LANDSAT DATA CONTINUITY MISSION

Operational Land Imager
Special Calibration Test Requirements

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Goddard Space Flight Center
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National Aeronautics and Space Administration

CM Foreword

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1 Introduction

1.1 Purpose

The LDCM program elements are dependent on the pre-flight and on-orbit commissioning phase characterization and calibration of the imaging sensor and related subsystems, and, in particular, on the data sets and written reports from those tests. It is through the preflight test reports that the required elements of the Image Assessment System will be identified. In addition, the algorithms and input parameters to process the image data will be developed using these preflight data sets.

The purposes of the pre-flight and commissioning phase test requirements are to:

- Verify that the instrument's operation conforms to specifications;
- Establish the instrument's as-built performance;
- Test for abnormalities in the sensor's response;
- Provide an at-launch estimate of the sensor's radiometric calibration;
- Provide characterization data sets that are otherwise unobtainable in flight or on the ground (such as spectral band characteristics, PSF parameters, and solar diffuser reflectance); and
- Determine the instrument's radiometric stability.

The OLI instrument contractor has the responsibility for providing an instrument(s) capable of providing well calibrated, well characterized and specification compliant data, to ensure Landsat data continuity. The Government has the responsibility for independently assuring that the delivered instrument will be specification compliant and sufficiently well calibrated and characterized to fulfill the Mission objectives. The following Special Calibration Test Requirements (SCTRs) are an essential component of that independent assurance program.

1.2 Definitions

The observatory elements identified in Figure 1-1 and defined below are provided for clarification of terms used in the SCTR and are not intended to dictate a design implementation.

Refer to the LDCM Acronym List and Lexicon for more Definitions.

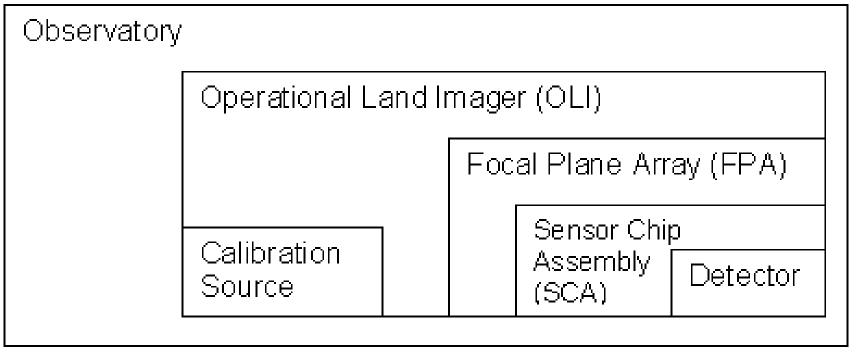

Figure 1 - 1 Relationship of Elements in the SCTR

Operational Land Imager (OLI) - The LDCM sensor payload designed to collect data for the LDCM reflective bands 1 through 9 (433-2300 nm).

Sensor - The integrated instrument comprising optics, spectral bandpass filters, sensing elements, electronics, calibration source(s), and associated mechanisms and structural elements.

Focal Plane Array (FPA) - This consists of a baseplate assembly, the 14 attached FPMs, a shadow mask, and the cover/window subassembly.

Calibration Source - A component of the sensor that provides controlled and/or measured reference radiance input to the OLI sensing elements for purposes of calibration.

Simulated On-Orbit Operating Conditions - Temperature and pressure environmental conditions similar to those experienced on-orbit, i.e., thermal vacuum.

Vacuum - Atmospheric pressure of 10^{-5} torr or less as defined in the LDCM Environmental Verification Requirements (LEVR).

Operational Temperature Range - The range of temperatures over which an LDCM subsystem or component is designed to operate while meeting all specifications.

Determine - Use one or more measurements and associated analyses to estimate the value for a particular system parameter or performance characteristic.

Focal Plane Electronics (FPE) - Main electronics box that interfaces with the FPA. The FPE provides power and clock signals to each of the FPMs on the FPA, and digitizes the analog output coming from each of the FPMs.

Focal Plane Module (FPM) - This includes the SCA mounted to a motherboard, which in turn is mounted to a molybdenum carrier. The FPM includes a filter and filter bezel that get mounted over the detectors. The FPM also includes an electrical connector on the underside of the pedestal.

Focal Plane Subsystem (FPS) - The FPE and FPA and the interconnecting cables.

Sensor Chip Assembly (SCA) - A subassembly of a single Focal Plane Module. The SCA contains the SiPIN and HgCdTe detectors that are bump-bonded to the ROIC, the ROIC, all glued to a ceramic leadless chip carrier.

