mission at the beginning of each flight when there is no baseline behavior of the MODIS-diffuser system to solar input; this reliance is somewhat reduced when the a database of lunar observations can be used to verify the diffuser degradation. The initial design for this system included cooled photodiode detectors to track diffuser performance in the near infrared. The Goddard Science and the SBRC Instrument teams have agreed to delete the cooled detectors from this subsystem.



Tech Team mtg 2/25/93

Contamination and degradation of the diffuser scattering surface is expected to be similar to a thin-film type of behavior, where the effect is strongest at the shortest wavelengths. Thus, the engineering challenge to use cooled detectors to cover the wavelength region beyond about 1.5 micrometers is considered less useful. The MODIS Science Team and the SBRC Team have agreed to delete the cooled detectors from the SDSM.

The Spectroradiometric Calibration Assembly (SRCA) is the most complex of the MODIS on-board calibrators. The SRCA includes three functional components: spectral, radiometric and geometric.

The spectral subsystem is necessary (a) because we are not confident the short wavelength filter/dichroic systems will remain within specification, and (b) because spectral errors are much more difficult to detect and correct for than the radiometric or geometric errors. Again, since verification of the instrument behavior is needed for EOS science objectives, the determination of the in-orbit spectral properties is necessary. (Frankly, we believe we may have made a mistake in not having spectral verification for the thermal emission channels. If studies show that these filters degrade with radiation effects at our operating temperatures, then we will be very concerned.) The spectral subsystem is "self-calibrating" with the use of didymium at the exit slit. This component will verify the location of the spectrometer gratings.

The science requirements demand calibration of MODIS in absolute (SI) units. The ground calibration will be transferred to the SRCA radiance component, and this will be used to verify the instrument calibration in orbit. The radiance component will be tracked primarily with an on-board photodiode, and verified with current-stabilize lamp sources. Ability to measure launch effects on the MODIS instrument are essential to meeting the radiance calibration accuracy requirements.

MODIS Level-2 data sets will be produced at the intrinsic instrument resolution. The geometric capability of the SRCA allows for cross-track registration (and along-track registration at a reduced accuracy from the cross-track) of the pixels and has become integral to meeting the in-orbit registration requirements. The in-orbit registration is accomplished through illumination of a reticle pattern at the spectrometer exit slit. Following analysis of the calibration data ground commands are given to adjust the phase of the detector readouts, providing cross-track registration of the calibration data. The complexity of the SRCA due to the geometric capability is a blackbody radiator and a reticle at the exit slit position. The geometric capability for the SRCA does not require additional mechanisms, given that a filter wheel at the spectrometer exit slit is in the design already. This filter wheel is there to allow for spectrometer "self-calibration" through the use of didymium or other colored glass filter.

In conclusion, the calibration of MODIS is required to meet the mission science, and the in-orbit calibrators proposed by SBRC are integral to meeting those requirements. The following Tables provide more detail on the specific capabilities of each system.

# MODIS ON-BOARD CALIBRATORS

## BLACK BODY/SPACE VIEW

| SUB-SYSTEM | FUNCTIONAL REQUIREMENTS | PROBLEMS | MITIGATING APPROACHES/ISSUES |
|---|---|---|---|
| Space view aperture | Provide gain and offset corrections once per scan line, with no degradation over the life of the mission. | No likely degradation mechanism.<br>The aperture may have an adverse effect on the scan cavity's thermal stability. | NVA* for use throughout mission lifetime |
| Blackbody (thermal emission only) | Provide gain and offset corrections once per scan line<br>-----------------<br>Provide stable gain corrections over periods from minutes to months | No likely problems on a per-scan basis.<br>--------------------<br>Source of error if sensitive to scan cavity temperature gradients and thermal loading<br><br>Emissivity changes may introduce errors if the scan cavity has temperature gradient | NVA*<br><br>----------------------------<br>May be able to verify this using scan cavity walls<br><br>could use vicarious methods; might need new aircraft instrument |

