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Toward Objective Uncertainty and Typing Probability

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EDR Description	Measurement Uncertainty: Threshold	Objective	Spec	Pred Perf	Ptype: Threshold	Objective	Spec	Pred Perf
1 Imagery	-	-	-	-	-	-	-	-
Cloud cover ARR	0.1	0.1	0.1	0.04	-	-	-	-
Cloud Type ARR	-	-	-	-	85%	90%	85%	59%
Ice Edge ARR	TBD	TBD	2 km	<1.2 km	-	-	-	-
Ice Conc ARR	0.1	0.1	0.1	0.066	-	-	-	-
2 Sea Surface Temperature	0.5 K	0.35*/0.1 K	0.35 K	0.192 K	-	-	-	-
3 Soil Moisture	10 cm/m	1 cm/m	5 cm/m	4.5 cm/m	-	-	-	-
4 Aerosol optical thickness	-	-	-	-	-	-	-	-
AOT (land)	0.05+0.2tau	TBD	tau<1: 0.14; tau>1: 0.15	tau < 0.3: 0.077; tau > 1.5: 0.17	-	-	-	-
AOT (ocean)	-	-	-	-	-	-	-	-
5 Particle Size	-	-	-	-	-	-	-	-
Particle Size(Land)	-	-	-	-	-	-	-	-
Particle Size (ocean)	-	-	-	-	-	-	-	-
6 Susp Matter	-	TBD	0.5	0.5	TBDdeg	TBDclass	90% Flag/85%class	90% Flag/87% class
7 Cloud base	2 km	0.25 km	2 km	1.5 km	-	-	-	-
8 Cover/Layers	-	-	-	-	TBD	TBD	stratified 85-87%	93-94%
9 Cloud Particle size	> of 10% or 2"	TBD	OD<1:2.5-4; OD>1:5.5-12	OD<1:2-3; OD>1:5-11	-	-	-	-
10 Cloud Optical thickness	> of 10% or 0.05*	TBD	OD<1: 10%; OD>1: 10-> 3	OD<1: <5 %; OD>1: 0.040-27	-	-	-	-
11 Cloud Top Height	0.5(water) - 1(ice) km*		water OD<1: 0.5-1; OD>1: 1-(ice) 1	water OD<1: 0.4-7; OD>1: .8-1.4(ice) 1	-	-	-	-
12 Cloud Top Pressure	50 mb*	TBD	stratified 20 - 130 mb	stratified 20 - 125 mb	-	-	-	-
13 Cloud Top Temp	5K	2K	3 - 6K	2 - 3K	-	-	-	-
14 Albedo	0.03*	TBD	0.025 - 0.03	0.025 - 0.3	-	-	-	-
15 Land Surface Temperature	2.5 K*	TBD	2.0 K	2.14 K	-	-	-	-
16 Veg Index	-	-	-	-	-	-	-	-
NDVI	0.07*	TBD*	0.02	0.014	-	-	-	-
EVI*	TBD	TBD	0.15	0.1	-	-	-	-
17 Snow Cover/Depth (Clear)	-	-	-	-	-	-	-	-
Binary Map (Threshold)	-	-	-	-	90%	-	95%	97%
Fraction (Objective)	-	10%	10%	10%	-	-	-	-
18 Surface Type	-	-	-	-	70%/70%*	TBD	82%	88%
19 Currents	-	-	-	-	-	-	-	-
20 Fresh Water Ice	-	-	-	-	-	-	-	-
Concentration	0.1	0.1	0.1	0.1	-	-	-	-
Edge Boundary	10 km	5 km	1.2 km	0.9 km	-	-	-	-
21 Ice Surface Temperature	1 K	TBD	0.6 K	0.35 K	-	-	-	-
22 Littoral Sediment Transport	-	-	-	-	-	-	-	-
23 Net Heat Flux	-	-	-	-	-	-	-	-
24 Ocean color	30%*	TBD	<20% to 10mg/40% to 50 mg (radio)*<27% to 10mg/<37% to 50mg (radio)*		-	-	-	-
25 Sea Ice Age/Motion	-	-	-	-	-	-	-	-
Ice Age	-	-	-	-	70%	90%	70 - 80%	72 - 87%
Ice Edge Motion*	1 km/day	1 km/day	1 km/day	5 km/day	-	-	-	-
26 Mass Loading	30%*	TBD*	30%	25%	-	-	-	-
27 Active Fires*	-	-	-	-	-	-	-	-
Subpixel Temp	50 K	25 K	50 K	50 K	-	-	-	-
Subpixel Area	30%	15%	30%	30%	-	-	-	-
28 Precipitable Water*	TBD	TBD	LW > 5mm, <33%; TPW < 5mm, 1.6 cPW > 5mm, <32%; TPW < 5mm, 1.5 m		-	-	-	-

