

Sustainable Land Imaging-Technology (SLI-T) Reference Mission Architecture

Since FY 2014, NASA and the USGS have been supporting the design of a system architecture for a sustainable, realistic, and affordable program that will provide future land imaging data compatible with the existing Landsat data record and, specifically, as consistent with the characteristics of the data stream currently produced by Landsat-8, as practical. Amongst the results of FY14 architecture studies indicated that recent advances in technologies, such as focal plane technologies, may enable smaller, lower-cost imaging instruments that can satisfy SLI performance requirements. Additional results of studies include that efficiencies may be gained by moving toward smaller, lower-cost missions (aka, “smallsats”) that can take advantage of lower cost launch options.

For the purposes of this solicitation only, a baseline SLI-T reference mission architecture, based upon, but not necessarily identical to the current Landsat 8 reference parameters is defined.

The SLI-T reference mission architecture is defined as follows:

1. SLI-T Reference Mission (RM) Parameters

1.1 SLI-T Reference Mission

The baseline SLI-T reference mission consists of a single spacecraft with a single instrument for perform the VIS and SWIR portions (Bands numbers 1 through 9) of the measurements, and a separate single instrument for performing the TIR (Band numbers 10 and 11) portion of measurement.

The baseline SLI-T reference mission orbit is based upon the current Landsat 8 orbit and assumes a repetitive, circular, Sun-synchronous, and near polar at a nominal altitude of 705 km (438 miles) at the Equator.

1.2 SLI-T RM Spatial and Temporal Coverage

1.2.1 The System shall provide a nadir-pointing imaging opportunity for all the 185 km x 180 km scenes identified in the Landsat Worldwide Reference System-2 (WRS-2) grid at least once every 16 days.

1.2.2 The System shall collect image data on the sunlit earth with an equatorial local solar crossing time of 10:00 AM +/- 15 minutes.

1.2.3 The System shall collect and archive an average of at least 600 individual WRS-2 scenes per 24 hour period; averaged over any WRS-2 observation period.

1.2.4 The System shall collect data for all spectral bands as defined in section 2 SLI-T Reference Missions Key Imaging Performance Parameters, within a twenty-second period for any point within a single scene observed by the System

2 SLI-T RM Key Imaging Performance Parameters

Key imaging performance parameters for the SLI-T reference mission includes;

- Imaging Bands
- Spectral Performance
- Spatial Performance
- Radiometry
- Geometric Precision, Geolocation and Cartographic Registration

2.1 SLI-T RM Imaging Bands

The system shall collect image data for each of the spectral bands specified in Table 1.

2.2 SLI-T RM Spectral Image Performance

The System shall collect image data for each of the spectral bands specified in Table A.2.

2.2.1 Spectral Bands Edges

Spectral Bands Edges	
Identifier	Requirements Description
VSWIR-1000 Spectral Band Edges	The band edges for each spectral band shall fall within the range of the minimum lower band edge and the maximum upper band edge as listed in Table A.2.
TIR-1000 Spectral Band Edges	The band edges for each spectral band shall fall within the range of the minimum lower band edge and the maximum upper band edge as listed in Table A.2.

2.2.2 Center Wavelength

Center Wavelength	
Identifier	Requirements Description
VSWIR-1001 Center Wavelength	The center wavelength of the spectral response, i.e. the midpoint between the band's upper and lower band edges, shall be the values listed in Table A.2 within the specified tolerances also listed in Table A.2
TIR-1001 Center Wavelength	The center wavelength of the spectral response, the midpoint between the band's upper and lower band edges, shall be the values listed in Table A.2 within the specified tolerances also listed in Table A.2.

2.2.3 Spectral Flatness

Spectral Flatness

The relative spectral radiance response between the lower band edge (lowest wavelength with 0.5 of peak relative response) and the upper band edge (highest wavelength with 0.5 of peak relative response) is required to have the following properties:

Identifier	Requirements Description
VSWIR-1002 Average Response	The average relative spectral radiance response shall be greater than 0.8.
TIR-1002 Average Response	The average relative spectral radiance response shall be greater than 0.8.
VSWIR-1003 Minimum Response	No relative spectral radiance response shall be below 0.4.
TIR-1003 Minimum Response	No relative spectral radiance response shall be below 0.4.
VSWIR-1004 Flatness Between 0.8 Relative Response Points	The relative spectral radiance response between the minimum wavelength within the band with a 0.8 relative response point and the maximum wavelength within the band with a 0.8 relative response point shall always exceed 0.7.
TIR-1004 Flatness Between 0.8 Response Points	The system relative spectral radiance response between the minimum wavelength within the band with a 0.8 response and the maximum wavelength within the band with a 0.8 response point shall always exceed 0.7.

2.2.4 Out of Band Response

Identifier	Requirements Description
VSWIR-1005 Beyond 0.01 Relative Response Points	The ratio of the integrated relative spectral radiance response outside the 0.01 response points of each defined spectral band to the integrated relative spectral radiance response between the 0.01 response points of each defined band shall be less than 2%. Note: The 0.01 relative response points are the points closest to the center wavelength where the relative response first drops to 0.01 of the peak relative response on each side of the center wavelength. The integrated responses will be weighted by the solar TOA irradiance. The “Chkur” solar spectrum will be used for this calculation. Electrical crosstalk is not included within this requirement.
TIR-1005 Out of Band Response	The ratio of the integrated relative spectral radiance response outside the 0.01 response points of each defined spectral band and between 3000 and 20000 nm to the integrated relative spectral radiance response between the 0.01 response points of each defined band shall be less than 2%.
VSWIR-1005 VNIR and Cirrus	For the Visible and Near-Infrared (VNIR), bands 1, 2, 3, 4, and 5, and Cirrus band, band 9, the value of the out of band relative spectral response at wavelengths lower than the lower band edge of the FWHM point minus 50 nm and the wavelengths higher than the higher band edge of the FWHM point plus 50 nm shall not exceed 0.001. Electrical crosstalk is not included within this requirement.

