GSFC-422-21-02

SPECIFICATION

FOR THE

MODERATE-RESOLUTION IMAGING

SPECTROMETER-TILT

(MODIS-T)

SEPTEMBER 1990

GODDARD SPACE FLIGHT CENTER

GREENBELT, MD 20771

SPECIFICATION FOR THE MODERATE-RESOLUTION IMAGING SPECTROMETER-TILT (MODIS-T)

TABLE OF CONTENTS

GSFC-422-21-02

Specification for the
Moderate-Resolution Imaging Spectrometer (MODIS-T)

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ACRONYMS AND DEFINITIONS RELEVANT TO MODIS-T

b - bit
B - Byte (8 bits)
Band - a wavelength interval in the radiated electromagnetic spectrum
BCU - Bench Check Unit
bpi - bits per inch
bps - bits per second
CCB - Configuration Control Board
CDR - Critical Design Review
CDRL - Contract Document Requirements List
Channel - a detector and associated electronics in a spectral band
CR - Change Request
Detector - converts radiant energy to an electrical quantity; may consist of one or more elements in a common package
EOS - Earth Observing System
EOS-A - First EOS polar platform, also called NPOP-1
EOS-B - Second EOS polar platform, also called NPOP-2
EOSDIS - Earth Observing System Data and Information System
FOV - Field of View
FWHM - Full Width at Half Maximum
GE - General Electric, the spacecraft developer
GIIS - General Instrument Interface Specification for the EOS Observatory
GSE - Ground Support Equipment
GSFC - Goddard Space Flight Center
ICD - Instrument Interface Control Document
IDD - Instrument Description Document
IFOV - Instantaneous Field of View
Lcloud - Spectral Radiance from a 100% reflectance Lambertian scene
Lmax - Maximum Spectral Radiance in a non-ocean spectral band
Lmax(O) - Maximum Spectral Radiance in an ocean spectral band
Ltypical - Typical Spectral Radiance in a non-ocean spectral band
Ltypical(O) - Typical Spectral Radiance in an ocean spectral band
MTF - Modulation Transfer Function
NASA - National Aeronautics and Space Administration
NEdL - Noise Equivalent Differential Spectral Radiance
NIR - Near Infrared, 700 - 1060 nanometers
NIST - National Institute of Standards and Technology
nm - Nanometer (10^{-9} meter)
NPOP - NASA EOS Polar Orbiting Platform, also called EOS-A or EOS-B
PAR - EOS Performance Assurance Requirements for General Instruments
PDR - Preliminary Design Review
Pixel - Sample of the IFOV measurement
PSR - Preshipment Review

r	-	Reflectance of a surface (of a scene)
S/C	-	Spacecraft
SNR	-	Signal-to-Noise Ratio
STE	-	System Test Equipment
UIID	-	MODIS-T Unique Instrument Interface Document (UIID)
υμ	-	Micrometer (10 -6 meter)
VIS	-	Visible Light, 400 - 700 nm
WBS	-	Work Breakdown Structure
WSMC	-	Western Space and Missile Center (EOS Launch Site)

1. SCOPE

This specification establishes the performance, testing, calibration, verification and product assurance requirements for the Moderate Resolution Imaging Spectrometer-Tilt (MODIS-T) that will be flown on a NASA EOS Polar Orbiting Platform.

2. APPLICABLE DOCUMENTS

The following documents of latest issue as of the signature date of this specification apply to the MODIS-T development. In the event of conflict between this specification and the referenced documents, this specification shall govern. The MODIS-T Unique Instrument Interface Document (UIID) is the second document in precedence. Any contradictions between this specification and the UIID shall be brought to the immediate attention of the Instrument Manager.

2.1 GSFC AND GENERAL GOVERNMENT SPECIFICATIONS AND STANDARDS

(1) 420-03-01: EOS Project Calibration Management Plan

(2) 420-02-02: EOS Configuration Management Plan

(3) 422-10-04: EOS Instrument Project Software Management Plan

(4) 420-05-01: EOS Performance Assurance Requirements for General Instruments

(5) 420-05-04: EOS Contamination Requirements

(6) 420-05-05: EOS Safety Plan

(7) Federal Standard 209B: Clean Room and Work Station Requirements, Controlled Environment

(8) Earth Observing System Data and Information System Level I Requirements, Revision C, June 1989

(9) Earth Observing System Data and Information System Level II Requirements

(10) GSFC General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components (GEVS - SE) NASA Goddard

(11) Execution Phase Management Plan for the Moderate Resolution Imaging Spectrometer - Tilt Instrument, September 1990

(12) NASA Ref. Publication 1124: Outgassing Data for Selecting Spacecraft Materials, August 1987

(13) GSFC-S-250-P-1C: Contractor Prepared Monthly, Periodic and Final Reports

2.2 MILITARY SPECIFICATIONS AND STANDARDS

(1) MIL-STD-130G: Identification Marking for U.S. Government Property

(2) DOD-D-1000B: Military Specification Drawings, Engineering and Associated Lists, for Categories, A, B, C, D, G, H, Using Form 2 Drawings.

2.3 EOS POLAR PLATFORM INSTRUMENT INTERFACE SPECIFICATIONS

(1) 420-03-02: EOS General Instrument Interface Specification (GIIS), Latest Issue

(2) 422-21-05: MODIS-T Unique Instrument Interface Document (UIID).

2.4 GE POLAR PLATFORM GENERAL REPORTS

(1) EOS-1 System Element Specification EOS Level 2

2.5 EOS REFERENCE DOCUMENTS

(1) 420-03-03: EOS Project Data Management Plan

(2) 420-05-03: EOS Ground Systems Performance Assurance Requirements

3. TECHNICAL REQUIREMENTS

3.1 Requirements Overview

3.1.1 General

MODIS-T shall observe the Earth from a NASA Polar Orbiting Platform (EOS-A etc) of the Earth Observing System. The sensor will be used for observation of land, ocean and atmospheric characteristics in the visible and near infrared spectral regions.

MODIS-T shall be an along-track pointable, cross-track scanning sensor which measures scene radiance in thirty-two spectral bands. It shall have an instantaneous-field-of-view of 1.1 kilometers at nadir from an altitude of 705 kilometers. In-flight calibration shall be accomplished using the sun, moon and on-board sources. High radiometric accuracy and a five-year orbital life without servicing are required.

3.1.2 Maintainability and Servicing

MODIS-T shall be designed to facilitate repair on the ground. Any servicing performed in orbit will be at the level of replacing the entire instrument; no component or module replacement in orbit is anticipated.