*No Viable Alternative

# MODIS ON-BOARD CALIBRATORS

## DIFFUSER

| SUB-SYSTEM | FUNCTIONAL REQUIREMENTS | PROBLEMS | MITIGATING APPROACHES/ISSUES |
|---|---|---|---|
| Diffuser scattering surface (reflected solar only) | Characterize the instrument sensitivity to the incident solar spectrum; stable over periods from one orbit to a few months.<br>--------------------<br>Provide cross-calibration among MODIS sensors (AM1 to PM1 to AM2, etc). | Surface contamination and solarization can degrade the scattering surface after a cumulative exposure period of weeks to months, resulting in a degradation of accuracy.<br>--------------------<br>requires very good MODIS system-level reflectance calibrations | *NVA*<br>Most accurate for orbit to orbit performance; requires SDSM for periods up to few months; requires lunar observations or SRCA for periods over months<br>-------------------<br>Pre-launch scattering surface BRDF calibrations will be made to high accuracy; it is not known how to do MODIS system-level (large aperture) calibrations to the required accuracy |

*No Viable Alternative

# MODIS ON-BOARD CALIBRATORS

## SDSM

| SUB-SYSTEM | FUNCTIONAL REQUIREMENTS | PROBLEMS | MITIGATING APPROACHES/ISSUES |
|---|---|---|---|
| Integrator and uncooled detectors | Determine stability of diffuser surface over periods up to few months (0.4 to 1.0 μm) | Diffuser degradation in both total hemispherical and BRDF characteristics | NVA* to track diffuser performance; more similar the viewing angles the better the experiment |
| Integrator and cooled detectors | Determine stability of diffuser surface over periods up to few months (1.0 to 2.5 μm) | Required thermoelectric coolers | Contamination of diffuser is linear with wavelength; the longer wavelengths are expected to change much more slowly; **agreed that this will be deleted** |

*No Viable Alternative

# MODIS ON-BOARD CALIBRATORS

## SRCA(page 1 of 2)

| SUB-SYSTEM | FUNCTIONAL REQUIREMENTS | PROBLEMS | MITIGATING APPROACHES/ISSUES |
|---|---|---|---|
| Spectral (reflected solar only) | Measure air-to-vacuum shifts for filters. These would probably be due to water adsorption.<br>------------------<br>Monitor long-term degradation of filters/dichroics | Air-to-vacuum shifts are likely to occur from hours up to a few months.<br>--------------------- | Test for air-to-vacuum shifts at subsystem level<br>----------------------<br>NVA*<br>There is no experience at discriminating between radiometric and spectral changes.<br><br>There is no evidence filters/dichroics stable over this time frame<br><br>Spectral changes are the most difficult change to detect with vicarious methods; the filters are the most likely source of drift in Level 2 products for periods ≥ a few months |

*No Viable Alternative

# MODIS ON-BOARD CALIBRATORS

## SRCA (page 2 of 2)

| SUB-SYSTEM | FUNCTIONAL REQUIREMENTS | PROBLEMS | MITIGATING APPROACHES/ISSUES |
|---|---|---|---|
| Radiometric | Temperature effects over an orbit, sensitivity to particle and fields space environment<br>--------------------<br>Provide a back-up in case of solar diffuser degradation<br>--------------------<br>based on good spectral characterization<br>--------------------<br>traceability to SI units | If we see unknown behavior, would expect to determine analytic description of it within 3 months | Temperature effects poorly characterized during instrument thermal vacuum testing; little useful particle and field testing in T/V chamber<br>----------------------------<br>also could use SDSM and moon as this back-up; amenable to vicarious calibrations |
| Geometric | Track alignment errors due to launch shifts; required for implementing on-board registration | Likely to need only for first few months of orbit | NVA*;<br>There would be no way to verify our choices.<br>We may want different registration selection 6-12 months after launch when products have been validated |

*No Viable Alternative

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Chief of Division Dr G. B. Tucker

December 21, 1992

First IVOS Meeting Attendees
IVOS Sub-Group Members

Dear Colleague,

Please find attached the minutes of the first meeting of the Infrared and Visible Optical Sensors Sub-Group of the CEOS Working Group on Calibration and Validation.

I would like to thank NOAA and Walter Planet for assisting with the arrangements of this first meeting, and also all those who attended. I believe we have made a good start to a productive sub-group.

Please note that the next meeting will be held at ISPRA in Italy 30 May-1 June 1993, just preceding the CEOS WGCV meeting to be held on the following three days.

Yours sincerely,

Ian Barton

(Ian J. Barton, E-mail: barton@larry.dar.csiro.au)

Tech Team Mtg 2/25/93

## Minutes of the First CEOS WGCV Sub-Group on Infrared and Visible Optical Sensors.

NOAA Science Centre, Camp Springs, Md., November 30 - December 1, 1992.