VSWIR-1006 SWIR and Panchromatic	For the two Short-Wave Infrared (SWIR), bands 6 and 7, and Panchromatic band, band 8, the value of the out of band relative spectral response at wavelengths lower than the lower band edge of the FWHM point minus 100 nm and the wavelengths higher than the higher band edge of the FWHM point plus 100 nm shall not exceed 0.001. Electrical crosstalk is not included within this requirement.
TIR-1006	The ratio of the integrated relative spectral radiance response outside the 0.01 response points of each defined spectral band and below 3000 nm to the integrated relative spectral radiance response between the 0.01 response points of each defined spectral band shall be less than 0.5%.
TIR-1007	The integrated responses will be weighted by the radiance from a 300K blackbody summed with the radiance from a Lambertian surface of 100% reflectance illuminated by the sun at a zenith angle of 30°. The “Chkur” solar spectrum shall be used for this calculation. The 0.01 response points are the points closest to the center wavelength where the response first drops to 0.01 of the peak response on each side of the center wavelength. Electrical crosstalk is not included within this requirement.

2.2.5 Relative Spectral Response Edge Slope

Relative Spectral Response Edge Slope	
Identifier	Requirements Description
VSWIR-1007 Wavelength Intervals - Case 1	The wavelength interval between the first 0.05 and the first 0.5 relative spectral response points and the last 0.5 and the last 0.05 relative response points shall not exceed the values in Table A.3.
TIR-1008 Wavelength Intervals - Case 1	The wavelength interval between the first 0.05 and the first 0.50 relative response points and the last 0.50 and the last 0.05 relative response points shall not exceed the values in Table A.3.
VSWIR-1007 Wavelength Intervals - Case 2	The wavelength interval between the first 0.01 and the first 0.5 relative spectral response points and the last 0.5 and the last 0.01 relative response points shall not exceed the values in Table A.3.
TIR-1008 Wavelength Intervals - Case 2	The wavelength interval between the 0.01 relative response points and the corresponding 0.50 response band edge shall not exceed the values in Table A.3.

2.2.6 Spectral Uniformity

Spectral Uniformity	
Identifier	Requirements Description
VSWIR-1008 Spectral Uniformity	Within a band the measured FWHM bandwidths for each detector shall be within $\pm 3\%$ of the measured mean FWHM bandwidth.
TIR-1009 Spectral Uniformity	Within a band the measured FWHM bandwidths for each detector shall be within $\pm 5\%$ of the measured mean FWHM bandwidth. Within a band the measured center wavelengths for each detector shall be within ± 50 nm of the measured mean center wavelengths.

2.2.7 Spectral Stability

Spectral Stability	
Identifier	Requirements Description
VSWIR-1009 Spectral Stability	Band center wavelengths and band edges shall not change by more ± 2 nm over the life of the mission.
TIR-1010 Spectral Stability	Band center wavelengths and band edges shall not change by more ± 50 nm over the life of the mission.

2.2.8 Spectral Band Simultaneity

Spectral Band Simultaneity	
Identifier	Requirements Description
VSWIR-1010 Spectral Band Simultaneity	For any point within a single WRS-2 scene, the data for spectral bands 1 through 9 shall be collected within a 1.5-second period.
TIR-1011 Spectral Band Simultaneity	For any point within an observed single scene, the instrument shall acquire data for all TIR spectral bands within a 2.5-second period.

2.3 SLI-T RM Spatial Performance

2.3.1 Reflective Band Ground Sample Distance

Reflective Band Ground Sample Distance	
Identifier	Requirements Description
VSWIR-1100 Multispectral Bands Pixel-to-Pixel Increment	VSWIR image data shall provide a pixel-to-pixel increment, in the in-track and cross-track directions, equivalent to a Ground Sampling Distance (GSD) up to and including 30-m across the WRS-2 scene for bands 1, 2, 3, 4, 5, 6, 7 and 9 measured at the equatorial crossing.
TIR-1100 Ground Sample Distance	Image sensor data shall provide a pixel-to-pixel increment, in the in-track and cross track directions, equivalent to a GSD 60 m or less for both thermal bands across the WRS-2 scene.
VSWIR-1101 Response Slope	The relative edge response slope for the VSWIR bands shall exceed the values shown in Table A.4 for radiometrically corrected data, across the entire field-of-view. Note: The relative edge response slope is defined as the slope between the 40% and 60% response points as depicted in Figure A-1.