3.1.3 Required Instrument Models

3.1.3.1 Thermal Analytical Models

Thermal Analytical Models are used to evaluate the thermal performance of the instrument. These models shall contain details of the design of all subsystems and critical interfaces so that they can accurately predict absolute temperature, temperature gradients, and heat flow between nodes and interfaces. These models shall be verified and refined after comparison with thermal test data. In addition, a "Surface Model" a "Thermal Model" and a top level "Thermal Analysis" shall be prepared for instrument/spacecraft interface definition. Thermal Analytical Models are further defined in the GIIS.

3.1.3.2 Structural Analytical Models

A Reduced Structural Analytical Model of the instrument shall be prepared in NASTRAN format and shall contain no more than 500 degrees of freedom. It shall meet the requirements specified in the Contract Document Requirements List (CDRL) and GIIS. The model will support coupled loads analysis cycles. The model shall be updated to agree with the structrual test results. The verified model will support the verification load cycle.

3.1.3.3 Instrument Physical Mass Model

The instrument Physical Mass Model is provided to support platform structures activities at the Platform Contractor's facility. Requirements are given in the GIIS.

3.1.3.4 Engineering Model

An Engineering Model (EM) is used to evaluate design choices and demonstrate system performance. It is similar to a Protoflight Model (PFM) in appearance, dimensions, function, performance, and interfaces. It incorporates parts and components of the same type called for in the PFM design, but it does not have to satisfy lifetime specifications. The EM shall have the redundancy planned for the protoflight and flight units, except where justified otherwise by the developer. The EM shall be tested in air and thermal vacuum and shall, as a goal, meet the performance requirements of this specification.

3.1.3.5 Protoflight Model

A Protoflight Model is the first model which meets all requirements for a flight instrument. It undergoes qualification level tests and, after any necessary refurbishment, is flown on the first EOS platform.

3.1.3.6 Flight Models

Flight Models are built and tested to satisfy all specification requirements. They undergo acceptance level tests and are flown on an EOS platform.

3.2 OPERATIONAL REQUIREMENTS

3.2.1 Nominal Orbit Parameters

MODIS-T will be flown in a 1:30 PM +/-15 minutes ascending node, circular, sun-synchronous, near-polar orbit at an altitude of approximately 705km.

3.2.2 Operational Modes

MODIS-T shall be capable of operating in the following modes:

1) Launch Phase and Orbital Acquisition Mode: The health and safety of the instrument shall be monitored during this phase.

2) Outgassing Mode: The instrument shall be non-operating or in partial operation during the early days of the mission, during which time the optics and other critical components shall be protected against contamination.

3) Activation Mode: Initial turn-on and warm-up of the instrument.

4) Mission Mode: Normal operation of the instrument.

5) Day Mode: Normal daytime full operating mode with commandable fore-aft pointing. Typically the day mode represents 40% of an entire orbit.

6) Night Mode: Normal nighttime standby operating mode with no science (i.e. surface viewing) data being generated.

7) Solar Calibration Mode: The instrument views a solar diffuser for a portion of each orbit. The duty cycle will be based on radiometric considerations.

8) Lunar Calibration Mode: The instrument occasionally views the moon when it is visible.

9) Spectral Calibration Mode: The on-board spectral calibrator is operating some of the time, while the instrument is in the mission mode. The duty cycle will be based on spectral stability considerations.

10) Survival Mode (Emergency Off Mode): This mode is used in case of a spacecraft emergency and shall be initiated with a minimum number of commands. Ideally no instrument reconfiguration shall be necessary before operating power is cut off.

3.2.3 Lifetime Requirements

MODIS-T shall be designed to operate within specification, without servicing, for six months prior to launch and five years in orbit. It will also be subject to a maximum period of eight years in storage plus two years of Integration and Test. If the storage period exceeds one year the sensor may be serviced and recalibrated prior to integration on the spacecraft. The PAR describes aging and storage requirements.

The probability of meeting the five-year in-orbit lifetime requirement shall be .85 as a minimum. The probability of providing the critical measurements from MODIS-T over the five year lifetime shall be .90 as a minimum.

For purposes of lifetime evaluation, the following failure criteria is proposed: failure of the instrument is defined as loss of 25% or more of the spectral bands. A band shall be considered to have failed if the response in more than 25% of the detector elements within that band fall 50% below the pre-launch calibrated response, or if the detector elements in the band cannot be calibrated to perform within specification.

A final definition of failure criteria and identification of what constitutes critical measurements from MODIS-T shall be negotiated by the Instrument Scientist and the Instrument Development Manager prior to the beginning of Phase C/D.

3.2.4 Orbital Radiation Environment

The ionizing radiation environment of the EOS orbit is described in the GIIS and in documents referenced therein. MODIS-T will encounter a nominal radiation background in its polar orbit and in addition will traverse the South Atlantic Anomaly several orbits per day. The following paragraphs specify what is expected from MODIS-T as a result of radiation exposure.

3.2.4.1 Total Dose Performance

Early in the hardware design phase, design requirements and guidelines shall be developed which will assure that the instrument will operate within specification following five years of radiation exposure. Total radiation dose-depth curves are specified in the GIIS.

3.2.4.2 Transient Event Recovery due to Radiation Exposure

MODIS-T will pass through the South Atlantic Anomaly while in orbit. The South Atlantic Anomaly is a radiation region characterized by protons having energies in the 1 MeV to 100 MeV range. It may not be practical to incorporate enough shielding in MODIS-T so that its performance will be completely unaffected when it passes through this radiation region. However, some shielding may be used in combination with selected circuits, parts and components in the signal processing chain (detectors through buffer memory) which will result in only short term interruptions in performance.

A radiation event in the buffer memory shall degrade no more than 5 pixels. The electronics which are not part of the signal processing chain shall continue to operate nominally while traversing the South Atlantic Anomaly.

3.2.4.3 Verification of Performance Effects Caused by Radiation

Verification of the radiation requirements shall be accomplished by analysis, radiation testing for total dose of custom electronics, and by in-orbit performance. Custom parts manufactured by a process certified by NASA, DoD or some other competent agency to be tolerant to the EOS level of radiation exposure over the five-year life do not require life testing.