*Nadir "fine" requirement, specification, or performance estimate "should not be allowed to significantly drive design"

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Toward Objective Accuracy and Precision

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EDR Description	Measurement Accuracy: Threshold	Objective	Spec	Pred Perf	Measurement Precision: Threshold	Objective	Spec	Pred Perf
1 Imagery	-	-	-	-	-	-	-	-
Cloud cover ARR	-	-	-	-	-	-	-	-
Cloud Type ARR	-	-	-	-	-	-	-	-
Ice Edge ARR	-	-	-	-	-	-	-	-
Ice Conc ARR	-	-	-	-	-	-	-	-
2 Sea Surface Temperature	0.2 K	0.1 K	0.2 K	0.16K	0.48	0.1 K	0.27	0.26
3 Soil Moisture	-	-	-	-	-	-	-	-
4 Aerosol optical thickness	-	-	-	-	-	-	-	-
AOT (land)	0.2	0.1	tau<1: 0.1; tau>1: 0.16	tau<1: 0.09; tau>1: 0.11	0.2	0.1	0.1	0.08
AOT (ocean)	0.03	0.01	<0.03 for tau<0.6	<0.03 for tau<0.6	0.03	0.01	<0.03 for tau < 1; 0.03 for tau <	
5 Particle Size	-	-	-	-	-	-	-	-
Particle Size(Land)	1	30%eff rad	0.6	0.6	1	30%eff rad	0.6	0.5
Particle Size (ocean)	0.3	10%eff rad	0.3 aot<0.4; 0.1 aot >0.4	0.3 aot<0.4; 0.1 aot >0.4	0.3	10%eff rad	aot<0.4: 0.1 aot; aot>0.4: 0.1 aot	
6 Susp Matter	-	-	-	-	-	-	-	-
7 Cloud base	-	-	-	-	-	-	-	-
8 Cover/Layers	0.1	0.05	0.07 - 0.1	0.02 - 0.08	0.15	0.025	0.15	0.03 - 0.14
9 Cloud Particle size	> of 10% or 4	> of 5% or 2	od>1: 3 - 4; od<1: 5.5 - 9	od>1: 1.1 - 3; od<1: 6-8	5% c	0.02	>1: 1-2; od<1: 1.1-1; 0.5-2; od<1: 0	
10 Cloud Optical thickness	> of 10% or 0.05	> of 5% or TBD	od>1: 5-10%; od<1: 05 - 25	od>1: 2.3-8.5%; od<1: .07 - .25	% or	> of 2% or TBD	3 - 5%	2-4%; od<1: .06
11 Cloud Top Height	OT>0.1 km OT<0.1 2km	0.3 km	OT>0.1: 0.5-1; OT<0.1: 3	OT>0.1: 0.35-0.5; OT<0.1: 0.7-1	0.3	0.15	0.3 km	0.25km
12 Cloud Top Pressure	50-100 mb	15 - 40 mb	30-100 mb	20 - 90 mb	50 m	5-10 mb	10 - 25 mb	7 - 15 mb
13 Cloud Top Temp	OT>0.1 3K; OT<0.1 6K	OT>0.1 1.5K; OT<0.1 TBD	OT>0.1: 2-3K; OT<0.1 6K	OT>0.1: 1.6-2.8K; OT<0.1: 5.3K	1.5K	0.5K	1.5K	1K
14 Albedo	0.05	0.0125	0.025	0.025	0.02	0.01	0.02 - 0.05	0.02 - 0.048
15 Land Surface Temperature	2.5 K	1 K	2.6 K	2.1 K	0.5 K	0.025 K	0.5K	0.42K
16 Veg Index	-	-	-	-	-	-	-	-
NDVI	0.05	0.03	0.016	0.006	0.04	0.02	0.03	0.013
EVI*	-	-	-	-	-	-	-	-
17 Snow Cover/Depth (Clear)	-	-	-	-	-	-	-	-
Binary Map (Threshold)	-	-	-	-	-	-	-	-
Fraction (Objective)	-	2%	20%	20%	-	0.1%	10%	10%
18 Surface Type	-	-	-	-	-	-	-	-
19 Currents	25mm/15deg	0.1m/s/15deg	0.1m/s/15deg	0.1m/s/15deg	m/s/15	1m/s/15deg	1m/s/15deg	1m/s/15deg
20 Fresh Water Ice	-	-	-	-	-	-	-	-
Concentration	-	-	-	-	-	-	-	-
Edge Boundary	-	-	-	-	-	-	-	-
21 Ice Surface Temperature	-	-	-	-	-	-	-	-
22 Littoral Sediment Transport	> of 30% or TBD	> of 15% or TBD	30%	38%	30% or	> of 15% or TBD	40%	38%
23 Net Heat Flux	10W/m 2	1W/m 2	10W/m-2	10 W/m 2	W/m 2	1W/m 2	20W/m-2	20W/m-2
24 Ocean color	30%	30%	<20% to 10 mg/<50% to 50 mg	<27% to 10 mg/<42% to 50 mg	20%	10%	to 1 mg/<50% to to 1 mg/<48% to	
25 Sea Ice Age/Motion	-	-	-	-	-	-	-	-
Ice Age	-	-	-	-	-	-	-	-
Ice Edge Motion	-	-	-	-	-	-	-	-
26 Mass Loading	> of 30% or TBD	0.1 mg/L	25%	16%	TBD	0.1 mg/L	25%	18.0%
27 Active Fires*	-	-	-	-	-	-	-	-
Subpixel Temp	-	-	-	-	-	-	-	-
Subpixel Area	-	-	-	-	-	-	-	-
28 Precipitable Water*	-	-	-	-	-	-	-	-