TIR-1101 Spatial Edge Response Slope	<p>The spatial relative edge response slope for the thermal bands after radiometric correction, shall conform to the criteria described in the following subsections. These edge response criteria apply to the near field response within 10 pixels of the edge.</p> <p>Note: The relative edge response, in the context of this section and all of its subsections, is the normalized response of the imaging system to an edge. That is, the relative edge response is normalized so that the mean low-side steady state edge response is set to zero and the mean high-side steady state edge response is set to 100%.</p>
TIR-1102 Relative Edge Response Slope	<p>The spatial relative edge response slope for the thermal bands after radiometric correction (slope between 40% and 60% response points, see Figure A.2 shall exceed 0.014 / meter in both the in-track direction and the cross-track direction across the entire field-of-view.</p> <p>Note: The relative edge response slope is defined as the slope between the 40% and 60% response points as depicted in Figure A.2.</p>
VSWIR-1102 Half Edge Extent	<p>The upper half edge extents and the lower half edge extents for the VSWIR spectral bands shall be less than the maximum half edge extent values shown in Table A.4 for radiometrically corrected image sensor data, across the entire field-of-view.</p> <p>Note: The lower half edge extent is defined as the horizontal distance, in meters, between the 5% and 50% relative response points as depicted in Figure A.1. The upper half edge extent is defined as the horizontal distance, in meters, between the 50% and 95% relative response points as depicted in Figure A.1.</p>
TIR-1103 Edge Extent	<p>The edge extents for the thermal bands shall be less than 75 m in both the in-track direction and the cross-track direction for radiometrically corrected image sensor data across the entire field-of-view.</p> <p>Note: The edge extent is defined as the horizontal distance, in meters, between the 10% and 90% relative response points as depicted in Figure A.2.</p>
VSWIR-1103 Edge Response Uniformity	<p>The relative edge response slope shall not vary by more than 10% (maximum deviation from the band average) in any band across the field-of-view and by not more than 20% (maximum deviation from the multi-band average) between spectral bands 1, 2, 3, 4, 5, 6, 7, and 9 for VSWIR image data.</p>
TIR-1104 Spatial Edge Response Uniformity	<p>The relative spatial edge response slope shall not vary by more than 10% (maximum deviation from the band average, $100\% * (\max - \text{avg}) / \text{avg}$) in each band across the field-of-view between spectral bands 10 and 11.</p>
TIR-1105 Spatial Edge Response Uniformity	<p>The relative spatial edge response slope shall vary by not more than 20% (maximum deviation from the two-band average) between spectral bands 10 and 11.</p>
VSWIR-1104 Aliasing	<p>The product of the relative edge response slope and the GSD provided by VSWIR image data shall be less than 1.0 for both the in-track and cross-track directions.</p>
TIR-1106 Spatial Aliasing	<p>The product of the relative edge response slope and the GSD provided by image data in the TIR bands shall be less than 1.0 for both the in-track and cross-track directions.</p>

VSWIR-1105 Light Rejection and Internal Scattering	<p>The magnitude of the change in the VSWIR image measured radiance for all spectral bands at the center of the light rejection scene shall be less than 0.004 times the magnitude of the difference between LB and LT, where target and background radiance levels range from a minimum of zero to a maximum of LMax, such that LT - LB ranges from a minimum of -LMax to a maximum of + LMax.</p> <p>Definition: A light rejection scene or a scene to assess internal light scattering is defined as follows:</p> <ul style="list-style-type: none"> • The image data are collected from a circular region having a radius = 0.25 degrees and having a uniform target radiance = LT. • That target region is surrounded by an annular region having an inner radius = 0.25 degrees and an outer radius = 25 degrees and having a uniform background radiance = LB. • When LB = LT, the image data radiance measured at the center of the target region has a nominal value = LT.
TIR-1107 Stray Light Rejection and Internal Scattering	<p>The magnitude of the change in the image measured radiance for all TIR spectral bands at the center of the light rejection scene shall be less than 0.004 times the magnitude of the difference between LB and LT, where the target radiance is LTypical and background radiance levels range from a minimum of L240K to a maximum of L330K.</p> <p>Definition: A light rejection scene or a scene to assess internal light scattering is defined as follows:</p> <ul style="list-style-type: none"> • The image data are collected from a circular region having a radius = 0.25 degrees and having a uniform target radiance = LT. • That target region is surrounded by an annular region having an inner radius = 0.25 degrees and an outer radius = 25 degrees and having a uniform background radiance = LB. • When LB = LT, the image data radiance measured at the center of the target region has a nominal value = LT.
VSWIR-1106 Ghosting	<p>For two dimensional objects subtending an angle up to 1.5 deg with: a radiance level between 95% and 100% of LMax, and located at a position anywhere in the telescope full FOV, the signal from the object at N pixels away from the object edge shall be less than the values in Table A.5.</p>
TIR-1108 Ghosting	<p>For two dimensional objects subtending an angle up to 1.5 deg with: a radiance level between 95% and 100% of LMax, and located at a position anywhere in the telescope full FOV, the signal from the object at N pixels away from the object edge shall be less than the values in Table A.5.</p>
VSWIR-1007 Bright Target Recovery	<p>Bright target recovery requirements apply when an image pixel "X" is exposed to a radiance level of up to 1.5 times that of the saturation radiance. Any pixel "Y" outside the 11 x 11 pixel region around image pixel "X" shall not have the "Y" signal changed by more than 1% of its LTypical for bands 1-7 and 9 and shall not have the "Y" signal changed by more than 2% of its LTypical for band 8 as compared to its response when image pixel "X" is exposed to LTypical.</p>
TIR-1109 Bright Target Recovery	<p>The thermal band data shall be such that for an image pixel that has been exposed to a pixel-sized area at a radiance level of less than or equal to that corresponding to a blackbody temperature of 500K, the pixels outside the 11 x 11 region around that pixel are not altered by more than 1% of their radiance at or above TTypical.</p>

2.4 SLI-T Reference Mission Radiometry Performance

2.4.1.1 Absolute Radiometric Uncertainty

Absolute Radiometric Uncertainty	
Identifier	Requirements Description
VSWIR-1200	The absolute radiometric uncertainty for VSWIR data shall be as given in Table A.7 for the range of L_{Typical} to $0.9 L_{\text{max}}$ (Table A.6) with all uncertainties established relative to National Institute for Standards and Technology (NIST) standards. This requirement applies to extended, spatially uniform, unpolarized targets. Uncertainty estimates include the NIST standard uncertainties.
TIR-1200	The thermal band absolute radiometric uncertainty shall be as given in Table A.8 with all uncertainties established relative to National Institute for Standards and Technology (NIST) standards. This requirement applies to extended, spatially uniform, unpolarized targets. Uncertainty estimates include the NIST standard uncertainties.
TIR-1201 Pixel Noise Equivalent Delta Temperature	For uniform scene temperatures between 240 K and 360 K extending over the full FOV, and for a data collection period corresponding to a WRS-2 scene (~ 25 seconds at the nominal frame rate), the median detector standard deviation when converted into radiance units shall be $\leq 0.059 \text{ W/m}^2 \text{ sr } \mu\text{m}$ for the $10.8 \mu\text{m}$ channel and $\leq 0.049 \text{ W/m}^2 \text{ sr } \mu\text{m}$ for the $12.0 \mu\text{m}$ channel. This includes quantization noise. Any detector with a standard deviation more than 1.25 times these values shall be considered out-of-specification. The Noise Equivalent Delta Temperature (NE Δ T) for each channel for several temperatures is given in Table A.9.
VSWIR-1201	At any other radiance across the range of $0.3 L_{\text{Typical}}$ to L_{Typical} the absolute uncertainty shall not exceed the values in Table A.7 by more than 0.5%. This requirement applies to extended, spatially uniform, unpolarized targets with a known spectral shape.