3.3 OPTICAL REQUIREMENTS

3.3.1 Instantaneous-Field-of-View (IFOV)

The along-track IFOV at nadir shall be equal to or less than 1.10 kilometers. The IFOV is defined as the projection of a detector element or field-stop onto the Earth at nadir, and excludes diffraction effects and optical aberrations. The tolerance on the mean along-track and cross-track IFOV for any band is +/-3%. The cross-track IFOV may be equal to or less than the along-track IFOV, depending upon signal/noise ratio and Modulation Transfer Function (MTF) considerations. Each detector element within a band shall have an IFOV that does not differ from the mean by more than +/-5% in either dimension. Sampling shall be once per nominal (square) IFOV.

3.3.2 Field of View

3.3.2.1 Cross-track

The active portion of the cross-track scan shall be 90 degrees or +/- 45 degrees about nadir.

3.3.2.2 Fore-and-Aft Pointing

The sensor shall be capable of pointing fore-and-aft to avoid specular reflectance from the ocean's surface and to obtain bi-directonal reflectance distribution function (BRDF) information over land surfaces. The maximum fore-and-aft pointing angle shall not be less than 20 degrees and not greater than 50 degrees (excluding requirements for viewing the moon). Intermediate pointing positions in commandable one-tenth degree steps shall be provided. Changes in pointing angle shall result in minimal loss of ground coverage during the time required to step and settle. Two consecutive scans at the same nominal pointing angle shall not differ by more than 0.01 degrees.

3.3.2.3 Pointing Control

The instrument shall be capable of storing at least five different pointing scenarios. The stored scenarios shall be capable of being modified or new scenarios may be transmitted and stored after launch. The following are examples of possible pointing scenarios:

(1) Glint Avoidance - the sensor shall point 20 degrees aft until the sub-polar point of the orbit is reached and then move to the 20 degree forward-pointing position for the remainder of the orbit;

(2) Bidirectional reflectance - a single scan shall be made at a look angle of 50 degrees forward, the look angle shall decrease by the along-track FOV during the backscan and the original area shall be scanned again. This process shall be repeated until a scan is made at a look angle of 50 degrees aft;

(3) Large Target BRDF - similar to (2) except that 2 - 5 lines 128 - 320 km along track are scanned at each angle;

(4) Extreme Angle BRDF - point 50 degrees forward until the first scan is at the sub-satellite point and then point at 50 degree aft angle for the same period;

(5) Glint II - same as (1) except there will be several changes in look angle both before and after the sub-solar point.

3.3.3 Spectral Bands

MODIS-T will operate in the visible and near-infrared spectral regions, and shall nominally cover the spectral range from 400 to 880 nanometers. A band set is given in Table 3.3.3 along with other pertinent parameters associated with each band. Table 3.3.3 consists of two parts, one lists bands that will be used for viewing the ocean and the other lists non-ocean bands.

A capability of aligning the focal plane and/or diffraction grating shall be provided so that the wavelengths of the final spectral band set can be adjusted, under the direction of the Instrument Scientist, to satisfy science requirements. (For example, it would be undesirable if a water vapor absorption band partially overlapped two spectral bands when a slight displacement of the array could make the absorption band fall entirely on one spectral band (saving the other for surface or aerosol observations) without making an impact on the performance of the rest of the instrument).

The alignment process may result in a final spectral band set that differs from that shown in Table 3.3.3. However, Table 3.3.3 as shown shall be used to design the sensor.

3.3.3.1 Background Bands and Dark Level Measurements

One to four background bands which consist of radiometrically opaque detectors shall be incorporated in the sensor. These detectors will be used for noise analyses and noise suppression. In these background bands data shall be collected in an amount and frequency dictated by the noise of the system.

3.3.3.2 Additional Spectral Bandwidth Considerations

The bandwidths of the thirty-two spectral bands shall not exceed 15 nanometers FWHM and shall not vary by more than a factor of two over the entire spectral range. Gaps between half-power points shall be less than 50% of FWHM.

3.3.3.3 Definitions

These parameters relate to performance of the complete instrument system. See Figure 3.4.3.3.

TABLE 3.3.3

MODIS-T OCEAN REQUIREMENTS

BAND	CENTER WVLNGTH (nm)	TYPICAL REFLEC.	LTYPICALO (**)	LMAXO (**)	REQ SNR (*)	LCLOUD (**)
1	410	0.071	45.9	144	820	472
2	425	0.072	43.8	140	859	510
3	440	0.075	42.0	133	838	522
4	455	0.055	39.1	120	826	592
5	470	0.044	36.4	110	814	570
6	485	0.032	33.6	100	802	560
7	500	0.041	30.9	94	786	564
8	515	0.057	29.1	84	770	556
9	530	0.055	26.7	80	754	571
10	545	0.053	24.3	75	752	557
11	560	0.041	21.0	64	750	538
12	575	0.042	20.0	62	736	545
13	590	0.043	19.0	59	724	505
14	605	0.044	18.1	56	711	522
15	620	0.044	17.0	49	699	507
16	635	0.043	16.1	42	661	488
17	650	0.040	14.9	38	616	466
18	665	0.037	13.7	34	571	460
19	680	0.039	13.1	31	558	441
20	695	0.041	12.5	30	546	424
21	710	0.043	11.9	28	535	408
22	725	0.043	11.2	26	522	398
23	740	0.044	10.5	25	508	374
24	755	0.044	9.9	24	495	370
25	770	0.045	9.3	21	490	355
26	785	0.043	8.8	21	472	348
27	800	0.041	8.3	20	454	336
28	815	0.039	7.8	19	435	326
29	830	0.037	7.3	18	417	315
30	845	0.036	6.8	17	398	304
31	860	0.035	6.3	16	380	294
32	875	0.034	5.8	15	317	286

* SNR REQUIRED AT LTYPICALO

** UNITS OF Watts/sq.meter/um/st.

LTYPICALO=RADIANCE OF A SCENE WITH TYPICAL OCEAN SURFACE REFLECTANCE AND SOLAR ZENITH ANGLE OF 70 DEGREES

LMAXO=SATURATION RADIANCE FOR OCEAN MODE SCENES

LCLOUD=RADIANCE OF A CLOUD WITH A SOLAR ZENITH ANGLE OF 22.5 DEGREES

a. Band Edge – The wavelength at which the response is half of ...

