MODIS

Level 1B ATBD Review

(ATB-MOD-01)

20 November, 1996

Presentation Outline

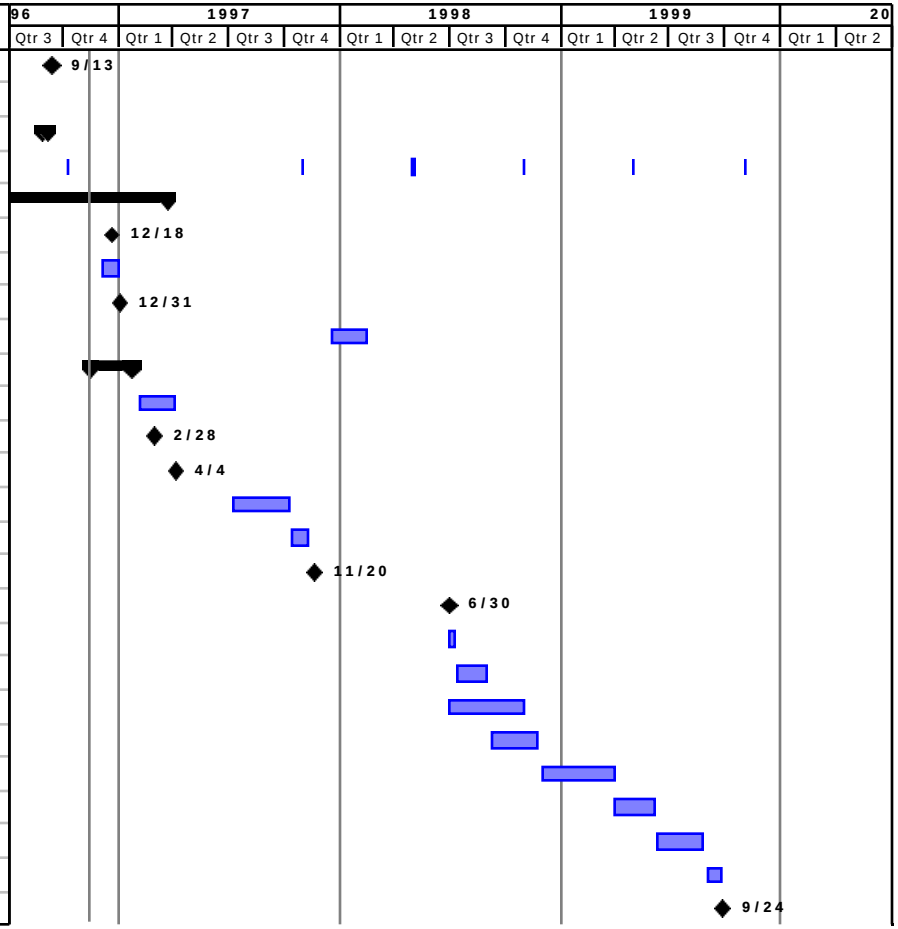
- Sensor Status and Software Schedule
- Reflected Solar Bands Algorithm
- Emissive Infrared Bands Algorithm
- Practical Considerations
- Validation

Presentation Outline (cont.)

- Responses to Formal Reviews
  - Formal Reviews:
    - AM-1 Land Data Products
    - Joe Klein
    - Frank Palluconi
    - Robert Lee
    - Carol Johnson
- Appendices
  - L1B file specification
  - Production Parameter Configuration Item List
  - Responses to Action Items

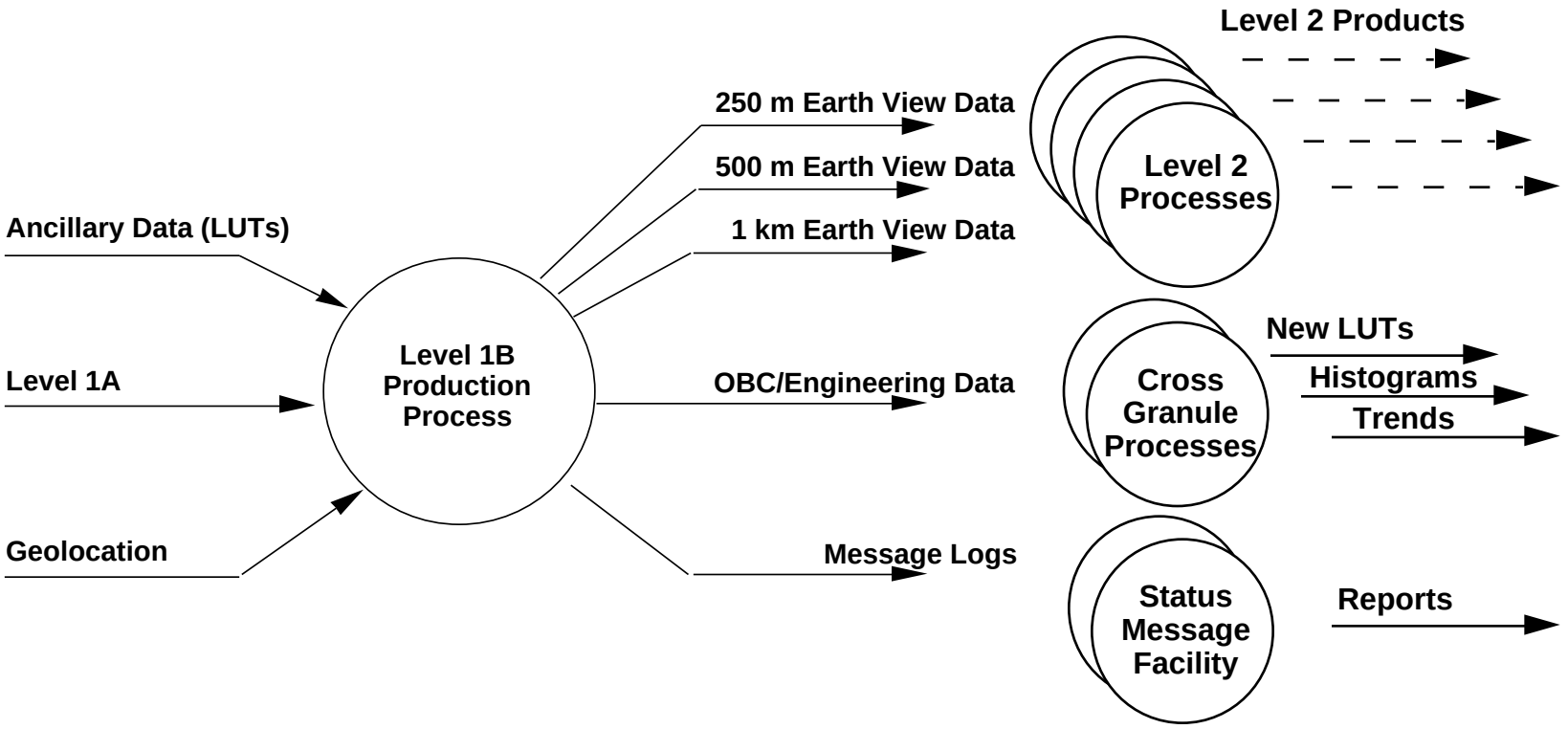
Sensor Status and S/W Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	L1B V2 PDR	0d	Fri 9/13/96	Fri 9/13/96	
2	**MCST Science Advisory Reviev**	**784d**	**Wed 7/31/96**	**Mon 8/2/99**	
10	**IR & Reflective Band Audits**	**8d**	**Wed 8/28/96**	**Fri 9/6/96**	
13	**MODIS Science Team Meeting**	**801d**	**Wed 10/9/96**	**Wed 11/3/99**	
21	**L1B V2 Coding**	**191d**	**Mon 7/1/96**	**Mon 3/24/97**	
29	L1B V2 CDR	0d	Wed 12/18/96	Wed 12/18/96	
30	Instrument Environmental Tests	22d	Mon 12/2/96	Tue 12/31/96	
31	Deliver ATBD '96	0d	Tue 12/31/96	Tue 12/31/96	
32	L1B V2 Testing	45d	Mon 12/15/97	Fri 2/13/98	
33	**Update L1B Documentation**	**51d**	**Fri 11/15/96**	**Fri 1/24/97**	
37	Thermal Vacuum Testing	45d	Mon 2/3/97	Fri 4/4/97	
38	Deliver L1B Version 2	0d	Fri 2/28/97	Fri 2/28/97	
39	Instrument Delivery to LMMS	0d	Fri 4/4/97	Fri 4/4/97	
40	Incorporate PFM Test Results (V2.1)	70d	Tue 7/8/97	Mon 10/13/97	
41	Test L1B V2.1	20d	Tue 10/14/97	Mon 11/10/97	
42	Deliver L1B V2.1	0d	Thu 11/20/97	Thu 11/20/97	
43	AM-1 Launch	0d	Tue 6/30/98	Tue 6/30/98	
44	Attain Orbit	9d	Tue 6/30/98	Fri 7/10/98	
45	Outgas	40d	Mon 7/13/98	Fri 9/4/98	
46	Activation & Evaluation	90d	Tue 6/30/98	Mon 11/2/98	
47	L1B S/W Support for A&E	60d	Mon 9/7/98	Fri 11/27/98	
48	Generate New Lookup Tables	90d	Mon 11/30/98	Fri 4/2/99	
49	Create Test Data for ST	50d	Mon 3/29/99	Fri 6/4/99	
50	Post A&E S/W Modifications	60d	Mon 6/7/99	Fri 8/27/99	
51	Test L1B V2.2	20d	Mon 8/30/99	Fri 9/24/99	
52	Deliver L1B V2.2	0d	Fri 9/24/99	Fri 9/24/99	