2.4.2 Absolute Radiometric Uncertainty

Radiometric Signal-to-Noise Ratios (SNRs)	
Identifier	Requirements Description
VSWIR-1202 Detector Signal-to-Noise Ratios (SNRs)	The median SNRs required for all VSWIR image data for each spectral band shall be as listed in Table A.10.
VSWIR-1203 Detector Signal-to-Noise Ratios (SNRs)	50% of all detectors for each band shall meet or exceed these SNR values.
VSWIR-1204 Detector Signal-to-Noise Ratios (SNRs)	Any detector below 80% of these values shall be considered out-of-specification per requirement VSWIR-1220

2.4.3 SWIR Data Quantization

SWIR Data Quantization	
Identifier	Requirements Description
VSWIR-1205	VSWIR image data shall be quantized to 12 bits. VSWIR image data SNR performance shall not be quantization noise limited at L_{Typical} and above, i.e., system noise is greater than or equal to 0.5 Digital Number, unless meeting this requirement would force greater than 12 bit quantization.
NOTES for VSWIR-1206, -1207, and -1208	<p>The following environmental conditions and measurement approach shall apply to requirements VSWIR-1206, -1207, and -1208.</p> <ol style="list-style-type: none"> 1. The requirements shall apply for uniform sources with the radiance level above $2 \cdot L_{\text{Typical}}$ 2. The radiometric values shall be corrected 3. Temporal noise shall be averaged to verify compliance with this specification. 4. Target radiances shall have spectral characteristics as follows: <ol style="list-style-type: none"> a. Spectral radiance from bare desert soil as observed through a dry atmosphere (excluding cirrus band) b. Spectral radiance proportional to the TOA solar irradiance c. Spectral radiance from a dense vegetation target as observed through a moist atmosphere (excluding cirrus band) d. These spectral radiances are shown in Figure A.5 and given in “Top of Atmosphere Radiance Values, MODTRAN 4 Model” table values, see GSFC 427-04-01 Top of Atmosphere Radiance Values. 5. Target radiances shall all be determined using the same gain calibration coefficients. <p>Note: A pixel column is a consecutive sequence of pixels generated by a single detector.</p>
NOTES for TIR-1202, -1203, and -1204	<p>The following environmental conditions and measurement approach apply to requirements TIR- 1202, -1203, and -1204</p> <ul style="list-style-type: none"> • The thermal band banding requirements apply to uniform sources with the radiance corresponding to a blackbody temperature above 260K and below 330 K. • The thermal band radiometric values are corrected • The thermal band temporal noise is averaged to verify compliance with this specification. <p>Note: A pixel column is a consecutive sequence of pixels generated by a single detector.</p>

2.4.4 Pixel-to-Pixel Uniformity

Pixel-to-Pixel Uniformity	
Identifier	Requirements Description
VSWIR-1206 Full Field of View	Within a WRS-2 frame, the standard deviation of all pixel column average radiances and the standard deviation of all pixel row average radiances within a band shall not exceed 0.5% of the scene average radiance
TIR-1202 Full Field View	The standard deviation of all pixel column average radiances across the FOV within a band shall not exceed 0.5% of the average radiance.
VSWIR-1207 Banding	The root mean square of the deviation from the average radiance across the full FOV for any 100 contiguous pixel column averages of radiometrically corrected VSWIR image data within a band shall not exceed 1.0% of that average radiance.
TIR-1203 Banding	a) The root mean square of the deviation from the average radiance across the full FOV for any 100 contiguous pixel column averages of radiometrically corrected TIR image data within a band shall not exceed 0.5% of that average radiance.
VSWIR-1208 Banding	The standard deviation of the radiometrically corrected values across any 100 contiguous pixels averaged along a column of VSWIR image data within a band shall not exceed 0.25% of the average radiance across the full FOV.
TIR-1204 Banding	b) The standard deviation of the radiometrically corrected values across any 100 contiguous pixels averaged along a column of TIR image data within a band shall not exceed 0.5% of the average radiance across the full FOV.
VSWIR-1209 Streaking	The maximum value of the streaking parameter within a column of radiometrically corrected VSWIR image data shall not exceed 0.005 for bands 1-7 and 9, and 0.01 for the panchromatic band.
TIR-1205 Streaking	The maximum value of the streaking parameter within a column of radiometrically corrected TIR data shall not exceed 0.005.