1.3 Scope

The following test requirements do not constitute a complete set of tests. The Contractor is responsible for verification and validation of all OLI instrument requirements. The tests described herein are included as part of the Contractor's overall validation program as required in the Calibration/Validation Plan CDRL (CV-1). The contractor reports the results of these tests in accordance with the Calibration/Validation Test Report CDRL (CV-3). For selected tests, indicated by "(CV-9)" following the test description, the image data collected during these tests is provided to the government in accordance with CDRL CV-9.

2 General Test Requirements

Sampling methods and their statistical validity will be described in the CDRL SE-7 Verification Reports. Note: A discussion of plans for sampling and their statistical basis (if not specified by requirements) will be reported in the Verification Plan.

The sampling of the instrument and focal plane temperatures to be used for the characterizations will be described in CDRL SE-7 Verification Reports. Note: A discussion of plans for instrument and focal plane temperatures will be reported in the Verification Plan.

SCTR-37 The Contractor shall calibrate radiance calibration sources to National Institute of Standards and Technology (NIST) standards for radiometric calibrations.

3 Pre-flight Test Requirements

3.1 Spectral Test Requirements

SCTR-421 The Contractor shall measure the spectral transmission of the spectral bandpass filters per the parameters in Table 3-1.

SCTR-658 The Contractor shall measure the relative spectral radiance response of a sample of the flight filter wafers using the integrating sphere attachment of the CARY spectrometer per the parameters in Table 3-1.

Rationale: The purpose of this requirement is to test for Angle Resolved Scatter from the filters at the wafer level.

SCTR-43 The Contractor shall measure the relative spectral radiance response of a sample of witness detectors from the same detector wafers as the flight FPM per the parameters in Table 3-1.

SCTR-45 The Contractor shall measure the spectral transmission or reflectance of the optical elements of the instrument telescope per the parameters in Table 3-1.

SCTR-659 The Contractor shall measure the special transmission or reflectance of the FPA window per the parameters of Table 3-1.

SCTR-47 The Contractor shall measure the in-band relative spectral radiance response of the instrument per the parameters in Table 3-1.

SCTR-49 The Contractor shall determine the out-of-band relative spectral radiance response of the instrument for each band via measurements conducted per the parameters in Table 3-1. (Note: The Contractor will design GSE to meet Table 3-1 requirements. If GSE capability permits, data from 330 nm-1100 nm will be taken in the VNIR and from 800-2700 nm in the SWIR. Best effort will be made to meet the SNR requirements over the extra wavelength range, but noisier data will be considered compliant.)

SCTR-51 The Contractor shall characterize the stability of the spectral transmission of the spectral band bandpass filters between ambient pressure and vacuum conditions per the parameters in Table 3-1.

SCTR-53 The Contractor shall measure the spectral transmission of the thermal vacuum chamber optical window per the parameters in Table 3-1.

Rationale: These spectral calibration tests are used to determine compliance with OLI spectral requirements (section 5.4 of OLI Requirements Document [OLI-RD]). Also, these measurements are required in order to perform the radiometric calibration of the instrument and provide the user community the fundamental spectral characteristics of the data. The component level measurements (SCTR-421, SCTR-43, and SCTR-45) will be used to predict the system level response and assure the final system will likely meet relative spectral response requirements; however, measuring the response on the assembled instrument in as close to operational conditions as possible is required for an adequate characterization (SCTR-47). The spectral uniformity requirement, in particular, requires characterization of the variation in the system level responses (section 5.6.2.3 of OLI-RD). It is difficult to obtain sufficient energy to measure the out-of-band response at the integrated instrument level, so measurements at the Focal Plane Module level are allowed for this characterization (SCTR-49). Spectral bandpass filters have historically shown stability problems in the transition from ambient to vacuum conditions, apparently due to the outgassing of absorbed water. Current filter fabrication techniques have reduced this problem significantly; test SCTR-51 is intended to verify that the OLI filters do not have this problem and will likely meet the spectral stability requirement for OLI (section 5.4.5 of OLI-RD). The spectral and radiometric characterizations of the integrated instrument will occur with the instrument in the Thermal Vacuum chamber and the calibration sources outside; a characterization of the spectral transmission of the optical window is thus required.