TABLE 3.3.3 (Cont'd)

MODIS-T NON-OCEAN REQUIREMENTS

BAND	WVLNGTH (nm)	TYPICAL REFLEC.	LTYPICAL (**)	LMAX (**)	REQ SNR (*)	LCLOUD (**)
1	410	0.071	45.9	465	289	472
2	425	0.072	43.8	502	289	510
3	440	0.075	42.0	514	289	522
4	455	0.072	41.2	583	289	592
5	470	0.070	40.3	561	289	570
6	485	0.080	38.3	546	274	560
7	500	0.090	36.2	531	259	564
8	515	0.100	34.1	516	244	556
9	530	0.100	32.0	501	229	571
10	545	0.100	30.9	495	221	557
11	560	0.110	29.7	488	213	538
12	575	0.110	28.5	481	205	545
13	590	0.090	24.9	473	183	505
14	605	0.080	23.1	463	173	522
15	620	0.070	21.2	454	163	507
16	635	0.060	19.3	445	153	488
17	650	0.060	17.4	436	142	466
18	665	0.080	18.8	422	156	460
19	680	0.100	20.2	408	170	441
20	695	0.120	21.5	394	185	424
21	710	0.170	25.2	381	222	408
22	725	0.220	28.9	367	260	398
23	740	0.300	38.3	353	344	374
24	755	0.310	37.5	337	356	370
25	770	0.310	36.6	322	368	355
26	785	0.340	35.7	307	379	348
27	800	0.400	38.7	291	431	336
28	815	0.039	7.8	19	435	326
29	830	0.037	7.3	18	417	315
30	845	0.036	6.8	17	398	304
31	860	0.035	6.3	16	380	294
32	875	0.410	39.3	270	437	286

* SNR REQUIRED AT LTYPICAL

** UNITS OF Watts/sq.meter/um/st.

LTYPICAL=RADIANCE OF A SCENE WITH TYPICAL SURFACE REFLECTANCE AND SOLAR ZENITH ANGLE OF 70 DEGREES

LMAX=RADIANCE OF A SCENE WITH SURFACE ...

3.3.3.4 Wavelength Tolerances

The edge range shall not exceed 50% of the bandwidth in any spectral band.

3.3.3.5 Out-of-Band Characteristics

The out-of-band response shall be less than 5% (three sigma). Each one-percent response point shall be within 1.5 times the bandpass from the corresponding band edge. Compliance with this specification shall be determined for a source spectrum equivalent to Lcloud (the spectral radiance of a Lambertian surface of 100% reflectance, illuminated by the sun at a zenith angle of 22.5 degrees). Lcloud is given in Table 3.3.3

3.3.3.6 Within-Band Detector-to-Detector Spectral Differences

The spectral response of all detector elements in a band shall be compared as to location and shape by use of normalized spectral response curves. The central wavelength of any element must be within +/- 0.5 nm of the average central wavelength for all elements of the band. Integrated spectral response between the ten percent response points shall not differ by more than ten percent for any two elements in the band.

3.3.3.7 Spectral Band Registration

The data from each spectral band in MODIS-T shall be registered to within 0.1 pixel.

3.3.4 Sensitivity Requirements

MODIS-T shall be capable of measuring spectral radiances from the Noise Equivalent Differential Spectral Radiance (NEdL) up to the maximum spectral radiance at the entrance aperture (Lmax(O)). Signal-to-noise ratios shall be measured over this range of spectral radiances.

Table 3.3.3 presents the SNR requirements for both ocean and non-ocean bands. The required SNR shall be achieved at the typical spectral radiance levels. NEdL may be calculated from the expression: NEdL = Ltypical/SNR or Ltypical(O)/SNR where Ltypical and Ltypical(O) are the typical spectral radiances for the non-ocean and ocean bands respectively. Lcloud is included in the table for use in determining the effects of scattered light.

3.3.4.1 Composite Mode

MODIS-T shall be capable of imaging both land scenes and ocean scenes without saturating the detector except in bands 28, 29, 30 and 31. This capability is termed the composite mode.

3.3.5 Instrument Polarization Insensitivity

MODIS-T shall be nominally insensitive to linear polarization. The polarization factor, as defined below, shall be no greater than 0.023

over scan angles of +/-45 degrees, wavelengths from 430 to 865 nanometers and tilt angles of +/-20 degrees. As a goal it would be desirable to achieve this polarization factor over the full wavelength range shown in Table 3.3.3.

$$PF = (Imax - Imin)/(Imax + Imin) < 0.023$$

The magnitude and direction of the polarization sensitivity shall be mapped over +/-45 degrees of scan, +/-50 degrees of tilt and at angles necessary to view the moon.

3.4 SYSTEM PERFORMANCE REQUIREMENTS

Performance and ground calibration data shall be analyzed and presented in a format which aids interpretation.

3.4.1 Dynamic Range

MODIS-T shall be designed to operate over a dynamic range that extends from the noise floor (NEdL) in each spectral band to the maximum levels (Lmax or LmaxO) given in Table 3.3.3.

3.4.2 Modulation Transfer Function

The MTF of the instrument shall equal or exceed the values tabulated below in both the along-track and cross-track directions for a sine wave input. The Nyquist frequency has a spatial period equal to two IFOV's on the ground.

Frequency/Nyquist Frequency	MTF
0.00	1.0
0.25	0.9
0.50	0.7
0.75	0.5
1.00	0.3

The MTF requirements shall be satisfied for modulations between dark and Ltypical(O) and between dark and Lmax(O), for every detector element in each spectral band. The MTF's shall be measured in representative spectral bands to verify that the specification is being met.

3.4.3 Minimum Quantizing Resolution

Quantizers shall be used to generate a digital data stream. The quantization step size shall be chosen to meet the signal-to-noise ratios specified at the typical spectral radiances given in Table 3.3.3. Differential linearity of the quantizer(s) shall be better than one-half a least significant bit (LSB).

3.4.4 Transient Response (Bright Target Recovery)

Overshoot and ringing shall be minimized when the IFOV scans across a steep gradient in radiance, from a maximum of Lcloud to a minimum of Ltypical(O). For this radiance step change the output signal shall have less than 1% overshoot and the output signal shall settle to within 0.5% of its final value within two IFOVs.

3.4.5 Radiometric Performance

3.4.5.1 Radiometric Accuracy (Spectral & Amplitude)

MODIS-T shall meet the radiometric accuracy requirements delineated below. More than one calibration approach shall be used to verify the radiometric accuracy and provide confidence in the measurements.

An end-to-end analysis of the total system shall be provided to show that the radiometric accuracy requirements are met over the specified dynamic range.

Recommendations shall be developed for frequency of calibration updates. Recommendations for routine, periodic calibration in orbit shall also be developed. Consideration shall be given to placing heaters within the sensor to aid in post-launch verification of calibration.