2.4.5 Coherent Noise

Coherent Noise	
Identifier	Requirements Description
VSWIR-1211 Coherent Noise	Each pixel column in an uniform scene or WRS-2 sized (1) dark background image in any VSWIR band, after radiometric calibration, shall contain coherent noise (CN) components with relative amplitude(2), Arel (in %), not exceeding the maximum amplitude level, Arelmax denoted by the following formula (see Figure 5-4):
TIR-1206 Coherent Noise	Each pixel column in a uniform scene or WRS-2 sized dark background image in any TIR band, after radiometric calibration, shall only contain coherent noise (CN) components with relative amplitude1, Arel (in %), that are lower than the maximum amplitude level, Arelmax denoted by the following formula (see Figure A.3):

2.4.6 Saturation Radiances

Saturation Radiances	
Identifier	Requirements Description
VSWIR-12112 Saturation Radiances	Signals up to the Lmax as shown in Table A.6 shall be collected without saturation in the VSWIR bands
TIR-1207 Saturation Temperatures	The thermal band shall detect, without saturating, signals from the noise floor ($NE\Delta L = 0.059 \text{ W}/(\text{m}^2 \text{ sr } \mu\text{m})$ for the 10.8 μm channel and $NE\Delta L = 0.049 \text{ W}/(\text{m}^2 \text{ sr } \mu\text{m})$ for the 12.0 μm channel) up to the maximum radiance (Lmax) as shown in Table A.7.

2.4.7 Polarization Sensitivity

Polarization Sensitivity	
Identifier	Requirements Description
VSWIR-1213 Polarization Sensitivity	The VSWIR polarization sensitivity, as defined by the linear Polarization Factor (PF), shall be less than 0.05, where $PF = (I_{\text{max}} - I_{\text{min}}) / (I_{\text{max}} + I_{\text{min}})$.

2.4.8 Radiometric Stability

Radiometric Stability	
Identifier	Requirements Description
VSWIR-1214 Radiometric Stability	For Bands 1-8, over any time period up to 16 days, after radiometric correction, with one set of gain coefficients that were determined prior to the 16 day period, the scene averaged VSWIR image data for radiometrically constant targets with radiances greater than or equal to L-typical shall not vary by more than plus or minus 1% (95% or 2 sigma confidence interval) of measured radiance.
TIR-1208 Radiometric Stability	Thermal band data for all pixels, after radiometric calibration, for radiometrically constant targets with radiances greater than or equal to the radiance corresponding to TTypical, shall not vary by more than plus or minus 0.7% (1-sigma) of their radiance over a 40 minute period. Pixels failing this specification are considered out-of-specification and are subject to the limitations of TIR-1211
VSWIR-1215 Radiometric Stability	For Band 9, over any time period up to 16 days, after radiometric correction, with one set of gain coefficients that were determined prior to the 16 day period, the scene averaged SWIR image data for radiometrically constant targets with radiances greater than or equal to L-typical shall not vary by more than plus or minus 2% (95% or 2 sigma confidence interval) of measured radiance.

VSWIR-1216 Radiometric Stability	Over any time period between 16 days and 5 years, after radiometric correction, the scene-averaged SWIR image data for radiometrically constant targets with radiances greater than or equal to L-typical shall not vary by more than plus or minus 2% (95% or 2 sigma confidence interval) of measured radiance.
VSWIR-1217 Radiometric Stability	Over any time period up to 60 seconds, after radiometric correction, the scene-averaged VSWIR image data for radiometrically constant targets with radiances greater than or equal to L-typical shall not vary by more than plus or minus 0.5% (95% or 2 sigma confidence interval) of measured radiance.

2.4.9 Dead, Inoperable, and Out-of-Spec Detectors

Dead, Inoperable, and Out-of-Spec Detectors	
Identifier	Requirements Description
VSWIR-1218	Less than 0.1% of all detectors shall be dead or inoperable.
TIR-1209	Less than 0.1% of detectors in either spectral band shall be dead or inoperable.

2.4.10 Dead or Inoperable Detectors per Band

Dead or Inoperable Detectors per Band	
Identifier	Requirements Description
VSWIR-1219	There shall be no across track adjacent dead or inoperable detectors.
TIR-1210	There shall be no across track adjacent dead or inoperable detectors.

2.4.11 Out-of-Spec Detectors

Out-of-Spec Detectors	
Identifier	Requirements Description
VSWIR-1220	Less than 0.25% of the operable detectors in any spectral band in any WRS-2 scene shall fail to meet one or more performance requirements.
TIR-1211	Less than 0.25% of the operable detectors in any spectral band in any WRS-2 scene shall fail to meet one or more performance requirements.

2.5 SLI-T Geometric, Geolocation and Cartographic Registration Performance

2.5.1 Band-to-Band Registration Accuracy

Band-to-Band Registration Accuracy	
Identifier	Requirements Description
VSWIR-1300	Corresponding pixels from the spectral bands in VSWIR image data that have been geometrically corrected including compensation for the effects of terrain relief shall be co-registered with an uncertainty of 4.5 meters or less in the line and sample directions at the 90% confidence level.
TIR-1300	Corresponding pixels from the two thermal bands in TIR data that have been geometrically corrected, including compensation for the effects of terrain relief, shall be co-registered with an uncertainty of 18 meters or less in the line and sample directions at the 90% confidence level.

2.5.2 VSWIR to TIR Band-to-Band Registration Accuracy

VSWIR to TIR Band-to-Band Registration Accuracy	
Identifier	Requirements Description
VSWIR-1301	Terrain-corrected Level 1 data products shall have band-to-band registration co--registration accuracy of 30 meters or less in the along and cross-track directions at the 90% level of confidence between bands 1-9 and the two thermal bands.
TIR-1301	Terrain-corrected Level 1 data products shall have band-to-band registration co--registration accuracy of 30 meters or less in the along and cross-track directions at the 90% level of confidence between bands 1-9 and the two thermal bands.

2.5.3 Image-to-Image Registration Accuracy

Image-to-Image Registration Accuracy	
Identifier	Requirements Description
VSWIR-1302	Two VSWIR image data sets of the same area, acquired on different dates, that have been geometrically corrected, including compensation for the effects of terrain relief, shall be co-registered with an uncertainty less than or equal to 12 meters, in the line and sample directions at the 90% confidence level when image-to-image correlation is applied to data from the same spectral band. This requirement applies to data from all spectral bands except band 9.