Table 3 - 1 Spectral Test Minimum Acceptable Requirements

Test	**Assembly Level**	**Unit**	**Measurement Conditions**	**Samples**	**Wavelength Range**	**Wavelength Sampling and Wavelength Resolution (FWHM)**	**Precision in Response***	**Other**
SCTR-421	Component	Filter	At ambient temperature, normal incidence	3X3 per flight filter wafer	200-1100 nm for VNIR bands; 800-2600 for SWIR bands	1 nm steps	The ratio of the Peak Signal to RMS Noise out of band > 10^4; SNR>300 in-band	
SCTR-421	Component	Witness Sample	At ambient and 210 K, normal incidence	2 per flight filter wafer	200-1100 nm for VNIR bands; 800-2600 for SWIR bands	1 nm steps	The ratio of the Peak Signal to RMS Noise out of band > 10^4; SNR>300 in-band	
SCTR-421	Component	Witness Sample, EDU or Flight	At ambient	N/A	200-1200 nm for VNIR bands; 800-3000 for SWIR bands	1 nm steps	The ratio of the Peak Signal to RMS Noise out of band > 10^4; SNR>300 in-band	
SCTR-658	Component	Filter	At ambient temperature, normal incidence	N/A	300-1000 nm for VNIR bands; 800-2500 for SWIR bands	1 nm steps		

SCTR-43	Component	Detector	Operational temperature conditions	Witness detectors from the same wafer as the flight FPMs	350-1100 nm for VNIR bands; 800-3000 nm for SWIR bands	VNIR: 10 nm steps; SWIR: 15.4 cm^{-1} wavenumber sampling for wavelengths >1200 nm; 5 nm for wavelengths , <1200 nm	Per Raytheon Vision Systems standard operating procedures	
SCTR-45	Component	Optical Surfaces or Witness Samples	Operational temperature conditions	3 samples of each optical surface	400 nm - 900 nm for VNIR bands; 1300-2300 for SWIR bands	VNIR: 5 nm steps; SWIR : 50 nm steps	The ratio of the Peak Signal to RMS Noise out of band > 10^4; SNR>300 in-band	
SCTR-659	Component	Optical Surfaces or Witness Samples	Operational temperature conditions +/- 10C	3 samples of each optical surface	300-2600 nm	VNIR: 5 nm steps; SWIR : 50 nm steps	The ratio of the Peak Signal to RMS Noise out of band > 10^4; SNR>300 in-band	
SCTR-47	Integrated Instrument		Vacuum, operational focal plane temperature	10% of detectors uniformly distributed across focal plane. Plus the edges of at least two FPM per band across the FPA.	Between 0.005 response points	1 nm below 1 μm; 2 nm above 1 μm	0.01 (1 σ) above 0.1 RSR; SNR >10 below 0.1 RSR	
SCTR-49	Assembly or above	Focal Plane Module Level or above	Operational temperature conditions with approximately a 6.4 F#	80% of all operational pixels in VNIR bands; 3% of all detectors on each FPM in the SWIR bands	350 nm to 1100 nm for VNIR bands; 800 nm to 2500 nm for SWIR bands. (see note under SCTR-49 reqt.)	10 nm below 1 μm; 20 nm above 1 μm	In-Band Peak-Signal-to-RMS Noise > 10^4 over the out-of-band wavelength range; SNR>20 in-band	Use SCTR-45 results to represent optics if no instrument level test

SCTR-51	Component	Filter witness samples	Ambient conditions then in vacuum after 1, 3, 5 and 7 days of vacuum exposure	1 filter Visible band; 1 filter SWIR band, 1 spot per filter	350-950 nm for VNIR bands; 1000-2500 for SWIR bands	In-band: 1 nm below 1 µm; 2 nm above 1 µm; Out-of band: 5 nm below 1 µm, 10 nm above 1 µm	The ratio of the Peak Signal to RMS Noise out of band > 10^4; SNR>300 in-band	
SCTR-53	Test Equipment	T/V Chamber Optical Window or Witness Sample	Ambient Conditions	10 spots	330-2700 nm	Within any band's in-band response: 1 nm below 1 µm; 2 nm above 1 µm; Out-of-band: 5 nm below 1 µm, 10 nm above 1 µm	0.001 (1 σ) in band; SNR of >10 down to 0.0005 of peak	

* Note: The units of the stated precision values match the units of the reported data for the corresponding specification for in band response and are given as a SNR value, which is a unitless ratio of the precision level to the actual reported measurement level, for out of band response.

3.2 *Spatial test requirements*

SCTR-151 The Contractor shall characterize the spatial edge response based on measurements at the integrated instrument level, post-vibration testing under simulated on-orbit operating conditions across the entire cross-track FOV in all bands under the following measurement conditions. (CV-9).