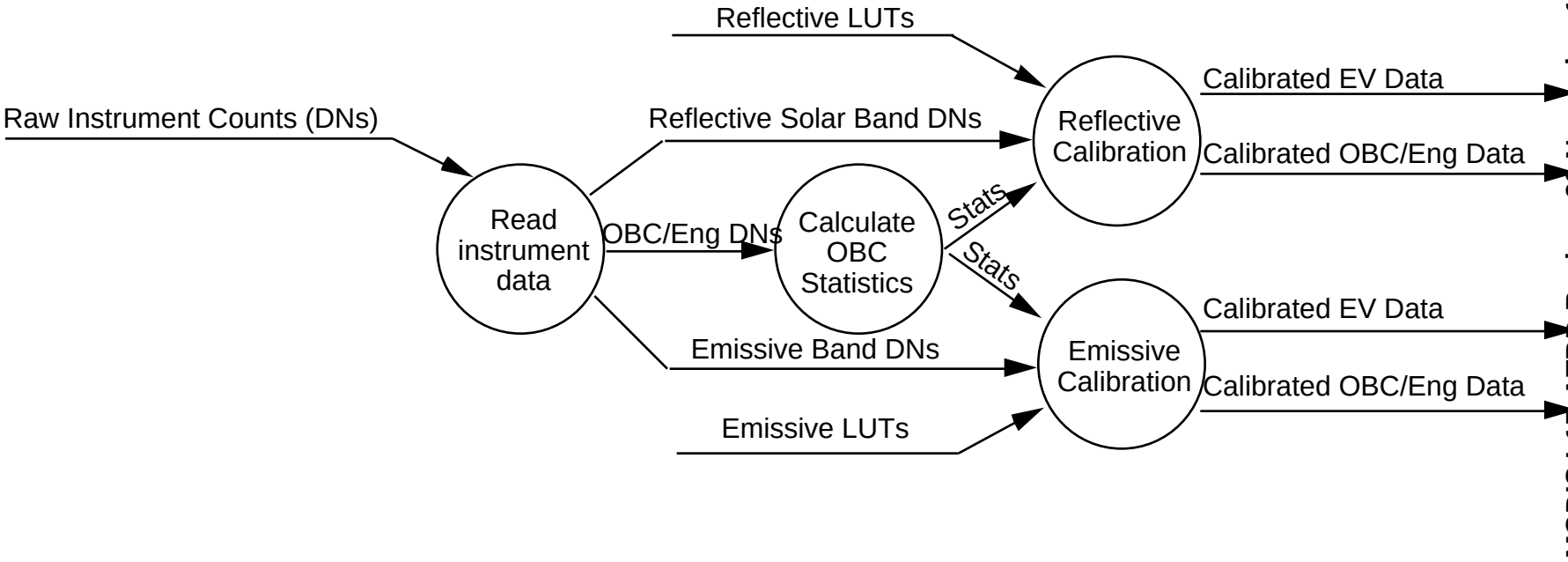


MODIS L1B ATBD Review, 20 November 1996

Level 1B External Data Flow

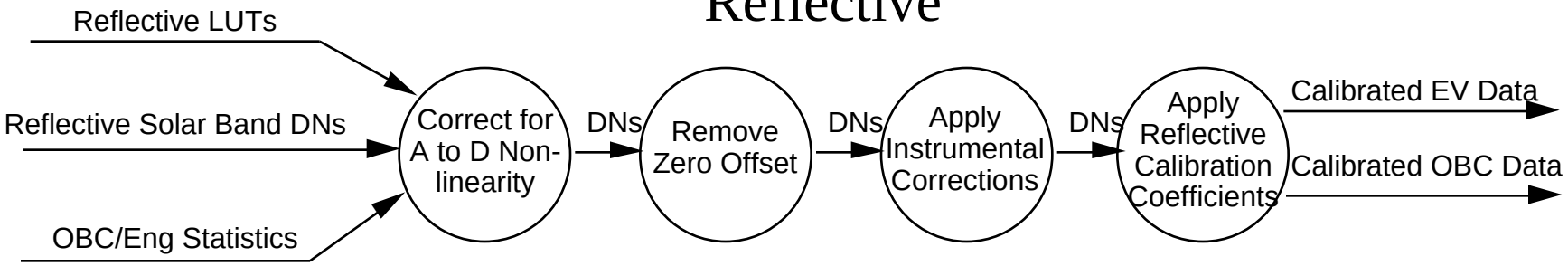


Level 1B Top Level Data Flow

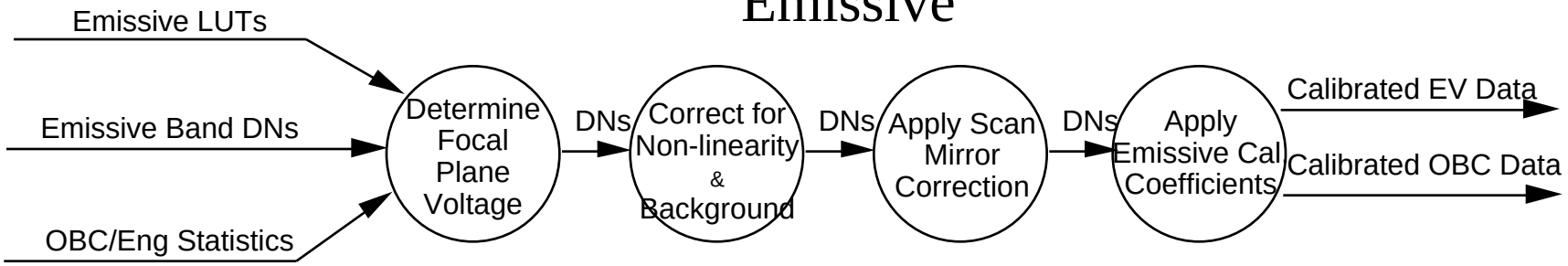


Level 1B Reflective and Emissive Calibration Data Flow

Reflective



Emissive



MODIS

Reflected Solar Bands Algorithm

Reference Sample Method to Determine Earth BRDF for Reflected Solar Algorithm

- MODIS measures the radiance from the solar diffuser and the Earth
- Both the Earth and the diffuser are illuminated by the same irradiance source (the sun)
- Fundamental equation : $$f_r = \frac{L_r}{E_i \cos(\Theta_i)}$$

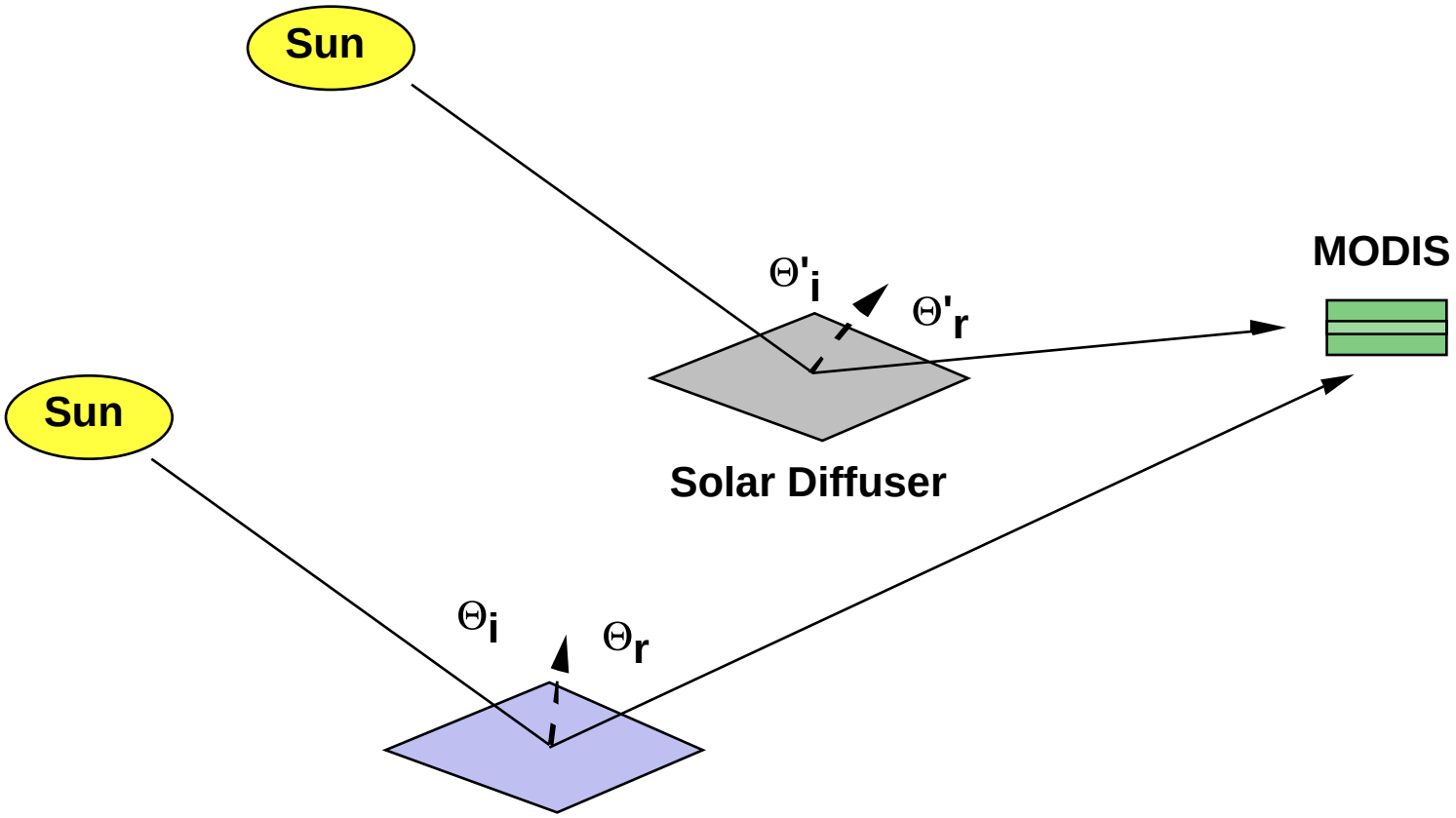
  f_r = BRDF of the reflecting surface

  L_r = reflected radiance

  E_i = incident irradiance

  Θ_i = irradiance incidence angle
- (Elevation and azimuth angles for incidence and reflectance are minimized to simplify presentation.)

MODIS Uses Solar Diffuser As Reference Sample



Diffuser and Earth Both Illuminated by the Sun

- For the solar diffuser : $f_{sd} = \frac{L_{sd}}{E_{sd}\cos(\Theta_{sd})}$
- For the Earth view: $f_{ev} = \frac{L_{ev}}{E_{ev}\cos(\Theta_{ev})}$
- $E_{sd} = E_{ev}$ = solar irradiance at normal incidence
- $f_{ev}\cos(\Theta_{ev}) = L_{ev}\left(\frac{f_{sd}\cos(\Theta_{sd})}{L_{sd}}\right)$
- For MODIS: $L = \frac{DN}{}$
- $f_{ev}\cos(\Theta_{ev}) = DN_{ev}\left(\frac{f_{sd}\cos(\Theta_{sd})}{DN_{sd}}\right)^{L}$

MODIS Determines Reflectance Coefficients On Orbit

- $\left(\frac{f_{sd}\cos(\Theta_{sd})}{DN_{sd}}\right)$

  determined on orbit from MODIS measurements of the solar diffuser (illuminated by the sun)