3.4.5.2 Absolute Radiometric Accuracy

An absolute radiometric accuracy of 5% (one-sigma) shall be achieved at the typical spectral radiance levels given in Table 3.3.3. At any other spectral radiances between 0.3*Ltypical(O) and 0.9*Lmax(O) the absolute radiometric accuracy shall not exceed 6%. Measurements shall be made at scan angles centered at 0, -40, and +40 degrees. Sources traceable to the National Institute of Standards and Technology (NIST) shall be used.

The on-board diffuser plate shall be used to achieve an absolute radiometric reflectance accuracy of 2% (one sigma) relative to the sun.

3.4.5.3 Relative Radiometric Accuracy

3.4.5.3.1 Root Mean Square Deviation

The RMS deviation from the mean of the spectral radiance measurements within any spectral band when viewing a uniform radiance target shall be no greater than the NEdL value computed for each band. This applies over the full range of spectral radiance levels.

3.4.5.3.2 Detector-to-Detector Uniformity

If multiple detector elements are used within a spectral band, the calibrated mean output of each detector element with respect to every other detector element shall be matched to within computed values of NEdL. This matching condition shall be met when the instrument views a uniform constant spectral radiance field (ocean and non-ocean) at levels of approximately 0.5*Ltypical(O), Ltypical(O) and 2*Ltypical(O) (or Lmax(O), if Lmax(O) <2 Ltypical(O)).

3.4.5.3.3 System Electronic Crosstalk and Coherent Noise

To obtain the highest radiometric accuracy, crosstalk and coherent noise shall be reduced to a minimum. Crosstalk shall be measured by exposing a single detector to a source having a radiance of Ltypical(O) and then reading out the array. The change in the output of all other detectors, except the two that trail the exposed element, shall be less than one least significant bit (LSB) after averaging an appropriate number of frames of data.

Coherent noise (e.g., herringbone patterns) shall be imperceptible. Tests for coherent noise shall be conducted with the sensor viewing a source of uniform radiance at a level of Ltypical(O).

3.4.5.4 Uniformity of Response Across a Detector Element

The response within the central 80% of the width of each detector element response shall not vary by more than +/-20% of the mean.

3.4.5.5 System Noise Measurements

The signal-to-noise ratio shall be determined for all bands at a sufficient number of spectral radiance levels between 0.3*Ltypical(O) and 0.9*Lmax(O) to characterize the signal dependence of the system noise.

3.4.6 Pointing Knowledge

The angular location of each IFOV with respect to the MODIS-T Payload Mounting Plate (PMP) reference cube shall be known to within 90 arc-seconds (three sigma) at all scan and tilt angles.

3.4.7 Radiometric Amplitude Stability and Repeatibility

Bias errors will be removed from the data during ground processing in order to improve radiometric accuracy. To accomplish this the instrument shall be stable over temperature and time as defined below.

3.4.7.1 Short-Term Stability

Short-term stability applies to time intervals less than two weeks. The mean radiometric response of each spectral band, corrected on the ground using in-flight calibration data, shall not differ by more than +/-1% from another response measurement made while viewing the same source operating at equal radiance levels, but separated by any time period up to two weeks, including the effects of perturbations at the orbital period. This stability requirement shall also be met for short-term temperature excursions that may be expected to occur in the MODIS-T instrument during sunlit portions of the orbit.

3.4.7.2 Long-Term Stability

Long-term stability applies to time intervals between two weeks and five years. The mean calibrated radiometric response of each spectral band, shall not change by more than +/-2% over these time intervals. Compliance can be demonstrated by an estimate based upon short-term tests plus analysis.

3.4.7.3 Spectral Band-to-Band Stability

The relative amplitude stability between all pairs of spectral bands shall be better than +/-0.5% measured at full-scale, and +/-1% at half-scale. Each band shall be exposed to a source and the mean responses determined. To compare outputs between bands, the ratio of the means shall be calculated for each band with respect to a common band. In addition, ratios shall be calculated for selected (approximately ten) pairs of bands which will be used in common retrieval algorithms, e.g., ocean science pairs and land science pairs. These ratios shall remain constant within +/-0.5% at full-scale and +/-1% at half scale over times separated by any interval up to two weeks, including orbital variations.

3.4.7.3.1 Within-Band Detector-to-Detector Spectral Differences

The location and shape of the spectral response curve of each detector in a spectral band shall be determined. The central wavelength of each detector shall be within +/-0.5 nm of the average central wavelength of all detectors in the band. The integrated spectral response between the 10 percent response points shall not differ by more than 10 percent in each detector in a spectral band.

3.4.7.4 Wavelength Accuracy, Precision and Stability

The pre-launch location of the half-power points in each spectral band shall be determined and shall be constant to +/-1 nm over the duration of the ground test program. This includes shifts caused by changes in humidity, temperature, pressure, or vibrations with time. Wavelength measurements of the entire system shall be made with an absolute accuracy of +/-0.5 nm for band 1 and a precision of +/-0.25 nm. The measurement accuracy and precision for all other bands shall scale with wavelength.

3.4.8 Stray Light Requirements

3.4.8.1 Stray Light Rejection

MODIS-T shall reject scattered and diffracted radiation so that radiometric accuracy is not affected. The instrument shall be designed to restrict stray light arising from any portion of the spacecraft from entering the entrance aperture and solar calibration port.

When the spacecraft is in an operational, nadir-facing attitude, and the sensor is moved over its complete range of tilt angles, the change in the response due to any stray light striking the instrument on any surface (except the entrance aperture and within the instrument FOV) shall be less than one least significant bit (LSB).

3.4.8.2 Bright Target Within-Field Stray Light

When MODIS-T views a 21 x 21 IFOV bright target of spectral radiance Lcloud, which is surrounded by a region of spectral radiance Ltypical(O), the instrument response shall increase by no more than 0.004*Lcloud when the brightness of the surround is increased to Lmax(O).

3.4.8.3 Dark Target Within-Field Stray Light

When MODIS-T views a 21 x 21 IFOV dark target of spectral radiance Ltypical(O), which is surrounded by a bright region of spectral radiance Lcloud, the instrument response shall decrease by no more than 0.004*Lcloud when the brightness of the surround is decreased to 0.02*Lmax(O).

3.4.9 In-Flight Calibration Requirements

An in-flight calibration system is required and shall be capable of calibrating the entire instrument. Sources for amplitude calibration include the sun and the moon. An in-flight spectral calibrator is also required. All absolute radiometric calibration sources shall fill the entrance aperture. Equations and procedures necessary for calibration shall be provided.