*Nadir "fine" requirement, specification, or performance estimate "should not be allowed to significantly drive design"

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EDR Spectral Requirements Suggest Sensor Design Drivers

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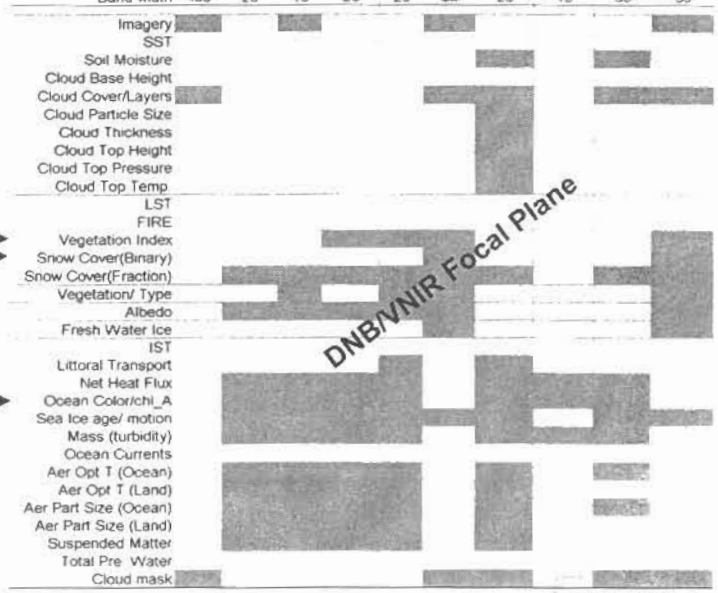
PDR FINAL 23APR00	DNB	M1	M2	M3	M4	I1	M5	M6	M7	I2
	DNB	Cl2w2	2	chlor8	4	5i	OC2	OC3	6	6i
Band position	700	412	445	488	555	645	672	751	865	865
Band width	400	20	18	20	20	50	20	15	39	39