- $f_{sd}\cos(\Theta_{sd})$

  measured pre-launch and checked on orbit by the SDSM

Reflective Bands Calibration Approach

	Calibration Function	Correction Factors
$\left(\frac{DN}{L}\right)_{FlatScene} = k_{SIS}\left(\frac{DN}{L}\right)_{SIS}$	Radiance Calibration	•SIS current profile •SIS color temperature •SIS scan angle to MODIS nadir •SIS atmospheric absorption •T/V window absorption •FPA temperatures •SIS size of source scatter
$= k_{SRCA}\left(\frac{DN}{L}\right)_{SRCA}$	Radiance Transfer Monitor	•SRCA lamp current •SRCA color temperature •SRCA scan angle to MODIS nadir •SRCA polarization
$= k_{SD}\left(\frac{DN}{BRDF_{SD} E_{Sun}}\right)_{SD}$	Reflectance Calibration	•Solar illumination angles •Eart-Sun distance •SD scan angle to MODIS nadir •SD screen transmission •SD polarization •SD degradation
$= f_{VC}\left(\frac{DN}{L}\right)_{VicCal}$	Vicarious Calibration	•Relative solar illumination angles •Calibration transfers •Atmospheric absorption •Relative pixel footprints •Near-field and far-field scatter

$f_{ev}\cos(\Theta_{ev})$ is the MODIS Reflectance Product

- Reflectance has units of sr^{-1}
- Reflectance is determined using pairs of MODIS radiance measurements
  - MODIS provides band-weighted (band-averaged_ spectral radiances over the spectral response of the bands
  - Spectral response is measured over the range where the detector in the band has significant quantum efficiency
  - Spectral responses are measured pre-launch
  - Band centers are monitored on orbit by the SRCA
- Reflectance band weighting derives from radiance band weighting

Reflectance Bands Radiance Uncertainty Estimation Approach

In terms of reflectance product: $\rho_c = \rho(\Theta_i, \Phi_i, \Theta_r, \Phi_r) \cdot \cos(\Theta_i) = \frac{DN_{EV}}{R_t}_{\rho}$

$$\frac{\Delta\rho_c}{\rho_c} = \sqrt{\left(\frac{\Delta\rho_c}{\rho_c}\right)^2_{algorithm\ based} + \left(\frac{\Delta BRDF}{BRDF}\right)^2_{solar-diffuser} + \left(\frac{\Delta\rho_c}{\rho_c}\right)^2_{polarization} + \left(\frac{\Delta\rho_c}{\rho_c}\right)^2_{crosstalk} + \left(\frac{\Delta\rho_c}{\rho_c}\right)^2_{scatter}}$$

Measured by Round-Robin

Scene dependent (not included in L1B uncertainty product

$$\frac{\Delta\rho_c}{\rho_c}_{algorithm-based} = \sqrt{\left(\frac{\Delta DN}{DN}\right)^2 + \left(\frac{\Delta\ _{\rho}}{\ _{\rho}}\right)^2 + \left(\frac{\Delta R_t}{R_t}\right)^2_{\substack{Relative\\ Earth-sun\\ Distance\\ Factor}}}$$

Reflectance Bands Radiance Uncertainty Estimation Approach (cont.)

$$DN = \left[Q(DN) - DN_0\right] \cdot Fr \cdot \left[1 + K\left(T - T_{ref}\right)\right] \cdot R_{mirror-side} \cdot R(\Theta)_{scan-angle}$$

$$\frac{\Delta DN}{DN} = \sqrt{\left(\frac{\Delta Q}{Q}\right)^2_{ADC} + \left(\frac{\Delta Fr}{Fr}\right)^2_{\substack{Sample\\ Timing\\ Correction}} + \left(\frac{\Delta K}{K}\right)^2_{\substack{FPA\\ Temperature\\ Coefficient}} + \left(\frac{\Delta T}{T}\right)^2_{\substack{FPA\\ Temperature}} + \left(\frac{\Delta R}{R}\right)^2_{\substack{mirror-side\\ correction}} + \left(\frac{\Delta R(\Theta)}{R(\Theta)}\right)^2_{\substack{scan\\ angle}}}$$

$$\rho = \frac{q\left(DN_{SD}, \rho_0, \cos\Theta, \Delta_{SD}\right)}{\tau_{SD} R_r}$$

constant over solar calibration

$$\frac{\Delta \rho}{\rho} = \sqrt{\left(\frac{\Delta q}{q}\right)^2 + \left(\frac{\Delta \tau_{SD}}{\tau_{SD}}\right)^2 + \left(\frac{\Delta R_t}{R_t}\right)^2}$$

Typical Reflective Bands Uncertainty Contributions and RSS Total for VIS Bands

Reflectance Calibration Uncertainties (%)

Uncertainty Source	Band 8	Band 9	Band 3	Band 10	Band 11	Band 12	Band 4
SD BRDF Varia. & Meas.'t	2.00	2.00	2.00	2.00	2.00	2.00	2.00
SD Degrad. Outside of SDSM	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SD Screen Trans Error	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SD Port Scatter	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Signal Noise(1/SNR@Ltyp)	0.11	0.12	0.41	0.12	0.13	0.13	0.44
ADC Quantization Correction	0.18	0.15	0.56	0.15	0.14	0.14	0.59
Sample Timing Errors(est.)	0.00	0.00	1.00	0.00	0.00	0.00	1.00
FPA Temp Correction	0.05	0.05	0.15	0.05	0.05	0.05	0.16
Scan Angle Reflect. Correction	0.21	0.17	0.67	0.17	0.16	0.17	0.70
Mirror Side Correction	0.19	0.16	0.60	0.16	0.15	0.15	0.63
Polarization (Scene Dependent)	-	-	-	-	-	-	-
Crosstalk (Scene Dependent)	-	-	-	-	-	-	-
Scatter (Scene Dependent)	-	-	-	-	-	-	-
RSS Total	2.15%	2.15%	2.61%	2.15%	2.14%	2.14%	2.64%

Radiance Calibration Uncertainties (%)

NIST to SIS100(per GSFC exp.)	2.3	2	1.8	1.68	1.42	1.37	1.35
Transfer to MODIS	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Signal Noise(1/SNR@Ltyp)	0.11	0.12	0.41	0.12	0.13	0.13	0.44
ADC Quantization Correction	0.18	0.15	0.56	0.15	0.14	0.14	0.59
Sample Timing Errors(est.)	0.00	0.00	1.00	0.00	0.00	0.00	1.00
FPA Temp Correction	0.09	0.08	0.30	0.08	0.07	0.07	0.31
Scan Angle Reflect. Correction	0.13	0.10	0.40	0.10	0.10	0.10	0.42
Mirror Side Correction	0.19	0.16	0.60	0.16	0.15	0.15	0.63
Polarization (Scene Dependent)	-	-	-	-	-	-	-
Crosstalk (Scene Dependent)	-	-	-	-	-	-	-
Scatter (Scene Dependent)	-	-	-	-	-	-	-
RSS Total	2.53%	2.25%	2.52%	1.97%	1.76%	1.72%	2.24%

Typical Reflective Bands Uncertainty Contributions and RSS Total for SWIR Bands

Reflectance Calibration Uncertainties (%)