### Agenda

Monday 30 Nov.
1000 Welcome
1010 Review of agenda items
1020 Brief member introductions and reports
1100 Description of CEOS and WGCV - Susan Till
        Review terms of reference for IVOS
1130 Outline of meeting objectives
1215 Lunch
1315 Pathfinder presentations - NOAA
1430 On-board calibration techniques - ATSR-2, MODIS, LANDSAT
1630 ISY SST group
1700 Funding
1730 Close

Tuesday 1 Dec.
0830 Review of yesterday's discussion
0900 MODIS calibration activities, NASA
0930 Discussion on IVOS initial activities
1100 Action items
1200 Revisit terms of reference
1215 Lunch
1315 Further discussion on action items and activities
1415 Wind-up discussion. Next meeting, communications, future activities.
1500 Close

### Opening remarks

The chairman thanked Walter Planet and NOAA for supplying the meeting room and arranging the accommodation, amongst other things. The draft agenda was accepted without discussion.

### Member reports

Each attendee gave a brief report of their activities to set the stage for future discussion.

NOAA - Rao desribed the problems with the visible channels of the AVHRR and briefly mentioned the Pathfinder activities. The different techniques used for calibration all gave the same degradation slopes but all had poor absolute accuracy.

NOAA - Walton described the new non-linearity coefficients for the infrared channels of the AVHRR and compared them with those developed at Miami and by the Steyn-Ross's. A full report on AVHRR calibration activities of the Pathfinder projects will be available soon.

UK - Mutlow described the ATSR-2 pre-launch calibration that was due to start the following week. Details of the on-board calibration would be given in the afternoon session.

U. of Arizona - Biggar described use of White Sands for calibration. Mention was also made of a possible NASA initiative to characterise the moon's surface at 20 wavelengths between 400 and 1000 nm. Degradation has been noticed in LANDSAT, SPOT and AVHRR channels. White Sands was to be used for MODIS cal. This would be somewhat easier as all the EOS sensors were on the one platform.

NASA - Barnes The Spectro-Radiometer Calibration Assembly (SRCA) for on-board measurement of filter response functions on the MODIS instrument was desribed. MODIS also uses a solar diffuser, lamps and a black body for on-board calibration. There was some concern at the lack of cross calibration opportunities between the AM and PM platforms.

Canada - Staenz described the past campaigns, ATCOR and GEORAD, as well as the future campaign BOREAS. This latter campaign would be over a uniform forested area and may be useful for the calibration of satellite sensors. The forest site would be overflown by various aircraft instruments and would be supported by ground data. An article on Airborne Imaging Spectrometry (AIS) would be appearing soon in the Canadian J. of Remote Sensing.

JRC - Maracci described an AIS that would be flying soon (79 channels from Vis to TIR).

France - Henry gave details of the SPOT calibration methods using various sites - one in France, La Crau and one in the north African desert near the border of Egypt and Libya. CNES were also developing new instruments - POLDER (on ADEOS) and VEGETATION on SPOT-4. On Dec. 15 1992 a campaign is planned to use White Sands for intercomparison of SPOT, MOS-1 and JERS-1.

EROS/USA - Helder EROS is to be the primary archive for LANDSAT data. Users are asking for calibration data. EROS was looking at historical data to determine the best coefficients.

Australia - Barton described some problems encountered with AVHRR data as well as giving details on the geophysical validation of ATSR-derived sea surface temperatures.

## CEOS and WGCV

Susan Till (CCRS) gave a brief description of CEOS and its working group on Cal/Val. Details of the previous week's meeting in Brazil were presented. One recommendation from WGCV to the CEOS plenary was to produce a dossier on cal/val methods, along with details and contact points for cal/val information. Till asked that members contribute to the CEOS WGCV newsletter (edited by Mark Hutchins, UK) and use the bulletin board installed on OMNET (send details to S. Till on OMNET or INTERNET).
Up-coming meetings/campaigns with potential for international participation should be publicised

### Terms of Reference

The draft terms of reference were discussed and a decision was made to revisit them tomorrow after our discussions.