2.5.4 Absolute Geodetic Accuracy

Absolute Geodetic Accuracy	
Identifier	Requirements Description
VSWIR-1303	The pixels for targets at the Earth's topographic surface in geometrically corrected data shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 65 meters (90% circular error), excluding terrain effects. This specification applies to the horizontal error of ground control points measured in the processed image, after compensation for control point height.

2.5.5 Relative Geodetic Accuracy

Relative Geodetic Accuracy	
Identifier	Requirements Description
VSWIR-1304	The pixels for targets at the Earth's topographic surface in geometrically corrected VSWIR image data shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 25 meters (90% circular error), excluding terrain effects, over a WRS-2 scene, after the removal of constant offsets. This specification applies to the standard deviation of ground control points measured in the processed image, after compensation for control point height.
TIR-1302	The pixels for targets at the Earth's topographic surface in geometrically corrected TIR thermal band data shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 76 meters (90% circular error), excluding terrain effects. This specification applies to the horizontal error of ground control points measured in the processed image, after compensation for control point height.

2.5.6 Geometric Accuracy

Geometric Accuracy	
Identifier	Requirements Description
VSWIR-1304	The pixels for targets at the Earth's topographic surface in VSWIR image data that have been geometrically corrected, including pointing refinement using ground control and terrain compensation using digital elevation data, shall be located relative to the WGS84 geodetic reference system, G1150 or current version, with an uncertainty less than or equal to 12 meters (90% circular error), including compensation for terrain effects.

2.5.7 Line-of-Sight Stability

Line-of-Sight Stability	
Identifier	Requirements Description
VSWIR-1305	The VSWIR instrument focal plane to optical axis mechanical alignment shall be internally stable to less than 6 micro-radians, 3-sigma for each axis over the full thermal operational design temperature range over each 16-day observation cycle.
TIR-1303	The internal mechanical alignment of the TIR instrument shall be stable such that each thermal detector line of sight varies relative to its modeled location by less than 27 micro-radians, 3-sigma for each axis relative to the instrument mounting interface, over the full thermal operational design temperature range over each 16-day observation cycle.

2.5.8 Timing Accuracy

Timing Accuracy	
Identifier	Requirements Description
VSWIR-1306	The VSWIR instrument shall time tag OLI instrument data with an accuracy relative to the external time reference of 100 microseconds or less, 3-sigma.
TIR-1304	TIR instrument data shall be time tagged with an accuracy relative to the external time reference of 1 millisecond or less, 3-sigma.

2.6 SLI-T Key Performance Parameter Tables

TABLE A.1 – BASELINE SLI-T RMA BANDS

Band Number	Band	Resolution	Wavelengths (nm)
1	Coastal Aerosol	30 m	433 – 453
2	Blue	30 m	450 – 515
3	Green	30 m	525 – 600
4	Red	30 m	630 – 680
5	NIR	30 m	845 – 885
6	SWIR 1	30 m	1560 – 1660
7	SWIR2	30 m	2100 – 2300
8	Panchromatic	15 m	500 – 680
9	Cirrus	30 m	1360 – 1390
10	Thermal 1	60 m	10300 -11300
11	Thermal2	60 m	11500 – 12500

TABLE A.2 SLI-T REFERENCE MISSION SPECTRAL IMAGE PERFORMANCE REQUIREMENTS

Band Number	Band	Center Wavelength (nm)	Center Wavelength Tolerance (nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)
1	Coastal Aerosol	443	2	443	453
2	Blue	482	5	450	515
3	Green	562	5	525	600
4	Red	655	5	630	680
5	NIR	865	5	845	885
6	SWIR1	1610	10	1560	1660
7	SWIR 2 ¹	2200	10	2100	2300
8	Panchromatic ²	590	10	500	680
9	Cirrus	1375	5	1360	1390
10	Thermal 1	10800	200	10300	11300
11	Thermal 2	12000	200	11500	12000

Notes:

1. Minimum bandwidth is 180 nm for band 7
2. Minimum bandwidth is 160 nm for the panchromatic band

**TABLE A.3 SLI-T REFERENCE MISSION SPECTRAL EDGE SLOPE INTERVALS
PERFORMANCE REQUIREMENTS**

Band Number	Band	Lower Edge Slope Interval ¹ (nm)	Lower Edge Interval ² (nm)	Upper Band Edge Slope Interval ³ (nm)	Upper Band Edge Slope Interval ⁴ (nm)
1	Coastal Aerosol	15	10	10	15
2	Blue	25	20	20	25
3	Green	25	20	20	25
4	Red	25	20	15	20
5	NIR	25	20	15	20
6	SWIR 1	40	30	30	40
7	SWIR 2	50	40	40	50
8	Panchromatic	50	40	40	50
9	Cirrus	15	10	10	15
10	Thermal 1	400	300	300	400
11	Thermal 2	400	300	300	400

Notes:

1. Lower Edge Slope Interval: 0.01 to 0.5 * (nm).
2. Lower Edge Slope Interval: 0.05 to 0.5 * (nm).
3. Upper Edge Slope Interval: 0.5 to 0.05 * (nm).
4. Upper Edge Slope Interval: 0.5 to 0.01 * (nm).

All Values normalized to peak spectral response for the band.