Uncertainty Source	Band 1	Band 13	Band 14	Band 15	Band 2	Band 16	Band 17	Band 18	Band 19	Band 5	Band 26	Band 6	Band 7
SD BRDF Varia. & Meas.'t	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
SD Degrad. Outside of SDSM	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SD Screen Trans Error	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SD Port Scatter	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Signal Noise(1/SNR@Ltyp)	0.78	0.11	0.09	0.17	0.50	0.19	0.60	1.75	0.40	1.35	0.40	0.36	0.91
ADC Quantization Correction	0.82	0.15	0.16	0.12	0.43	0.12	0.60	1.14	0.46	0.64	0.39	0.38	0.67
Sample Timing Errors(est.)	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00
FPA Temp Correction	0.38	0.05	0.05	0.05	0.14	0.05	0.22	1.20	0.12	0.52	0.10	0.09	0.37
Scan Angle Reflect. Correction	0.97	0.18	0.19	0.14	0.51	0.14	0.71	1.36	0.55	0.76	0.46	0.45	0.80
Mirror Side Correction	0.87	0.16	0.17	0.13	0.46	0.13	0.64	1.22	0.49	0.68	0.41	0.40	0.72
Polarization (Scene Dependent)	-	-	-	-	-	-	-	-	-	-	-	-	-
Crosstalk (Scene Dependent)	-	-	-	-	-	-	-	-	-	-	-	-	-
Scatter (Scene Dependent)	-	-	-	-	-	-	-	-	-	-	-	-	-
RSS Total	2.94%	2.15%	2.15%	2.14%	2.54%	2.15%	2.49%	3.70%	2.33%	3.01%	2.28%	2.48%	2.84%

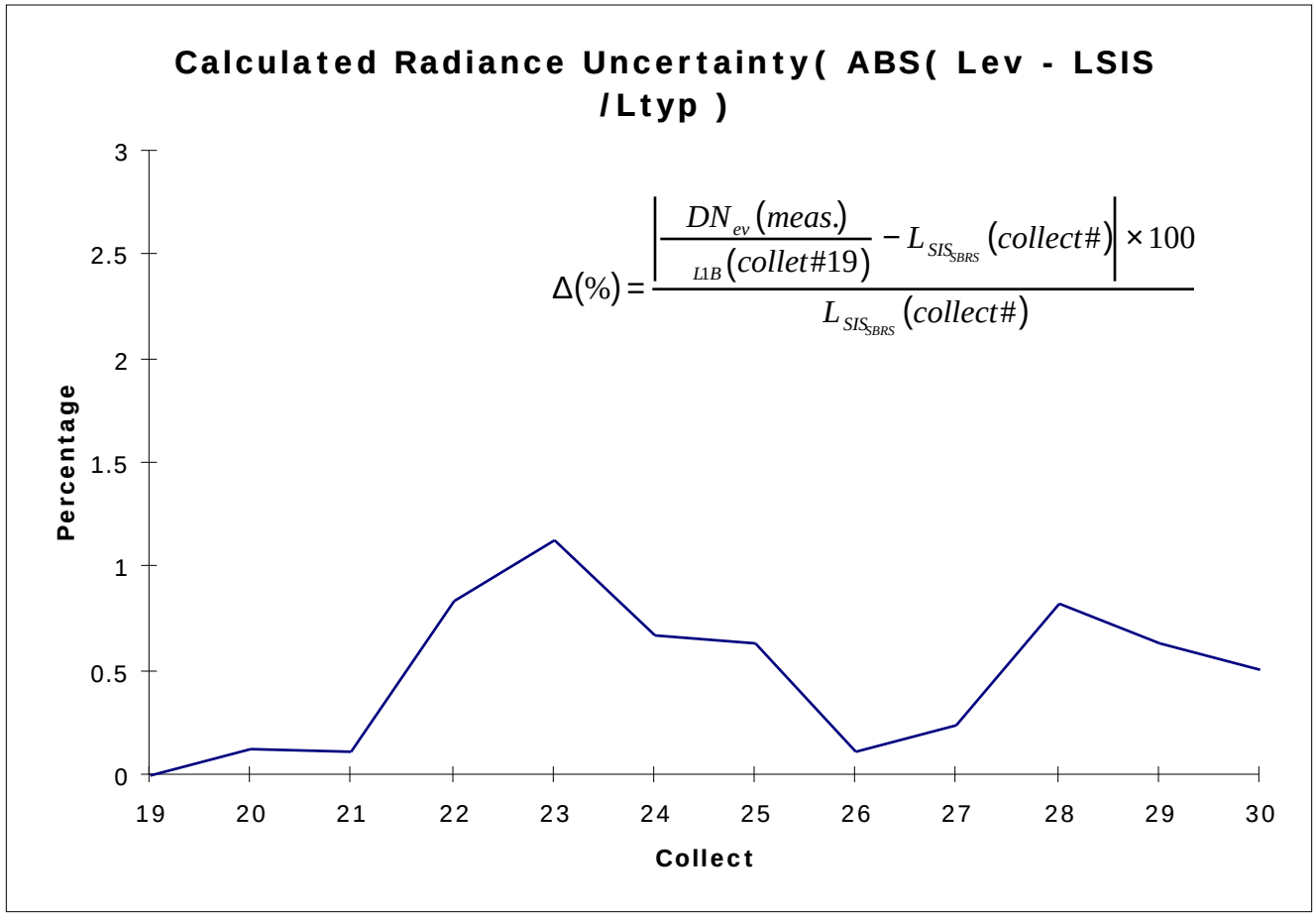
Radiance Calibration Uncertainties (%)

NIST to SIS100(per GSFC exp.)	1.28	1.28	1.28	1.28	1.28	1.29	1.3	1.31	1.31	1.46	1.58	1.81	2.4
Transfer to MODIS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.27	1.16	1.00	3.07	1.00	1.00
Signal Noise(1/SNR@Ltyp)	0.78	0.11	0.09	0.17	0.50	0.19	0.60	1.75	0.40	1.35	0.67	0.36	0.91
ADC Quantization Correction	0.82	0.15	0.16	0.12	0.43	0.12	0.60	1.14	0.46	0.64	0.39	0.38	0.67
Sample Timing Errors(est.)	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00
FPA Temp Correction	0.43	0.08	0.09	0.06	0.23	0.06	0.32	0.61	0.24	0.34	0.21	0.20	0.35
Scan Angle Reflect. Correction	0.58	0.11	0.12	0.09	0.31	0.09	0.43	0.82	0.33	0.46	0.28	0.27	0.48
Mirror Side Correction	0.87	0.16	0.17	0.13	0.46	0.13	0.64	1.22	0.49	0.68	0.41	0.40	0.72
Polarization (Scene Dependent)	-	-	-	-	-	-	-	-	-	-	-	-	-
Crosstalk (Scene Dependent)	-	-	-	-	-	-	-	-	-	-	-	-	-
Scatter (Scene Dependent)	-	-	-	-	-	-	-	-	-	-	-	-	-
RSS Total	2.49%	1.65%	1.65%	1.65%	2.11%	1.66%	2.03%	3.20%	1.96%	2.67%	3.58%	2.41%	3.15%