Fine Resolution Band

Required to meet Raytheon Specified EDR Value



Imagery 645 nm & Fine Resolution 865 nm Band Adjacency Driver

Fine Resolution 1.61 μm Band Driver

VNIR Bands Driver

Coregistration with SWIR/MWIR/LWIR Improves Aerosol EDRs and others

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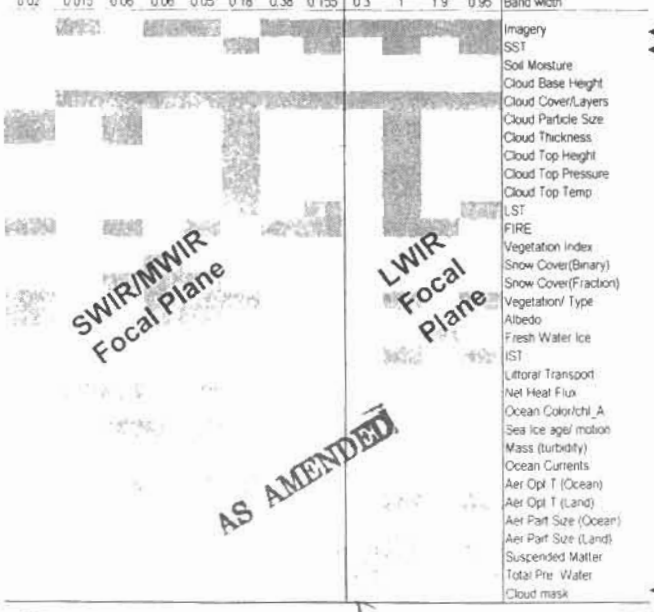
EDR Spectral Requirements Suggest Sensor Design Drivers

M8	M9	M10	I3	M11	M12	I4	M13	M14	M15	I5	M16	PDR FINAL 23APR00
cloud1	7	8	8i	9	10	10w	sst2	sst4	11	12w	12	
1.24	1.378	1.61	1.61	2.25	3.7	3.74	4.05	8.55	10.76	11.45	12.013	Band position
0.02	0.015	0.06	0.06	0.05	0.18	0.38	0.155	0.3	1	1.9	0.95	Band width



2:1 Nadir to Edge-of-Scan Resolution & Sampling Driver

Emissive Band NEdT & Calibration Driver

Fine Resolution Band

Required to meet Raytheon Specified EDR Value

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Significant all-Band Co-registration Driver

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Summary of Stratified Dimensions in Specification

EDR	STRATIFICATION DIMENSIONS	RATIONALE
Imagery	Not Stratified in specification	Sensor Explicit Requirements
Sea Surface Temperature	Not Stratified in specification	System design ensures objective performance over entire range
Soil Moisture	Not Stratified in specification	Category III
Aerosol Optical Thickness	Ocean/Land * Measurement Range	Significant performance variation over measurement range
Aerosol Size Parameter	Ocean/Land * Aerosol Optical Thickness	Significant performance variation over measurement range
Suspended Matter	Subtypes of Suspended Matter Identified	Need to specify objective level flags
Cloud Base Height	Not Stratified in specification	Category III
Cloud Mask	day/night * ocean/land * optical depth	Significant performance variation over measurement range
Cloud Cover Layers	Singel layer/multiple layer * Nadir/EOS	Significant performance variation over measurement range
Cloud Effective Particle Size	Cloud type * day/night * Optical depth	Significant performance variation over measurement range
Cloud Optical Thickness	Cloud type * day/night * Optical depth	Significant performance variation over measurement range
Cloud Top Height	Cloud type * day/night * Optical depth	Significant performance variation over measurement range
Cloud Top Pressure	Cloud type * day/night * Optical depth	Significant performance variation over measurement range
Cloud Top Temperature	Cloud type * day/night * Optical depth	Significant performance variation over measurement range
Albedo	Not Stratified in specification	Limited performance variation over measurement range
NDVI	Not Stratified in specification	Limited performance variation over measurement range
Land Surface Temperature	Not Stratified in specification	Limited performance variation over measurement range
Snow Cover	Not Stratified in specification	Limited performance variation over measurement range
Surface Type	Not Stratified in specification	Limited performance variation over measurement range
Ocean Current	Not Stratified in specification	Category III
Fresh Water Ice	Scan angle	Significant performance variation over scan angle
Ice Surface Temperature	Not Stratified in specification	Limited performance variation over measurement range
Littoral Sediment Transport	Not Stratified in specification	Category III
Net Heat Flux	Not Stratified in specification	Category III
Ocean Color	Measurement Range	Significant performance variation over measurement range
Ice Age/ Edge location	First year v Multi-year v New/Young	Significant performance variation over ice types
Mass Loading	Not Stratified in specification	Category III
FIRE	Not Stratified in specification	Limited performance variation over measurement range
Total Precipitable Water	Land/Ocean/Cloud	Significant variation over different surfaces

- Performances stratified over a wide range of cases
- Significant variation causes specification to be stratified (System Verification Report)

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Explicit Imagery Provides Near Objective Performance