TABLE A.4 SLI-T REFERENCE MISSION GSD, MINIMUM EDGE SLOPE, AND MAXIMUM HALF EDGE EXTENT PERFORMANCE REQUIREMENTS

Band Number	Band	Nominal GSD (m)	Minimum Edge Slope	Maximum Half Edge Extent (M)
1	Coastal Aerosol	30	.027/m	23.0
2	Blue	30	027/m	23.0
3	Green	30	027/m	23.0
4	Red	30	027/m	23.5
5	NIR	30	027/m	24.0
6	SWIR 1	30	027/m	28.0
7	SWIR 2	30	027/m	29.0
8	Panchromatic	15	027/m	14.0
9	Cirrus	30	027/m	27.0

TABLE A.5 GHOSTING REQUIREMENTS

Bands	Distance form Edge (N pixels)	Maximum Signal
Band 1-7, 9 (30 m Multispectral)		
	Between the 5% Relative Edge Response point and 10 pixels	\leq linear threshold from 5% of Lsat to 6.5% of Ltyp at 10 pixels, with relative Edge response slope <0 (i.e. Monotonically decreasing)
	Between 10 and 30 pixels	$<$ linear threshold from 6.5% of Ltyp at 10 pixels to 2% of Ltyp at 30 pixels
	Greater than 30 pixels	$<2\%$ of Ltyp at >30 pixels
Bands 8 (15 Panchromatic)		
	Between the 5% Relative Edge Response point and 20 pixels	\leq linear threshold from 5% of Lsat to 6.5% of Ltyp at 20 pixels, with relative Edge response slope <0 (i.e. Monotonically decreasing)
	Between 20 and 60 pixels	$<$ linear threshold from 6.5% of Ltyp at 20 pixels to 2% of Ltyp at 60 pixels
	Greater than 60 pixels	$<2\%$ of Ltyp at >60 pixels
Bands 10 and 11 (TIR)		
	Between the 5% Relative Edge Response point and 10 pixels	Less than the linear threshold from 5% of Lmax to 6.5% of Ltyp at 10 pixels.
	Between 10 and 30 pixels	Less than the linear threshold from 6.5% of Ltp to 6.5% of Ltyp at 10 pixels to 2% of Ltyp at 30 pixels
	Greater than 30 pixels	Less than 2% of Ltyp

TABLE A.6 VSWIR SYSTEM REFERENCE RADIANCE REQUIREMENTS

Band Number	Band	Radiance Level for SNR, L (W/m ² sr μ m)		Saturation Radiances, Lmax (W/m ² sr μ m)
		Typical, LTypical	High, LHigh	
1	Coastal Aerosol	40	190	555
2	Blue	40	190	581
3	Green	30	194	544
4	Red	22	250	462
5	NIR	14	150	281
6	SWIR 1	4.0	32	71.3
7	SWIR2	1.7	11	24.3
8	Panchromatic	23	156	515
9	Cirrus	6.0	N/A	88.5

TABLE A.7 TIR SYSTEM REFERENCE RADIANCE REQUIREMENTS

Band		Typical Temperature	Typical Radiance (W/m ² sr μm)	Saturation Temperature (K)	Saturation Radiance (W/m ² sr μm)
		T _{Typical}	L _{Typical}	T _{Max}	L _{Max}
10	Thermal 1	300K	9.64	360 K	20.5
11	Thermal 2	300K	9.64	360 K	17.8

TABLE A.8 THERMAL BANDS ABSOLUTE RADIOMETRIC UNCERTAINTY

Equivalent Blackbody Temperature Range	Absolute Radiance Uncertainty (1-sigma)
260 K – 330 K	<2%
240 K 260 K : 330 K – 360K	<4%

TABLE A.9 NOISE EQUIVALENT DELTA TEMPERATURE (NEΔT) REQUIREMENTS

Channel	NEΔT				
	240 K	260 K	300 K	320K	360 K
10.8 μm	0.80 K	0.61 K	0.40 K	0.35 K	0.27 K
12.8 μm	0.71 K	0.57 K	0.40 K	0.35 K	0.29 K

TABLE A.10 SNR REQUIREMENTS

Band Number	Band	SNR Requirements	
		At L _{Typical} *	At L _{High} *
1	Coastal Aerosol	130	290
2	Blue	130	360
3	Green	100	390
4	Red	90	340
5	NIR	90	460
6	SWIR 1	100	540
7	SWIR2	100	510
8	Panchromatic	80	230
9	Cirrus	50	N/A