Measurement conditions:

- SCTR-153 14 field angles (scale factors of field-of-view (FOV): -0.97, -0.80, -0.65, -0.50, -0.35, -0.21, -0.07, 0.07, 0.21, 0.35, 0.50, 0.65, 0.80, 0.97)
- SCTR-154 0.05 IFOV increments from ± 3 IFOV from center of detector in both along-track and across-track directions
- SCTR-155 0.5 IFOV increments from 3 to 10 IFOV from center of detector in both along track and across-track directions
- SCTR-156 At the nominal operational temperatures

Rationale: These measurements will be used to verify the OLI Edge Response requirements (Section 5.5.2 of the OLI-RD). Edge response may be a function of location within the focal plane, hence the requirement to characterize across the entire FOV. The angular sampling provides equal enclosed area increments.

SCTR-159 If spatial measurements are done with the source outside the thermal vacuum chamber, the Contractor shall measure the optical power and distortion of the thermal vacuum chamber optical window under expected thermal vacuum operating conditions.

Rationale: Spatial measurements performed through the chamber window will be affected by the window's optical properties.

SCTR-162 The Contractor shall characterize and analyze the stray light rejection and internal light scattering of the instrument based on measurements at the component level or above.

Rationale: These measurements and analysis will be used to verify section 5.5.4 of the OLI-RD and section 3.3.1.3.1 of the IRD.

SCTR-594 The contractor shall validate the OLI stray light model by stray light measurements at the integrated telescope level.

Note: Integrated telescope level includes the stimulation source assembly and the light shade assembly. It may exclude the focal plane assembly.

SCTR-595 The contractor shall update the stray light model to account for discrepancies between the stray light test of SCTR-594 and the stray light model that are beyond the combined model and measurement uncertainties.

Note: The stray light requirements verification is done per SCTR-162.

SCTR-164 The stray light model shall be developed using a Government-approved non-sequential ray trace method, e.g. ASAP, APART, GUERAP, FRED, or Trace Pro.

SCTR-166 The stray light model shall encompass the entire optical system, including baffles and the focal plane, detectors and mounting devices and all portions of the satellite bus and other payloads that may reflect light into the sensor.

SCTR-169 The Contractor shall include a stray light analysis of the solar diffuser panel(s) in the deployed position.

SCTR-171 This analysis shall include glints and shadowing on the diffuser by other observatory structures as well as the instrument itself.

SCTR-481 As part of this analysis, the Contractor shall demonstrate that diffuser measurements on orbit are not contaminated by reflected light from the Earth and the atmosphere.

SCTR-482 The contractor shall validate, by measurements at the integrated instrument level in two separate bands, the diffuser stray light model's (excluding observatory effects) prediction of the enhancement of the light reflected off the diffuser above that calculated using its inherent reflectance due to reflections off the instrument back to the diffuser.

Rationale: This characterization will allow the solar diffuser to be used as an absolute calibration source: the observatory, the instrument itself and the Earth may all contribute stray light to the solar diffuser.

SCTR-182 The Contractor shall analytically verify the ghosting requirements (sec 5.5.5 of the OLI-RD) are met by using the stray light model in SCTR-162.

SCTR-184 The Contractor shall verify requirement OLI-788 (Ghosting) of the OLI-RD by test using broadband far-field illuminated test object(s).

SCTR-484 The test objects, for verification of requirement OLI-788 (Ghosting) of the OLI-RD, shall be scanned across the full FOV of the telescope.

SCTR-485 Requirement OLI-788 (Ghosting) of the OLI-RD shall be verified through one of the following:

(1) At the integrated instrument level with a two-dimensional test object subtending a minimum of 1.5°, or

(2) At the integrated instrument level with a two-dimensional test object subtending a minimum of 0.2° and at the subassembly or higher level of integration with a two-dimensional test object subtending a minimum of 1.5°. Verification using the 1.5° object can be achieved by combining sub-assembly (e.g. early focal plane integration level & telescope) tests data as inputs to an analysis using Ray-trace and Stray-light models. In this case, the sub-assembly measurements shall emulate the effect of scanning this two dimensional object anywhere in the OLI telescope FOV.

3.3 Radiometric Test Requirements

SCTR-187 The Contractor shall radiometrically calibrate all detectors at the integrated instrument level per the parameters in Table 3-2. (CV-9).

SCTR-189 The Contractor shall characterize the radiometric response of all detectors across the design instrument operating temperature range per the parameters in Table 3-2 (CV-9).

SCTR-191 The Contractor shall collect calibration data sets and characterization data to demonstrate that the calibrated data will meet the absolute radiometric accuracy, pixel-to-pixel uniformity and radiometric stability requirements on orbit per the parameters in Table 3-2 (CV-9).

SCTR-193 The Contractor shall determine the mathematical equation(s) to convert the instrument output in DN to input radiance per the parameters in Table 3-2.