### Meeting Objectives

The CEOS WGCV IVOS should aim to identify one or two cal/val activities that would benefit from international collaboration. These activities would be the framework for improving the overall calibration and validation of data from satellite sensors. The meeting should also consider action items on members to develop these activities and to lead to improved understanding and techniques for the calibration of satellite sensors. Some recommendations for S Till to take to the CEOS plenry session next week would be appropriate. As an action item from the WGCV, IVOS should note on-going AVHRR cal/val activities and make recommendations as appropriate about coordination and consolidation of these activities.

### Pathfinder Activities

Rao (NOAA) gave a detailed account of the NASA/NOAA Pathfinder activities. A draft report would be available soon and would be distributed to members of this sub-group.

Pathfinder activities had commenced for AVHRR, TOVS, GOES and SSM/I.

The south-east Libyan desert had been used as a target for calibration of the visible channels - although this site was different to that used by CNES for SPOT cal.

### On-board Calibration Techniques

ATSR-2 will include an on-board calibration of the vis/NIR channels using a view of a solar diffuser (Russian opal).

SPOT uses an on-board halogen lamp, and a sloar diffuser (? material).

SeaWIFS uses a solar diffuser (YB 71) once an orbit.

MODIS plans to use a solar diffuser(Spectralon) for on-board calibration.

GOME, LANDSAT, MERIS, ASTER, MISR and MOPITT all plan on-board calibration but there were no details available on the methods or solar diffuser material to be used.

The subject of on-board calibration seemed to be rather hazy with no interaction between the various instruments and techniques. This could lead to some future activity by IVOS for some intercomparison and cross calibration of the various methods and diffusers used.

### The ISY SST group

This group had met regularly over the last two years under the auspices of the ISY. The future of the ISY was uncertain, but the activities of this group, which relate mainly to intercomparison of SST derivation techniques and products, may fit into the activities of IVOS . No action to be taken, but a watching brief on the fate of ISY should be kept.

### Funding

The problem of support for CEOS and IVOS activities were identified and IVOS should encourage the WGCV to continue to impress the plenary meetings with the importance of continued funding for calibration activities for the mutual benefit of the agencies themselves as well as the wider user community through the improved quality of satellite data.

### IVOS Activities

Following some general discussion two activities were identified.

1. Test Sites

All member agencies to develop a database for selected test sites and to investigate a means of easy exhchange of data. At the next IVOS meeting this activity will be reviewed and a mechansism established to collate these data.

Actions: 1) By end of January, 1993, agencies to make available the location of possible test sites, including low reflectance sites such as water (off Australia), and details of their size, homogeneity, time variability, etc.
2) A start be made on collecting data for/from White Sands and one site in North Africa.
3) Develop ideas for the collation of test site data into a useful data set.

The co-ordinator for this activity would be John Barker (NASA/GSFC)
Subcommittee: Stuart Biggar (UAz), Patrice Henry (CNES)

2. Intercomparison of solar diffusers and on-board calibration techniques.

This activity would also be coordinated by John Barker.
Subcommittee: The ESA members of IVOS would be approached to contribute to this effort.

### Action Items

1. All members

To identify potential test sites and forward details to John Barker.

2. Members with information on solar diffusers to contact John Barker with details.

3. U. Arizona
To investigate a mechanism for wider use of White Sands test site during their intensive ground-based campaigns.

4. CNES and other agencies
To investigate a means whereby satellite-derived data collected over ground test sites can be released for mutual in-flight calibration of all IVOS, and thus improve the characterization of the test sites for the mutual benefit of the space agencies involved.

A comprehensive set of radiometric histograms of test sites is already being prepared by CNES for SPOT calibration.

NASA has a program directed from Headquarters for accessing a certain number of SPOT images.

5. Transmission code intercomparison.

IVOS members to give some thought to a future activity of intercomparison of transmission codes. This will be discussed at the next meeting.
There was some discussion about the problems of intercomparison of calibration techniques using different transmission codes. Rao suggested that a useful activity would be some means of comparing the different codes and some recommendations of which to use under certain conditions. It was felt that this was a mammoth task, and discussion on this activity would be held over to the next meeting. Meanwhile members were to give some thought to this problem. Possible codes identified were -

| | |
|---|---|
| Lowtran | AFCRL |
| Hitran | |
| Genlin2 | UK./USA |
| 5S (6S) | LOA, France, (Tanre) |
| MODTRAN | |
| RAL | UK |
| Other more rigorous codes | |

The aims of this activity would be
a) to minimize ambiguity in the comparison of calibration activities
b) to recommend code(s) for use in calibration

## CEOS WGCV IVOS Terms of Reference

After some discussion the following terms of reference were agreed.