Reflective Solar Bands Production Parameters

Serial Number	Name	Symbol
R-001	Radiance responsivity correction factor	$F_{VC,L}(B)$
R-002	Dead detector list	Dead detector list
R-003	Noisy detector list	Noisy detector list
R-004	A/D nonlinearity correction	Q(AD,DN)
R-005	Temperture coefficent	K(B,D)
R-006	Ground mirror side relative reflectance	R(B,MS)
R-007	Scan angle effect coefficients (RVS)	S(B,D,MS,i)
R-008	Set point table	Set point table
R-009	Angle between SD normal and MODIS scan-mirror center	θ_M
R-010	Angle between SD azimuth axis (corner 2 - corner 1) and MODIS scan-mirror center	φ_M
R-011	BRDF measurement random error	S_{BRDF}
R-012	BRDF bias error (NIST traceability)	σ_{BRDF}
R-013	System level transmission measurement at available solar incidence angles in solar test	τ_{SD}
R-014	System level transmission measurement at available solar incidence angles in solar test	τ_{SDSM}
R-015	SDSM band spectral response	$R_{SDSM}(b,\lambda)$
R-016	MODIS band spectral response	$R_M(B,\lambda)$
R-017	Non-linearity coefficients of SiPDs	TBD
R-018	SD View stray light correction factor	WSD
R-019	Solar irradiance at 1 AU in the MODIS bands 1-19, and 26 (output)	$E_{sun}(B)$

Reflectance Band 20 Comparison of L1B Radiance Algorithm Output Wiht Calculated SIS 100 Radiance



MODIS

Emissive Infrared Bands Algorithm

Emissive Infrared Bands, Primary Equations --Knowles/GSC

$$V_s = a_o E_{det}^2 + b_o E_{det} + V_o + V_n$$

where

V_s	Focal plane voltage.
a_o	2nd order term gain coefficient
b_o	1st order term gain coefficient
E_{det}	Total detector irradiance (includes signal and background)
V_o	Zero irradiance voltage (includes bias and offset)
V_n	voltage attributed to noise

- Parameters which vary spectrally are summed across the wavelength
- New to MODIS: the absolute offset voltage in telemetry

Emissive Infrared Bands, Primary Equations

$$V_{ev} = \alpha m^2 \left(L_o + D_{ev} \rho_{ev} \left(L'_{ev} - L_{mir} \right) \right)^2 + m \left(L_o + D_{ev} \rho_{ev} \left(L'_{ev} - L_{mir} \right) \right) + V_n$$

where

V_{ev}	Focal plane voltage while viewing an Earth pixel.
α	Pre-launch measured nonlinear calibration coefficient dependent on patch and optics temperature.
m	System gain calibration coefficient.
L_o	Calibration coefficient measured on-orbit which accounts for detector background flux and bias power.
D_{ev}	Scan mirror correction term for on-orbit change of the reflectivity relative to the blackbody view angle.
ρ_{ev}	Pre-launch measurement of the absolute reflectivity of the scan mirror while viewing an Earth pixel..
L_{mir}	Planck radiance applied to the scan mirror temperature.
L'_{ev}	Apparent spectral radiance of the Earth view scene (Watts / µm-m^2-sr).
V_n	Voltage attributed to noise.

- Parameters which vary spectrally are summed across the wavelength
- This equation for a 2-temperature-zone sensor, one zone is sensor bulk temperature and other is scan mirror temperature
- Conversion to a 3-temperature-zone analysis involves substituting $L_{mir} + L_{3\text{-zone}}$ for L_{mir} and analyze space view and blackbody equations accordingly

Radiance Product

$$L_{ev} = \frac{-1 + \sqrt{1 + 4\alpha\left(V_{ev} - V_n\right)}}{2\alpha m D_{ev}\left(1 - w_{port}\right)\rho_{ev}\sum_{\lambda=\lambda_1}^{\lambda_n} R\Delta\lambda} + \frac{-L_o + D_{ev}\rho_{ev}\sum_{\lambda=\lambda_1}^{\lambda_n} L_{mir} R\Delta\lambda}{D_{ev}\left(1 - w_{port}\right)\rho_{ev}\sum_{\lambda=\lambda_1}^{\lambda_n} R\Delta\lambda}$$

where

V_{ev}	Focal plane voltage while viewing an Earth pixel.
α	Pre-launch measured nonlinear calibration coefficient dependent on patch and optics temperature.
m	System gain calibration coefficient (calculated on-orbit with blackbody and space view)
L_o	System background calibration coefficient (calculated on-orbit with blackbody and space view)
D_{ev}	Scan mirror correction term for on-orbit change of the reflectivity relative to the blackbody view angle.
ρ_{ev}	Pre-launch measurement of the absolute reflectivity of the scan mirror while viewing an Earth pixel..
L_{mir}	Planck radiance applied to the scan mirror temperature.
L_{ev}	Level 1B radiance product (Watts/µm-m^2-sr).
V_n	Voltage attributed to noise.
R	Spectral response of the system
w_{port}	Earth port background weighting term (function of view angle)

- Space view and blackbody background terms are contained within the parameters m and Lo
- Units for this product are Watts/µm-m^2-sr

Emissive Infrared Band Radiance Uncertainty Estimation Approach

DN(Digital Number) → V(Volts) → L(Radiance)

- ADC Non-linearity
- ADC Instability

ΔL/L computed based on L1B algorithm and measured or modeled parameter uncertainties

$$\left(\frac{\Delta L}{L}\right)_{Total} = \sqrt{\left(\frac{\Delta Q}{Q}\right)_{ADC}^2 + \left(\frac{\Delta L}{L}\right)_{algorithm}^2 + \left(\frac{\Delta L}{L}\right)_{NIST-BCS}^2 + \left(\frac{\Delta L}{L}\right)_{Crosstalk}^2 + \left(\frac{\Delta L}{L}\right)_{Scatter}^2}$$

- Measured by SBRS
- algorithm-based estimate using measured parameter uncertainties
- NIST-BCS radiance transfer
- Scene dependent (not included in L1B uncertainty)

From Gauss's Law of Error Propagation:

$$\left(\frac{\Delta L}{L}\right)_{algorithm} = \sqrt{\sum \left(\frac{f(x_1 + \Delta x_1, x_2, \ldots, x_n) - L_{Nom}}{L_{Nom}}\right)^2 + \left(\frac{f(x_1, x_2 + \Delta x_2, \ldots, x_n) - L_{Nom}}{L_{Nom}}\right)^2 + \ldots + \left(\frac{f(x_1, x_2, \ldots, x_n + \Delta x_n) - L_{Nom}}{L_{Nom}}\right)^2}$$