Rationale: These tests (SCTR-187, SCTR-189, SCTR-191 and SCTR-193) provide the basic radiance calibration of the instrument. The characterization of the mathematical form of the radiance calibration (e.g., linear) may be more accurately performed before integration of the focal plane into the instrument, whereas the final pre-launch calibration (SCTR-187) is performed on the integrated instrument. Characterization of the temperature sensitivity of this calibration (SCTR-189) is performed on a subset of the radiance levels used for the primary calibration. Verification that the instrument, the radiance calibration and the radiance calibration algorithm perform to requirements for accuracy, stability and pixel-to-pixel uniformity (in part) (sections 5.6.1, 5.6.2.3, 5.6.5 of the OLI-RD) occurs in SCTR-191.

SCTR-547 Flight Diffuser Preparation Step 1: As an initial step, the Contractor shall vacuum bake out the flight diffuser material and measure released contaminants.

SCTR-550 Flight Diffuser Preparation Step 2: The Contractor shall measure the BRDF of the flight diffuser materials after the bake out.

SCTR-548 Flight Diffuser Preparation Step 3: The Contractor shall keep the flight diffusers and several (at least 6) witness samples in a clean, sealed or purged environment when not in use.

SCTR-549 Flight Diffuser Preparation Step 4: The Contractor shall subject some of the witness samples to lifetime ultraviolet exposure.

SCTR-556 Flight Diffuser Preparation Step 5: The Contractor shall establish criteria for acceptable diffuser degradation due to ultraviolet exposure, and reject any diffuser material lots that do not meet these criteria.

SCTR-557 Flight Diffuser Preparation Step 6: If the lot is rejected, flight diffuser preparation steps 1 though 6 shall be performed with a new material lot.

SCTR-551 During I&T, the Contractor shall use test (non-flight) diffusers and several witness samples for all instrument and observatory I&T activities, except for those activities where by mutual agreement, the flight diffusers will be used.

SCTR-552 Post I&T, the Contractor shall subject the witness samples, which accompanied the test (non-flight) diffusers during I&T, to ultraviolet damage testing and characterize their reflectance.

SCTR-553 Post I&T, the Contractor shall select one witness sample, which accompanied the flight diffusers, and subject the sample to ultraviolet damage testing and characterize its reflectance afterward.

SCTR-558 Post I&T, the Contractor shall select another witness sample, which accompanied the flight diffusers, and subject the sample to vacuum bake out and ultraviolet damage testing and characterize its reflectance afterward.

SCTR-554 If necessary, based on the results of the post I&T tests on the witness samples which accompanied the flight diffusers, the Contractor shall subject the flight diffusers to vacuum bake out.

SCTR-555 The Contractor shall integrate the flight diffusers to the instrument as close to launch as possible.

SCTR-559 The Contractor shall reserve, for potential post-launch analysis, at least two witness samples, which accompanied the flight diffusers and which did not undergo additional testing, and maintain the samples in a clean, sealed or purged environment.

SCTR-196 The Contractor shall measure the absolute repeatability of reflectance due to solar diffuser deployment. Measurement of this repeatability at the system level constitutes characterizing the BRDF Factor at operational angles.

SCTR-486 The Contractor shall characterize the reproducibility instrument response under repeated diffuser deployments at the integrated instrument level.

Rationale: The solar diffuser provides the reflectance-based calibration of the instrument (section 5.6.1 of OLI-RD); the characterization of the reflectance and deployment angles of the diffuser are required to use the solar diffuser as a reflectance calibration source, as well as a radiance calibration source assuming knowledge of the solar spectral irradiance.

SCTR-204 The Contractor shall characterize the warm-up behavior of the Internal Lamps at the integrated instrument level over a period of greater than 5 minutes per the parameters in Table 3-2 (CV-9).

Rationale: The internal light sources provide the only technique for monitoring the short-term stability of the radiometric calibration, i.e., minutes to days.

SCTR-207 The Contractor shall provide an integrated instrument-level observation of at least one on-board calibration device that is radiometrically stable through launch (CV-9).

SCTR-488 This observation shall be repeatable on orbit to assess the transfer of the pre-launch radiometric calibration to on-orbit calibration (i.e., Transfer to Orbit Measurement).

Rationale: A recurring problem with satellite sensors is a loss of certainty in the absolute calibration of the instrument during the launch process. Changes in conditions between ground and on-orbit, e.g. gravity, make certain devices perform differently. The contractor is required to provide a transfer to orbit calibration source (5.8.2.h of the OLI-RD) that is free of known differences in performance between these environments. This device needs to be exercised during pre-launch testing and once on-orbit to assess the instruments stability through this period.