3.4.9.1 In-Flight Radiometric Calibration

MODIS-T shall provide in-flight radiometric calibration of all spectral bands, and shall measure changes in gain or throughput of the optical, focal plane, and electronic subsystems. In-flight radiometric characterization, i.e., output digital value versus input spectral radiance, shall be made with sufficient accuracy to assure that the calibration requirements delineated in this specification are achieved.

3.4.9.2 In-Flight Wavelength Calibration

An in-flight wavelength calibration system shall be provided which is sensitive enough to detect a 1.0 nm shift in the shortest wavelength band with a precision of 0.5 nm.

3.4.9.3 In-Flight Reflectance Calibration

MODIS-T shall provide an in-flight reflectance calibration, using the sun to illuminate a diffuser surface which is viewed through the complete instrument optical system. Knowledge of the diffuser characteristics shall be adequate, when combined with other on-board calibration systems, to maintain the calibration and stability of the MODIS-T within specification throughout the five year mission lifetime.

3.4.9.4 In-Flight Lunar Calibration

Provision shall be made to occasionally use the moon as a calibration source. No spacecraft maneuvers shall be required to view the moon.

3.4.9.5 In-Flight Electronics Calibration

Methods shall be considered for in-flight calibration of the analog and digital electronics by injecting an appropriate reference signal, such as a ramp or a stair-step, and monitoring the electronic response at appropriate points. Failure in the calibration circuitry shall not disable the sensor.

3.4.10 Miscellaneous Instrument Requirements

3.4.10.1 Operational Limitations

The developer shall identify and document warnings regarding all sensitive parts, materials, components and operational limitations in appropriate plans, procedures or lists.

3.4.10.2 Solar Flux into Optics or Radiators

Under certain unplanned spacecraft attitudes, the sensor may scan through the sun. The sensor shall be capable of scanning direct solar input for a period of thirty seconds per event, and a total of five minutes in five years without detectable performance degradation or reduction in operating lifetime.

The sensor shall return to its calibrated condition within one orbit after any exposure to the sun.

Normal, expected solar inputs shall not degrade performance for any portion of the orbit.

3.5 COMMAND, CONTROL, COMMUNICATIONS AND TELEMETRY REQUIREMENTS

3.5.1 Command and Control Functions

Ground commands to operate the sensor shall be accepted from the platform C&DH subsystem. A complete list of MODIS-T commands shall be developed along with definitions of their function and necessity. A single command or sequence of commands shall not damage the instrument.

3.5.2 Instrument Data

Instrument data shall be sent to the platform C&DH subsystem. Selected housekeeping and ancillary data shall be included in the data.

3.5.2.1 Data Rates

The maximum data rate, averaged over one minute, without any data compression, shall not exceed 3.076 Mbps, including packetizing overhead. The data shall be buffered to provide a steady data stream.

3.5.2.2 Data Packet Format

Data shall be packetized within the instrument. The format of the data packets is defined in the EOS General Instrument Interface Specification. Packetized data shall be Band Interleaved by Line (BIL) and time tagged.

3.5.3 Instrument Health and Status Monitoring

Telemetry shall be provided to monitor instrument health and operating status and to locate failures. During ground testing additional test points may be provided on a test connector, however their number should be minimized.

3.5.3.1 Command Status

The command status shall be incorporated in the telemetry data. Update rates shall be compatible with the frequency of commands sent during testing or flight operation.

3.5.3.2 Engineering Telemetry

Telemetry of temperatures, voltages, currents, and other engineering parameters sufficient to evaluate the condition of the instrument and to permit accurate calibration, shall be provided. Update intervals shall be compatible with anticipated rates of change of these parameters. The telemetry data shall be included in the packetized image data stream.

3.6 INTERFACE REQUIREMENTS

3.6.1 General

Interface requirements between MODIS-T and the EOS spacecraft are given in the referenced documents, particularly the General Instrument Interface Specification (GIIS) and the MODIS-T Unique Instrument Interface Document (UIID). The GIIS contains interface specifications which apply to all instruments on the EOS spacecraft.

3.6.2 Unique

The MODIS-T Unique Instrument Interface Document (UIID) contains a complete description of the interfaces of the MODIS-T instrument with the platform. The MODIS-T UIID is to be developed by the EOS Instruments Project, in cooperation with the MODIS-T Developer.

3.6.2.1 Power Consumption

The orbital average power consumption shall not exceed 90 watts. The peak power consumption shall not exceed 150 watts.

3.6.2.2 Mechanical Dimensions and Mass

The MODIS-T shall be designed to mount on a double EOS Payload Mounting Plate (PMP). The mechanical dimensions of the instrument shall not exceed the standard envelopes as illustrated in the GIIS for the Platform Bay 7, Plates C and D. Appendages (including doors, shields, diffusers, cover, etc.), which exceed the standard envelopes or move through the field of view of a neighboring instrument will be negotiated separately and described in the MODIS-T ICD.

The MODIS-T mass shall not exceed 149kg.

3.6.2.3 Coldplate

The EOS Platform Contractor will provide a size A coldplate to MODIS-T. A description of the coldplate can be found in the GIIS. The mass of the coldplate will not be charged to MODIS-T; the mass of coldplate support hardware will be charged to MODIS-T. The developer shall provide any necessary thermally equivalent coldplate for his test use.

3.6.2.4 View Angles

The following fields-of-view have been factored into the EOS-A payload accommodation studies. Any views outside of these bounds are subject to negotiation.

3.6.2.4.1 Ground View

MODIS-T will have a clear +/-50 degree ground view plus the ability to see the moon.

3.6.2.4.2 Sun and Moon View

MODIS-T will be located at the front (velocity) end of the EOS platform and will be able to view the sun when EOS is passing over the South Pole and moving into sunlight or the nearly full moon when EOS is passing over the North Pole and moving into darkness. Obstructions in front of MODIS-T will be no lower than the plane defined by the nadir face of the EOS payload mounting plates.

4.0 SOFTWARE REQUIREMENTS

4.1 GENERAL

A MODIS-T Software Management Plan shall be prepared and maintained. All software necessary to design, operate, test, verify calibration specifications and analyze instrument performance shall be provided and shall conform to the requirements of the EOS Instrument Project Software

Management Plan. Software assurance requirements shall be in accordance with the PAR.

4.1.1 Data Processing Software

Software shall be provided to analyze MODIS-T test data.

4.1.2 Instrument-Based Software/Firmware

MODIS-T shall be capable of operating in the various modes defined in Section 3.2.