Typical Radiance Uncertainty Contributions and RSS Total for PV Bands

	Symbol	Nominal	Perturb.	Band 20	Band 21	Band 22	Band 23	Band 24	Band 25	Band 27	Band 28	Band 29	Band 30
BCS Transfer to BB Temp Adj.	K_{bb}	0 K	Band Dep.	0.55 %	0.53 %	0.53 %	0.52 %	0.46 %	0.47 %	0.29 %	0.26 %	0.22 %	0.21 %
Scan Mirror Temp	T_{mir}	285 K	1 K	0.01 %	0.01 %	0.01 %	0.01 %	0.05 %	0.01 %	0.02 %	0.02 %	0.02 %	0.05 %
BB Temp	T_{bb}	300 K	0.1 K	0.42 %	0.40 %	0.40 %	0.39 %	0.34 %	0.35 %	0.23 %	0.22 %	0.19 %	0.17 %
Scan Cavity Temp	T_{cav}	290 K	10 K	0.21 %	0.21 %	0.21 %	0.21 %	0.19 %	0.19 %	0.08 %	0.06 %	0.04 %	0.05 %
SAM Temp (SV Surround)	T_{sam}	290 K	10 K	0.00 %	0.27 %	0.00 %	0.00 %	2.38 %	0.49 %	0.59 %	0.21 %	0.00 %	0.06 %
BB Earthshine Eff. Temp	T_{swath}	250 K	50 K	0.19 %	0.19 %	0.19 %	0.19 %	0.18 %	0.18 %	0.10 %	0.07 %	0.06 %	0.06 %
Fraction BB Refl. Rad from Cavity	w_{cav}	0.75	-0.25	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
BCS Transfer to BB Eff. Emiss.	e_{bb}	Band Dep.	0.004	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
Fraction of SV Rad from SAM	w_{sv}	Band Dep.	0.001	0.01 %	0.06 %	0.01 %	0.01 %	0.51 %	0.10 %	0.37 %	0.20 %	0.01 %	0.13 %
On-Orbit Rel. Refl. Adj. (EV/BB)	D_{ev}	1	0.001	0.10 %	0.17 %	0.09 %	0.09 %	0.77 %	0.10 %	0.61 %	0.32 %	0.05 %	0.21 %
On-Orbit Rel. Refl. Adj. (SV/BB)	D_{sv}	1	0.001	0.04 %	0.11 %	0.04 %	0.04 %	0.82 %	0.15 %	0.65 %	0.36 %	0.01 %	0.25 %
DN (Ltyp)	DN	Band Dep.	Band Dep.	0.03 %	0.31 %	0.03 %	0.03 %	0.12 %	0.04 %	0.07 %	0.04 %	0.02 %	0.03 %
Alpha (2.5% nonlinearity)	α	Band Dep.	Band Dep.	0.00 %	0.00 %	0.00 %	0.00 %	0.25 %	0.20 %	0.48 %	0.50 %	0.00 %	0.64 %
Center Wavelength	λ	Band Dep.	1 Wave No.	0.29 %	0.33 %	0.33 %	0.33 %	0.25 %	0.26 %	0.14 %	0.10 %	0.06 %	0.00 %
NEdL (Spec.)	NEdL	Band Dep.	Band Dep.	0.21 %	0.63 %	0.28 %	0.28 %	1.29 %	1.05 %	0.93 %	0.79 %	0.09 %	0.59 %
NIST Transfer to BCS (est.)	N/A	N/A	N/A	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %
ADC Nonlinearity (est.)	N/A	N/A	N/A	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %
Crosstalk (Scene Dependent)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Scatter (Scene Dependent)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			RSS	1.31 %	1.50 %	1.32 %	1.30 %	3.23 %	1.71 %	1.89 %	1.53 %	1.06 %	1.41 %

Typical Radiance Uncertainty Contributions and RSS Total for PC Bands

	Symbol	Nominal	Perturb.	Band 31	Band 32	Band 33	Band 34	Band 35	Band 36	Band 31hi	Band 32hi
BCS Transfer to BB Temp Adj.	K_{bb}	0 K	Band Dep.	0.19 %	0.19 %	0.20 %	0.21 %	0.22 %	0.23 %	0.19 %	0.19 %
Scan Mirror Temp	T_{mir}	285 K	1 K	0.01 %	0.01 %	0.03 %	0.03 %	0.04 %	0.07 %	0.00 %	0.00 %
BB Temp	T_{bb}	300 K	0.1 K	0.15 %	0.14 %	0.13 %	0.12 %	0.12 %	0.12 %	0.15 %	0.14 %
Scan Cavity Temp	T_{cav}	290 K	10 K	0.05 %	0.06 %	0.08 %	0.09 %	0.10 %	0.11 %	0.05 %	0.06 %
SAM Temp (SV Surround)	T_{sam}	290 K	10 K	0.00 %	0.00 %	0.01 %	0.02 %	0.02 %	0.03 %	0.01 %	0.01 %
BB Earthshine Eff. Temp	T_{swath}	250 K	50 K	0.07 %	0.09 %	0.12 %	0.13 %	0.14 %	0.15 %	0.07 %	0.09 %
Fraction BB Refl. Rad from Cavity	w_{cav}	0.75	-0.25	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
BCS Transfer to BB Eff. Emiss.	e_{bb}	Band Dep.	0.004	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
Fraction of SV Rad from SAM	w_{sv}	Band Dep.	0.001	0.01 %	0.01 %	0.06 %	0.08 %	0.12 %	0.21 %	0.07 %	0.07 %
On-Orbit Rel. Refl. Adj. (EV/BB)	D_{ev}	1	0.001	0.04 %	0.04 %	0.09 %	0.14 %	0.20 %	0.38 %	0.15 %	0.14 %
On-Orbit Rel. Refl. Adj. (SV/BB)	D_{sv}	1	0.001	0.01 %	0.01 %	0.12 %	0.17 %	0.23 %	0.41 %	0.12 %	0.11 %
DN (Ltyp)	DN	Band Dep.	Band Dep.	0.02 %	0.02 %	0.02 %	0.02 %	0.03 %	0.04 %	0.01 %	0.01 %
Alpha (2.5% nonlinearity)	α	Band Dep.	Band Dep.	0.00 %	0.00 %	0.64 %	0.74 %	0.83 %	0.98 %	0.29 %	0.31 %
Center Wavelength	λ	Band Dep.	1 Wave No.	0.09 %	0.13 %	0.20 %	0.22 %	0.22 %	0.22 %	0.09 %	0.13 %
NEdL (Spec.)	NEdL	Band Dep.	Band Dep.	0.07 %	0.07 %	0.40 %	0.43 %	0.45 %	0.74 %	0.64 %	0.54 %
NIST Transfer to BCS (est.)	N/A	N/A	N/A	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %	1.00 %
ADC Nonlinearity (est.)	N/A	N/A	N/A	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %
Crosstalk (Scene Dependent)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Scatter (Scene Dependent)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			RSS	1.04 %	1.05 %	1.31 %	1.39 %	1.47 %	1.74 %	1.27 %	1.23 %

IR Bands, Production Parameters

Serial Number	Name	Symbol
T-001	System nonlinearity coefficient	α
T-002	Scan mirror relative reflection correction factor	D_{ev}
T-003	Scan mirror absolute reflectance	ρ
T-004	Relative Spectral Response of System	R_{opt}
T-005	Space view stray light correction factor	$\omega_{\sigma\varpi}$
T-006	Blackbody apparent emissivity	$\varepsilon_{\beta\beta}$
T-007	Cavityshine thermistor weighting factors	$\omega_{cav\ (15)}$
T-008	Blackbody effective temperature correction factor	K_{bb}
T-009	Earth view stray light correction factor	ω_{ev}
T-010	Noise Equivalent Radiance	NEdL
T-011	Systematic Uncertainties	ΔL_{g}
T-012	A/D converter response curve	$\varsigma_{a/d\{\}}$
T-013	DC Restore Pieces	
T-014	Earthshine correction factors	$\omega_{swath\ (2)}$