1. To identify and agree on calibration and validation requirements and standard specifications for IVOS, including on-board calibration systems.

2. To promote international and national collaboration in the calibration and validation of all infrared and visible optical sensors and thus assist in the improved application of data from satellite instruments.

3. To include all sensors (ground based, airborne and satellite) where there is a direct link to the cal/val of satellite sensors.

4. To identify test sites and encourage continuing observations and inter-comparisons of data from these sites.

5. To encourage the timely and unencumbered release of data relating to cal/val activities, including details of pre-launch and in-flight calibration parameters.

## Recommendations to CEOS WGCV

1. Recognizing that accurate long term calibration is crucial for the use of satellite data in climate and global change applications, the IVOS sub-group recommends that CEOS member agencies support the identification, characterisation and maintenance of ground test sites for the verification of on-board calibration systems, the in-flight calibration of infrared and visible sensors, and subsequent cross-calibration of satellite instruments.

Discussion:
To ensure the accuracy and continuity of satellite data and their use for climate and global change

research, this is a vital activity that allows for quantitative scientific intercomparison of global change parameters derived from different instruments.
In view of the on-going problems related to the use of in-flight calibration of infrared and visible sensors, the IVOS recommends that member agencies support the maintenance of ground test sites for the cross-calibraiton of these sensors for their mutual benefit.
Rocket Sounding Programs, Solar Radiation Networks and other existing sources of required ancillary data should be supported within this framework.

2. That, as a matter of urgency, CEOS supports the establishment of a comprehensive data base on selected test sites for the future in-flight calibration of infrared and visible sensors.

Discussion:
IVOS is currently indentifying test sites and exploring data collection procedures.

3. CEOS WGCV IVOS congratulates NOAA/NASA on the implementation of the "Pathfinder" activities and encourages the producers and users of satellite data to support similar activities for other satellite systems.

A fourth recommendation (as follows) was not agreed as it was similar to that presented to the last CEOS plenary meeting by WGCV.
That IVOS endorses the recommendations of the ad-hoc group on data policy regarding the exchange and availability of data (including imagery at cost-of-copy prices).

### Items for discussion at Next Meeting of IVOS

1. Intercomparison of Radiative Transfer Codes
2. Collation of data on test sites
3. Use and experience of histograms data base of SPOT cal. test sites.
4. Possible Coordination of validation activities
5. AVHRR cal/val campaigns - undertaken under the auspices of Pathfinder.

### Next meeting

Philosophy: Meet less than twice a year, perhaps every 9-10 months. If possible meet just before WGCV and stay through part of that meeting.

Next Meeting of CEOS IVOS tentatively 31 May-1 June 1993, at ISPRA, Italy. THIS IS NOW CONFIRMED (9 Dec. 1992)
CEOS WGCV will meet at the same venue, 2-4 June 1993.

### Close

The meeting closed at 1445. The Chairman thanked all those present for attending, and was confident that a good start had been made with achievable objectives and activities. NOAA and NOAA personnel were thanked for providing the venue and local arrangements for the meeting, as well as logistic support over the last two days.

## Attendees

CEOS (Committee on Earth Observation Satellites)
WGCV (Working Group on Calibration and Validation)
IVOS (Infrared Visible Optical Sensors)
NOAA Science Center (formerly World Weather Building)
Camp Springs, Maryland USA
Monday, 30 November - Tuesday, 1 December 1992.

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|---|---|---|---|
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| Biggar, Stuart F. | University of Arizona | 1 602 621 8163 | |
| Helder, Dennis | EROS Data Center | 1 605 688 4523 | 1 605 688 5880 |
| Henry, Patrice | CNES | 33 6 12747-12 | 33 6-1273-167 |
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| Sherman,John W. III | NOAA/NESDIS | 301 763-4626 | |
| Staenz, Karl | CCRS Canada | | 613 947-1250 |
| Till, Susan | CCRS Canada | 613 998-9060 | |
| Weinreb, Michael | NOAA/NESDIS | 1 301 763-8763 | 1 301 763-8108 |

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