4.1.3 Command List and Description

A Command List and Description document shall be provided which describes all commands and command sequences necessary for operation of the instrument to enable EOSDIS to generate and validate commands for in-flight or ground operations.

4.2 INSTRUMENT GROUND SOFTWARE

Software necessary to operate, test and calibrate the instrument at the developer's facilities and at the spacecraft integrator's facilities shall be provided. The software shall support instrument verification, integration, monitoring of performance, and ground operations, as well as supporting evaluation of data acquired during spacecraft integration and during the early portion of the mission.

5. VERIFICATION AND CALIBRATION REQUIREMENTS

5.1 GENERAL

The design, operation and performance of the MODIS-T shall be verified to establish that it meets the requirements of this specification and the applicable documents referenced in Section 2. When tests or calibration activities are conducted in differing ground environments, such as in vacuum or air, justification shall be provided that the results are valid for orbital conditions.

The verification program shall:

a. Demonstrate design qualification;

b. Allow flight acceptance test of the hardware and software, and demonstrate that the performance, operational, safety and interface requirements of this specification are met;

c. Utilize calibration data, equations and procedures to demonstrate full performance;

d. Provide post launch evaluation to show that all verifiable performance requirements are met. Comparison shall be made to ground test data and any observed changes shall be analyzed and evaluated.

5.1.1 Verification Plan

A MODIS-T Verification Plan shall be prepared and maintained as required by the PAR. This plan shall describe how the information needed for demonstrating specification compliance will be obtained. The use, interconnections, and function of all ground support equipment and calibration sources shall be described.

5.1.2 Verification Specification

A MODIS-T Verification Specification shall be prepared and maintained as required by the PAR. This specification may be combined with the Verification Plan. The specification shall define environmental test parameters, and shall list the specific tests and parameter limits within the environmental envelope.

5.1.3 Verification Procedures

Formal procedures for verification of the instrument, or for subsystems which will be verified before incorporation into a larger assembly, as required by the PAR, shall be prepared and maintained. The verification procedures shall be reviewed and approved before use. Verification reports shall be prepared as required by the PAR.

5.1.4 MODIS-T Calibration Plan

A MODIS-T Calibration Plan shall be written and maintained in response to the EOS Project Calibration Management Plan. This plan shall define procedures for subassembly and instrument calibration. The plan shall define how all information needed for demonstrating specification compliance is obtained. Calibration accuracy analyses shall address both systematic and random errors. This plan and any modification shall be submitted for review and approval.

5.1.5 Documentation of Test and Calibration Data

Specification Compliance and Calibration Data Books shall be provided and shall present, as a minimum, the specification requirements and calibration results, such as spectral response curves and measured signal-to-noise ratios. Calibration curves, equations and procedures shall also be provided.

5.1.6 Limits Program

Software shall be provided to monitor command states, selected voltages, currents, temperatures and other parameters of MODIS-T in real-time. Functions which are critical shall be monitored and if a fault occurs the sensor shall be automatically shut down if operator action is not taken. The software shall also verify all operational modes and print out any out-of-tolerance items as they occur. This program shall be used any time the instrument is operated from the System Test Equipment (STE).

All automatic sequences resident in the instrument or in any computer shall be capable of being bypassed by command.

5.1.7 Configuration Management

The MODIS-T Verification Plan, the MODIS-T Calibration Plan, and all individual test and calibration specifications and procedures shall be controlled documents. Any changes to the plans shall be effected by Configuration Change Request procedures.

5.2 ENVIRONMENTAL TEST REQUIREMENTS

5.2.1 General

The MODIS-T protoflight and flight models shall be subjected to qualification level and acceptance level environmental tests respectively and shall meet all functional and performance requirements of this specification and the PAR. During tests the units are to be operated in a manner simulating flight operation.

Any subsystem testing shall include the effect of the instrument itself, as determined by the developer's analyses, on the environment for that subsystem.

The spectral properties of all bands shall be determined both in ambient (non-vacuum) and vacuum conditions.

Environmental test and analysis requirements and conditions for MODIS-T are contained in the PAR and the GIIS.

5.3 SYSTEM CALIBRATION

5.3.1 Responsibility For Calibration

MODIS-T shall be calibrated by the instrument developer. Acceptance of the instrument is predicated upon its successful calibration as specified in the MODIS-T Calibration Plan.

All tests conducted to verify integration with the platform shall also be conducted beforehand at the developer's facility to establish a performance baseline.

5.3.2 Calibration of System Response

A calibration and test program shall be conducted to determine the instrument response to known stimuli and to develop any required corrections to this response over the expected orbital range of instrument temperatures. The expected orbital thermal environment shall be simulated, and the instrument shall be tested with its full complement of shields and thermal insulation. Final calibration shall be carried out in thermal vacuum conditions.

5.3.2.1 Sources

Sources of spectral radiance or irradiance traceable to NIST shall be used. A plan for maintaining the relationship between the sources and the NIST standards through the life of the program shall be developed.

5.3.2.2 Radiometric Calibration Temperature Plateaus

Radiometric response measurements shall be made at temperature plateaus and during temperature transitions specified in the MODIS-T Calibration Plan.

Analyses and dynamic temperature measurements shall be performed as specified in the MODIS-T Calibration Plan to permit determination of radiances to the specified accuracies when the instrument temperature is changing in orbit.

5.4 SPECIAL DATA REQUIREMENTS

5.4.1 History Storage Media

A digital history record of selected instrument acceptance test and calibration data shall be generated, and shall be stored on some form of mutually agreed upon media. It shall contain the MODIS-T output data plus any required ancillary data.

5.4.2 Special Data History

Selected portions of the digital history record shall be provided on a suitable storage media for data analysis. These records shall be identified by date, test particulars and location on the storage media.

6. GROUND SUPPORT EQUIPMENT REQUIREMENTS

6.1 GENERAL

Ground Support Equipment (GSE) shall be provided and maintained through the duration of the program. The GSE consists of the System Test Equipment, software, calibration equipment, shipping containers, expendable materials and other equipment and fixtures required to operate, test, calibrate and maintain the MODIS-T in a contamination-free environment. The GSE will also support instrument-to-spacecraft integration and cross-calibration with other sensors. Tests necessary to demonstrate that the GSE is functioning properly shall be performed. The GSE will also be used to support in-flight performance verification activities during the early part of the mission.