Practical Considerations

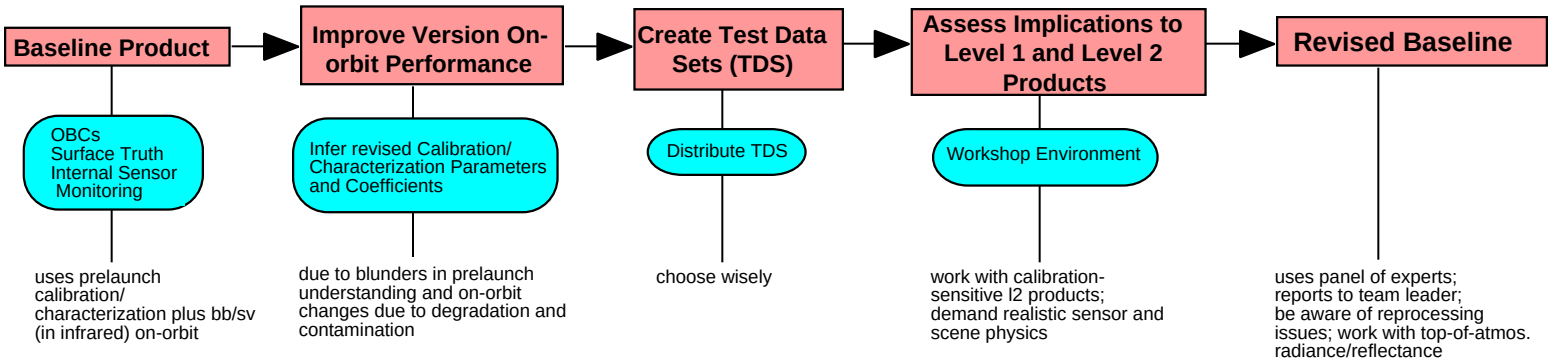
- Number of files to be managed in the production environment
- Size of files to be sent across the network
- Desire to maximize the utility of the L1B product for the largest sector of the user community.
- Remain within computer resource budget

Exception Handling, Diagnostics and Quality Control

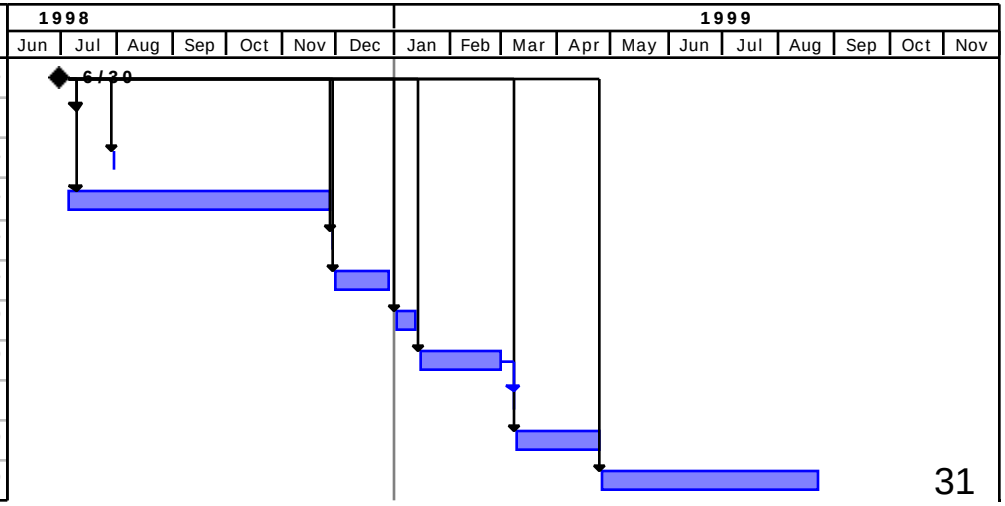
- Exception handling and diagnostics
  - Handled through the Status Messaging Facility, as prescribed by ECS
  - Messages defined and stored in MCST Message Seed File
- Quality control
  - MCST Quality Assurance Plan
  - Space provided in Level 1B file for QA flags
  - Preliminary QA flags defined in L1B file specification

Validation

Process Flow for MODIS Level 1B Product Validation



ID	Task Name	Duration	Start	Finish
1	AM-1 Launch	0d	6/30/98	6/30/98
2	Reflected Solar Bands Turn-on	1d	7/9/98	7/9/98
3	Emissive Infrared Bands Turn-on	1d	7/30/98	7/30/98
4	OBC Results Available to MCST	145d	7/5/98	11/26/98
5	Vicarious Calibration Results to MCST	1d	11/27/98	11/27/98
6	Calculation of Cal Coeffieients, LUTs	31d	11/28/98	12/28/98
7	Create and Distribute Test Data Sets	13d	1/1/99	1/13/99
8	Science Team Review of Test Data Sets	45d	1/15/99	2/28/99
9	Calibration/Validation Workshop	1d	3/8/99	3/8/99
10	Implement Workshop Results	46d	3/9/99	4/23/99
11	S/W Engineering and DAAC Ingest	121d	4/24/99	8/22/99



Validation Techniques and Application to Reflected Solar Bands

Band	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	26
Validation Technique																				
SRCA - geometric																				
SRCA - spectral																				
SRCA - radiometric																				
Solar Diffuser/SDSM																				
Moby ocean site																				
ARM Sites																				
Hay, Australia																				
U Arizona studies																				
Ocean field campaigns																				
U Wisconsin HIS																				
HAUCCS - Abel																				
Clouds, glint and molecular																				

At-launch, the algorithm will use pre-launch algorithms with prelaunch parameters and LUTs. Consequently, the use of On-Board Calibrators for the early on-orbit processing phases fall into the validation analysis. If the sensor does under go change in intrinsic performance which we find can be tracked using the OBCs, then the OBC data become part of the processing algorithm. Validation techniques other than the OBCs will be used throughout the entire mission.

Bands identified with this mark can be validated with this technique.

It is unknown at the present time if the bands identified by this mark can be validated with this technique.

Validation Techniques and Application to Emissive Infrared Bands

Band	20	21	22	23	25	25	27	28	29	30	31	32	33	34	35	36
Validation Technique																
SRCA - geometric																
SRCA - spectral																
SRCA - radiometric																
Solar Diffuser/SDSM																
Moby ocean site																
ARM Sites																
Hay, Australia																
U Arizona studies																
Ocean field campaigns																
U Wisconsin HIS																
HAUCCS - Abel																
Clouds, glint and molecular																

Bands identified with this mark can be validated with this technique.

It is unknown at the present time if the bands identified by this mark can be validated with this technique.

Responses to Formal Reviews

- Written ATBD Reviews
- Land ATBD Review
- Complete package provided as Appendix C in the handouts