SCTR-489 The Contractor shall characterize the Signal to Noise Ratio (section 5.6.2.1 of OLI-RD) of all detectors per the parameters in Table 3-2 (CV-9).

SCTR-490 The Contractor shall characterize the predictability of all imaging detector biases from the dark reference detectors for each SCA per the parameters in Table 3-2 (CV-9).

SCTR-491 The Contractor shall characterize the bias stability and noise levels of all imaging and dark reference detectors per the parameters in Table 3-2 (CV-9).

Rationale: The bias stability of the imaging detectors and the correlation of the imaging detectors variation with the dark reference detectors are fundamental to the performance of the bias determination algorithm and thus ability to determine the bias values applicable to an individual acquisition. The longest continuous WRS-2 path over land masses is about 30 minutes in length.

SCTR-219 The Contractor shall characterize the baseline 1/f noise parameters for all imaging and dark reference detectors per the parameters in Table 3-2 (CV-9).

SCTR-222 The Contractor shall characterize the coherent noise of the instrument (section 5.6.2.4 of OLI-RD) per the parameters in Table 3-2 (CV-9).

SCTR-493 The Contractor shall characterize the dark level coherent noise of the instrument (section 5.6.2.4 of OLI-RD) per the parameters in Table 3-2 (CV-9).

SCTR-496 The Contractor shall characterize the linear polarization sensitivity of the instrument (section 5.6.4 of OLI-RD) by component level measurements (witness mirrors) and analysis.

SCTR-497 The Contractor shall measure the linear polarization sensitivity of a sampling of detectors from each band (center and edges of field of view) per the parameters in Table 3-2.

SCTR-499 The Contractor shall verify the bright target recovery requirements of the instrument (section 5.6.6 of OLI-RD) per the parameters in Table 3-2.

SCTR-231 The Contractor shall provide and maintain a detector operability status list that includes dead, inoperable, and out-of-spec detectors for each band.

Table 3 - 2 Radiometric Test Minimum Acceptable Requirements

Test	Assembly Level	Measurement Ambient Atmospheric Conditions	Measurement Temperature Conditions	Radiance Levels	Calibration Source Location	Comments
SCTR-187,	Integrated Instrument	Thermal Vacuum (nominal temperature)	Nominal operational focal plane temperature	Dark and 5 levels between 0.3 Ltypical and LMAX	Ambient viewed through chamber window	
SCTR-189,	Integrated Instrument	Thermal Vacuum (nominal and high temperature plateau)	Nominal operational focal plane temperature	Dark and 5 levels between 0.3 Ltypical and LMAX	Ambient viewed through chamber window	
SCTR-191,	Integrated Instrument	Thermal Vacuum (nominal and high temperature plateau)	Nominal operational focal plane temperature	Dark and 5 levels between 0.3 Ltypical and LMAX	Ambient viewed through chamber window	
SCTR-193,	Integrated Instrument		Nominal operational focal plane temperature	Dark and 10 levels between 0.3 Ltypical and LMAX;		
SCTR-489	Integrated Instrument	Thermal Vacuum (nominal and high temperature plateau)	Nominal operational focal plane temperature	Dark and 10 levels between 0.3 Ltypical and LMAX;	Ambient viewed through chamber window	

SCTR-490,	Integrated Instrument	Thermal Vacuum	Nominal operational focal plane temperature	Dark Level, measurements over 40 minutes (may be sampled non-contiguously) three repeats		
SCTR-491	Integrated Instrument	Thermal Vacuum	Nominal operational focal plane temperature	Dark Level, measurements over 40 minutes (may be sampled non-contiguously) three repeats		
SCTR-219	Integrated Instrument	Thermal Vacuum	Nominal operational focal plane temperature	Dark Level, continuous over 60 sec,non-contiguous,but continuous over 40 minutes		
SCTR-222	Integrated Instrument	Thermal Vacuum (nominal temperature)	Nominal operational focal plane temperature	Dark and 1 level above 0.3 Ltyp	Ambient viewed through chamber window	
SCTR-493	Integrated Instrument	Thermal Vacuum (nominal temperature)	Nominal operational focal plane temperature	Dark Level		
SCTR-497	Integrated Instrument		Nominal operational focal plane temperature			
SCTR-499	Focal plane level or above		Nominal operational focal plane temperature			
SCTR-204	Integrated Instrument	Thermal Vacuum (nominal and high temperature plateau)	Nominal operational focal plane temperature			Internal Lamps to be operated and warm-up behavior characterized during these tests;FPA reset as per on-orbit ops

3.4 Geometric Test Requirements

SCTR-322 The Contractor shall determine each detector's LOS relative to the Contractor defined instrument reference axes, to an accuracy ≤ 12 µrad (3-sigma), at the integrated instrument level. Note: The determination of the detectors lines of sight may be based on a combination of measurement and analysis.