6.2 SYSTEM TEST EQUIPMENT

6.2.1 General

The System Test Equipment (STE) shall be used to operate MODIS-T during all testing at the instrument developer's facility. The STE shall also interface with the EOS platform GSE. The STE shall be capable of recording instrument data and conducting performance analyses. It shall also perform off-line analyses of data stored on the history media.

Two functionally identical copies of the STE shall be produced. One copy, STE1, shall be delivered to the spacecraft contractor's facility with the first flight instrument. The STE1 will follow the spacecraft to the WSMC prior to launch, and will then be returned to the instrument developer's facility. STE1 will be used to perform functional and operational checks on MODIS-T when it is either on the bench or on the spacecraft. It will also support instrument cross-calibration activities on the spacecraft. The other copy, STE2, shall remain at the developer's facility throughout the program. Calibration sources shall also be delivered with STE1 for MODIS-T test and calibration at the spacecraft contractor's facility.

6.2.2 STE Requirements

(1) The STE shall duplicate as closely as possible all spacecraft interfaces. Test points shall be provided for monitoring all spacecraft signals.

(2) The STE shall, as a minimum, be capable of generating self-test programs, execute command verification and sending programs, prevent instrument damage, monitor command status, perform limit checks, record special data, and perform engineering analyses on the MODIS-T data. Recorded data shall be formatted and annotated so that it is readily accessible. A record of running time on each instrument model in each mode of operation shall be maintained.

(3) STE operation shall be generally transparent to whether the instrument is alone or mounted on the spacecraft.

(4) The STE shall include all cabling necessary to operate MODIS-T. Breakout boxes may be used to test electrical interfaces.

(5) The STE shall interface with ancillary test equipment where desirable. Data from the ancillary equipment shall be integrated with the instrument data for correlation purpose.

(6) The STE shall provide test points for all MODIS-T and STE voltages and signals that are required to assess the operational health of each system.

(7) The STE shall be capable of inputting simulated instrument data for self-test purposes.

(8) Performance and ground calibration data shall be analyzed and displayed in real time on the STE.

6.2.3 Shipping Containers

Environmentally controlled shipping or storage containers shall be provided. They shall be capable of being pressurized with dry nitrogen and shall include shock recorders, and temperature and humidity recorders. The containers shall protect the instruments while in storage or in transit. The number of shipping containers required shall be determined by the developer. Further definition of shipping container requirements are in the PAR.

6.3 EQUIPMENT FOR AMBIENT OPERATION

Equipment shall be provided to permit ambient (in-air) operation of the instrument with any cooled zones at their proper operating temperature. Water, ice or contamination shall not form on the instrument during such operation.

6.4 ANCILLARY EQUIPMENT

6.4.1 Mounting Hole Templates

Mounting hole templates shall be provided for use in drilling mounting hole patterns in the PMP. The MODIS-T instrument (including physical model) mounting holes and test fixtures shall be drilled using this template for the mounting hole pattern.

6.4.2 Handling and Lifting Fixtures

Handling and lifting fixtures shall be provided in accordance with NHB 6000.1C. These fixtures shall be used during assembly, test, shipment, and spacecraft integration operations. A set of fixtures shall be shipped with the instrument to the Observatory Integrator's facility.

APPENDIX A

A.1 Measurements

A.1.1 Precision

In this specification the use of the term "measurement precision" is defined as the standard deviation of a statistically meaningful number of samples of that measurement.

A.1.2 Repeatability

In this specification the use of the term "repeatability" is defined as the allowable difference between successive measurements of the same parameter, or successive occurrences of the same event.

A.1.3 Accuracy

In this specification the use of the term "accuracy" or "measurement accuracy" is defined as the error (estimated uncertainty) in the measurement. This estimate shall include both systematic and random errors.

A.1.4 Tolerance

Tolerance is the allowable range for a specified parameter.

A.2 Tests

Verification by test consists of any or all of the following activities.

A.2.1 Functional Test

A functional test demonstrates an event or condition with a small discrete number of possible outcomes, e.g., a go/no-go or yes/no type event.

A.2.2 Performance Test

A performance test provides a measurement of an event or condition with a continuum of possible outcomes; this test measurement is then compared with the acceptable range of measurements for that parameter.

A.2.3 Design Qualification Environmental Tests

Design qualification environmental tests prove the flight-worthiness of the design and method of manufacture. Qualification is accomplished by imposing environmental levels more severe than those expected during ground, launch, and orbital operations. Environmental levels and durations imposed shall be in accordance with the GIIS.

A.2.4 Flight Acceptance Environmental Tests

Flight acceptance environmental tests are intended to demonstrate adequate workmanship and the absence of defects in flight hardware. Environmental levels and durations imposed shall be in accordance with the GIIS.

A.2.5 Analytical Model Validation Tests

Analytical model validation tests are tests intended to validate the mathematical models used in the analytical predictions. Applicable tests include, but are not limited to, modal surveys, static deflection, static load and thermal balance tests. The analytical model validation tests may be conducted on either engineering model hardware or flight hardware and not necessarily at the hardware level of assembly the model represents.

A.3 Analysis

Analysis is used in lieu of or in addition to testing to verify compliance with specification requirements. Where applicable, environmental levels used in analyses to qualify the design shall be determined by applying the design qualification factors of Section 3 of the PAR to the limit levels of the environment.

A.4 Assessments

Verification by assessment consists of any of the following activities.

A.4.1 Similarity Assessment

Similarity assessment is the process of assessing, by review of prior test data or hardware configuration and application, that the article under consideration is sufficiently similar or identical in design and manufacturing process to another article that has previously been qualified to equivalent or more stringent specifications.

A.4.2 Inspection Assessment

Inspection assessment is the process which may be used in lieu of, or in conjunction with, testing to verify design features (e.g., physical verification of compliance with drawings, wire coding, material compliance).

A.4.3 Demonstration Assessment

Demonstration assessment is the process by which demonstration techniques (e.g., service access, transportability, hardware interfaces, replacement provisions) are used in lieu of or in conjunction with test to verify compliance with requirments.

A.4.4 Validation of Records Assessment

Validation of records assessment is the process by which manufacturing records are used to verify construction features and processes for flight hardware.

A.5 Environmental Limit Levels

Environmental limit levels are those which are expected in actual use in ground, launch, and orbital operations. Limit levels of environmnets for the Titan IV are specified in the documents referenced in the PAR. However, in determining appropriate structural load limit levels for MODIS-T and its elements, dynamic amplification by the EOS platform and within the MODIS-T instrument shall be considered per GIIS. Thermal limit levels shall be determined, including the effects of the spacecraft.