2.7 SLI-T Key Performance Parameter Figures

FIGURE A.1 VSWIR EDGE RESPONSE SLOPE

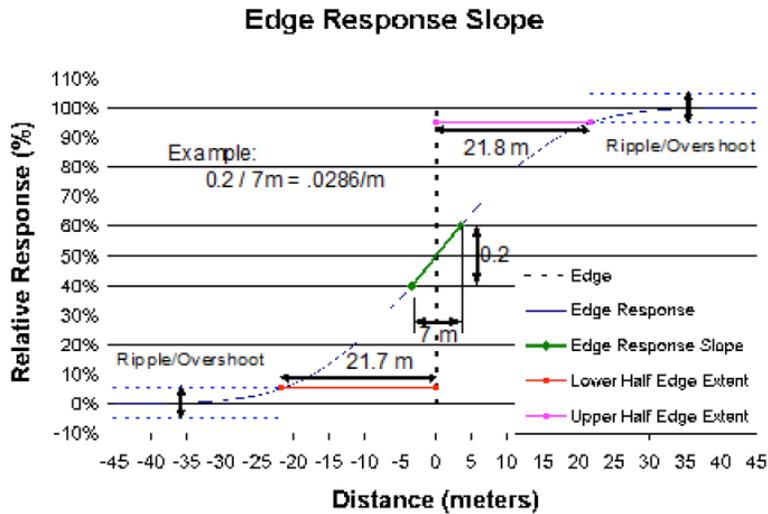


FIGURE A.2 TIR EDGE RESPONSE SLOPE

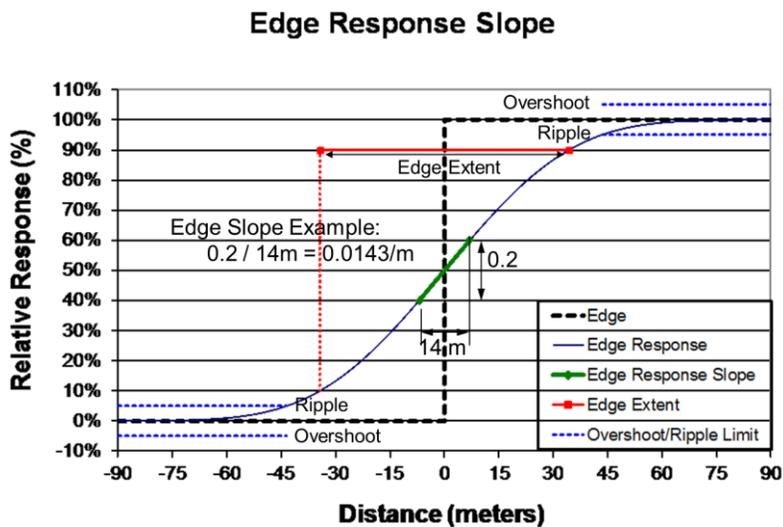


FIGURE A.3 TIR COHERENT NOISE THRESHOLD CURVE

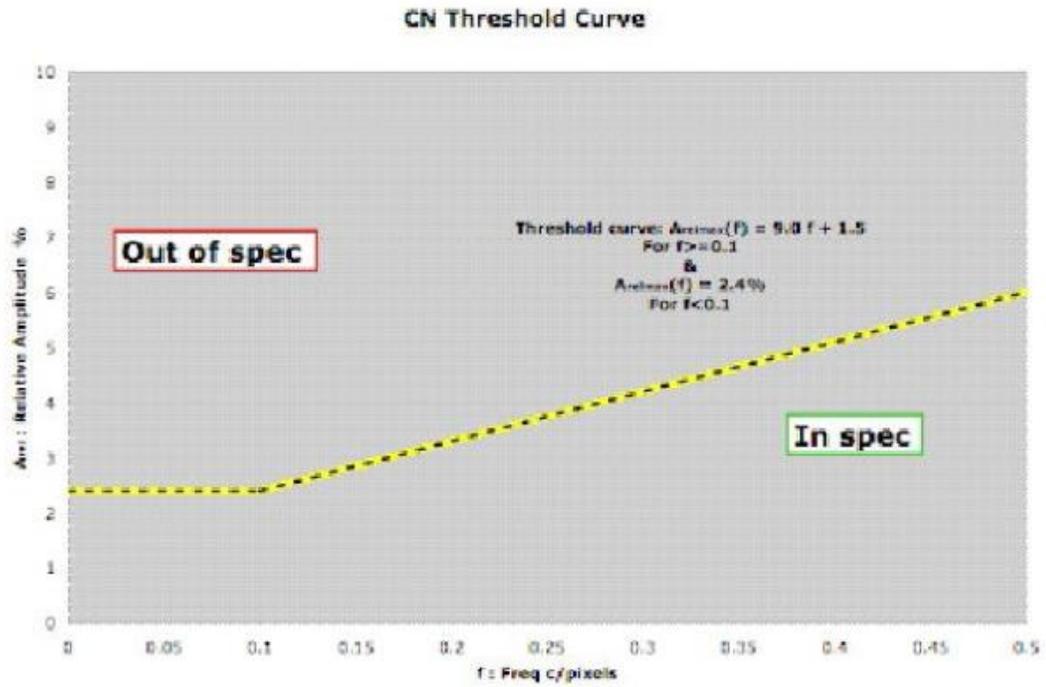


FIGURE A.4 VSWIR COHERENT NOISE THRESHOLD CURVE

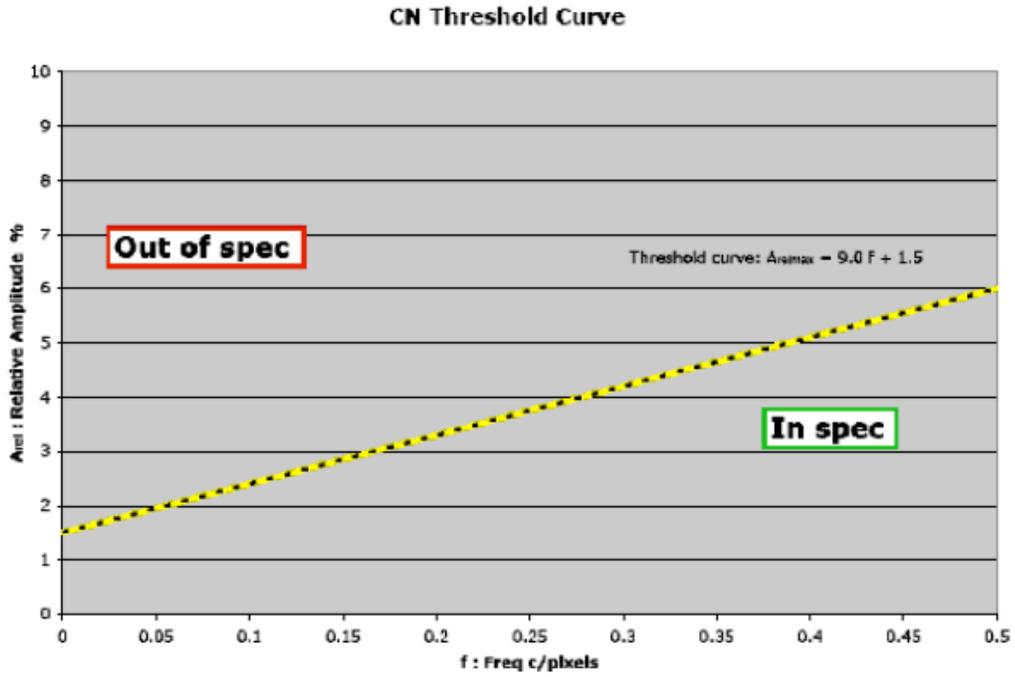


FIGURE A.5 TOP OF ATMOSPHERE SPECTRA