Rationale: Band-to-band and image-to-image registration error budgets are driven by platform stability and line-of-sight knowledge and stability. The current error budgets assume 6 µrad (3-sigma) LOS knowledge and stability. On-orbit results from ALI showed focal plane calibration consistency of 3.9 µrad (3-sigma) for SCA-level offset, rotation and scale parameters.

SCTR-325 The Contractor shall measure the detector lines of sight by measuring the relative locations of a selected set of detectors with a repeatability ≤ 6 µrad (3-sigma), at integrated instrument or observatory level, post-vibration.

SCTR-327 The selected set of detectors for SCTR-322 and 325 shall include, at a minimum, the first, middle, and last detector in each row,(due to even/odd detector stagger) from each band on each SCA. Detectors that are not selected for flight do not have to be measured.

Rationale: Line-of-sight stability (over the range of expected operating temperatures) of 6 µrad (3-sigma) or better is required by the current band registration and image registration error budgets. The measurements intended to demonstrate stability to this level must be more accurate by a factor of 2 or better.

SCTR-330 The Contractor shall characterize the detector-sampling timing pattern, to an accuracy of 150 microseconds (3-sigma) or better, via measurement of any detector-specific electronic delays, sample phasing (e.g., even/odd detector timing offsets), and frame rate (i.e., time between samples) for each detector.

Rationale: Detector to detector timing/latency variations must not significantly degrade the line-of-sight knowledge of 6 µrad (3-sigma). Timing knowledge to 50 microseconds corresponds to an additional LOS uncertainty of approximately 1.5 µrad. This is slightly less that the overall absolute timing knowledge accuracy requirement of 100 microseconds (3-sigma) cited in OLI-RD sections 11.1.

SCTR-333 The Contractor shall measure the alignment of the Contractor defined instrument reference axes relative to the OLI alignment reference/ alignment cube.

Rationale: The prelaunch alignment of the instrument to the ACS reference frame is an initial measurement used to get the on-orbit calibration procedure started. The actual instrument alignment is expected to shift due to launch and zero-G release. This measurement is the instrument portion of the overall OLI to observatory ACS alignment measurement. The geodetic accuracy error budgets are based on on-orbit alignment calibration accuracy so the accuracy of the prelaunch measurements is not critical.

SCTR-336 The Contractor shall demonstrate the ability to reconstruct and register images in all spectral bands from data collected under conditions that simulate the on-orbit target motion (CV-9).

Rationale: This test is intended to verify the integrity of the instrument to recorder data path.

Note: This demonstration may be performed in segments over the full FOV of the instrument.

SCTR-340 Following observatory-level vibration testing, the Contractor shall demonstrate that the data from the VNIR detectors are mapped to the correct locations in the observatory downlink data stream.

Rationale: This observatory level test is intended to demonstrate that the instrument and spacecraft data handling systems were successfully integrated and that no data connections were damaged during vibration testing. An internal source that provides input that varies across the focal plane should be sufficient for verifying the integrity of the data path.

Note: This test may be performed using an internal source.

4 On-Orbit Commissioning Phase Test Requirements

4.1 Spatial Test Requirements

SCTR-346 The Contractor shall examine the stray light and ghosting of the instrument using the moon at least twice, using data acquired at least 16 days apart.

Rationale: Although a true characterization of the stray light response and ghosting is not possible using the moon, the data can be examined for effects that are not predicted by the stray light model. In other instruments, e.g. ALI and ASTER lunar views have revealed stray light and ghosting issues.

4.2 Radiometric Test Requirements

SCTR-350 The Contractor shall characterize the on-board lamp-based calibrator's on-orbit performance and stability including warm-up behavior and within and between orbit stability relative to the instrument.

SCTR-352 The Contractor shall characterize the variation in the bidirectional reflectance of the solar diffuser across the range of azimuth and zenith angles to be used for on-orbit calibration.

SCTR-354 The contractor shall characterize the reproducibility of the solar calibration technique with a minimum of 5 measurements, with each measurement acquired a minimum of 1 day apart.

SCTR-356 The contractor shall complete the on-orbit portion of the Transfer to Orbit Measurement (See SCTR-207).

SCTR-358 The Contractor shall characterize the stability of the instrument by reference to the internal lamps by a minimum of daily measurements.

SCTR-360 The Contractor shall update the absolute calibration coefficients and uncertainties as required to meet performance specifications.

SCTR-362 The Contractor shall characterize any variations in detector responsivity over a minimum of 2 instrument outgassing cycles, if outgassing is required.

SCTR-364 The Contractor shall characterize the relative detector response for detectors within a band and update the calibration parameters to correct pixel-to-pixel non-uniformity as necessary.

SCTR-366 The Contractor shall characterize both the coherent and total noise of the instrument at dark and at multiple (at least 2) illuminated levels between dark and Lhigh at least twice with data acquired at least 16 days apart.

SCTR-368 The Contractor shall characterize the bias stability for all imaging and dark reference detectors over a 36-minute period at least twice, with data acquired a minimum of 16 days apart.

SCTR-370 The Contractor shall characterize the 1/f noise parameters for all imaging and dark reference detectors over a 36-minute period at least twice, with data acquired a minimum of 16 days apart.

SCTR-372 The Contractor shall characterize the predictability of the imaging detectors biases from the dark reference detectors over a 36-minute period at least twice, with data acquired a minimum of 16 days apart.

SCTR-374 The Contractor shall characterize the performance of the bias determination algorithm using on-orbit data for acquisition intervals of up to 36 minutes.

SCTR-376 The Contractor shall support imaging the full lunar disk at a phase angle of 5° to 9° or -9° to -5°.

SCTR-378 At least 2 SCA's shall image the moon at least twice during commissioning at the same phase angle, one lunar cycle apart.

SCTR-380 All SCA's shall image the moon at least once within this same 4° increment of phase angles.

SCTR-382 If Landsat-7 is still operational, the Contractor shall support collection of data of common ground targets within 20 minutes of the Landsat-7 ETM+ acquisitions.

SCTR-384 The Contractor shall update the detector operability status list with newly identified dead, inoperable, and out-of-spec detectors for each band.

Rationale: To the extent possible, the pre-launch radiometric tests need to be repeated on orbit to assess whether anything has changed since pre-launch testing and to characterize the system under its actual operating conditions. Noise levels, particularly coherent noise, may change with the change in grounding of the spacecraft. The radiometric response, both absolute and relative, may change during launch. Calibration techniques not readily available prior to launch, e.g., solar and lunar calibration, need to be conducted and their repeatability assessed.

4.3 Geometric Test Requirements

SCTR-388 The Contractor shall characterize the instrument to Attitude Determination System Reference alignment.

Rationale: The instrument alignment is expected to change due to launch shift and zero-G release, so an on-orbit update is required to achieve the required on-orbit geodetic accuracy performance. The accuracy is here left as a component of the overall geodetic error budget to be determined by the contractor. Internal error budgets call for an alignment calibration accuracy of 45 microradians (3-sigma).

SCTR-391 The Contractor shall characterize the detector arrays lines of sight for bands 1-8 relative to the panchromatic band using ground targets at least twice, using data acquired at least 16 days apart.

Rationale: The prelaunch line-of-sight calibration could change on-orbit due to the reaction of the optical system to launch and/or zero-G release. Any such changes would be expected to be slowly varying (not detector-by-detector) and subject to calibration using SCA-level on-orbit adjustments (as was done for the ALI). Once on-orbit, these LOS measurements are necessarily relative, so the calibration operation measures the offsets of bands 1-8 relative to the panchromatic band. The accuracy is here left as a component of the overall band registration error budget to be determined by the contractor. Internal error budgets call for a band alignment calibration accuracy of 6 microradians (3-sigma).

SCTR-394 The Contractor shall characterize the alignment of band 9 (cirrus) relative to the other reflective bands using the lunar scan data described in SCTR-376, SCTR-378, and SCTR-380.

Rationale: The band alignment procedure used for bands 1-8 (see previous requirement) are unlikely to be effective for the cirrus band which will not provide clear images of ground targets. Instead, this procedure must be carried out using the lunar scan data. The accuracy is here left as a component of the overall band registration error budget to be determined by the contractor. Internal error budgets call for a band alignment calibration accuracy of 6 microradians (3-sigma).

SCTR-397 The Contractor shall characterize the relative locations of the individual SCA's on the focal plane at least twice, using data acquired at least 16 days apart.

Rationale: The prelaunch line-of-sight calibration could change on-orbit due to the reaction of the optical system to launch and/or zero-G release. Any such changes would be expected to be slowly varying (not detector-by-detector) and subject to calibration using SCA-level on-orbit adjustments (as was done for the ALI). Once on-orbit, these LOS measurements are necessarily relative, so the calibration operation measures the offsets of each SCA relative to the mean of the SCA's. The accuracy is here left as a component of the overall image-to-image registration error budget to be determined by the contractor. Internal error budgets call for an SCA alignment calibration accuracy of 6 microradians (3-sigma).

5 Appendix A

6 Appendix B

7 Appendix C