Imagery	Threshold	Objective	Spec
a. HSR (km)			
1. nadir	0.4	TBD	0.4
2. Worst case	0.8	0.1	0.8
3. Day/Night Band, worst	2.6	0.65	0.74
b. HRI	Nr. Gapless	Nr. Gapless	HSR
c. Horiz Coverage	Global	Global	Global
d. Measurement Range	W/(cm^2 sr)		
DNB Minimum	4.00E-09	Threshold	4.00E-09
Maximum	3.00E-02		3.00E-02
	W/(m^2 sr μm)		
0.645μm Minimum	Derived	Derived	5
Maximum			462
	K		
3.7μm Minimum	Derived	Derived	210
Maximum			353
11.45μm Minimum	Derived	Derived	210
Maximum			340
e. Measurement Noise Level			
DNB	Derived	Derived	6.5 E-10 @ 4.0 E-9 W/(cm2.sr)
0.645μm	Derived	Derived	130.7 @ 22W/(m2.sr.μm)
3.7μm	Derived	Derived	2.5K @ 270K
11.45μm	Derived	Derived	1.5K @ 210K
Swath width	3000 (TBR)	TBD	3000

Near Objective Performance

Additional band to identify low stratus at night

- Meets or exceeds current operational capabilities
- Imagery demonstration on Day 3 will show VIIRS multispectral imagery capabilities

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Imagery Application Requirements: Cloud Types Satisfied at Objective Level

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Cloud Type	Abbreviation	Approach to Accurate Classification: Spectral Signature	Shape/Texture	Temperature Contrast (cloud top vs cloud-free)	Comments
Altocumulus	AC		x	x	
Altocumulus Castellanus	ACCAS				
Altocumulus (Standing Lenticular)	ACSL				
Altostratus	AS		x	x	
Cirrocumulus	CC	x	x	x	
Cirrocumulus (Standing Lenticular)	CCSL	x	x	x	
Cirrostratus	CS	x	x	x	
Cirrus	CI	x	x	x	
Cumulonimbus	CB	x	x	x	
Cumulus	CU		x	x	
Cumulus Fractus	CUFRA				
Towering Cumulus	TCU		x	x	
Stratus Fractus	STFRA				
Nimbostratus	NS				requires ancillary precipitation data
Stratocumulus	SC		x	x	
Stratocumulus (Standing Lenticular)	SCSL		x	x	
Stratus	ST	x		x	
Obscured/Not Cloudy	OBS	x	x		
Clear	CLR	x			

- Threshold cloud types achieved for all five types
- Objective cloud types achieved nine out of 14 types
- Not differentiated in Raytheon specification

Cloud Cover Imaging requirements satisfied at objective level

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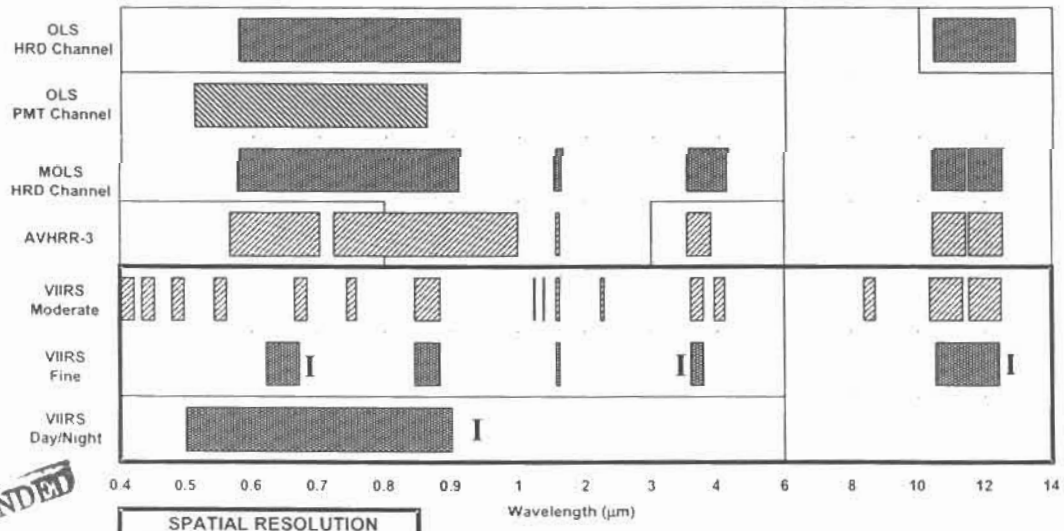
Imagery EDR Benefits from True Multispectral Capability



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SPATIAL RESOLUTION: Fine, Moderate, Coarse

Bands marked "I" are required for Imagery thresholds

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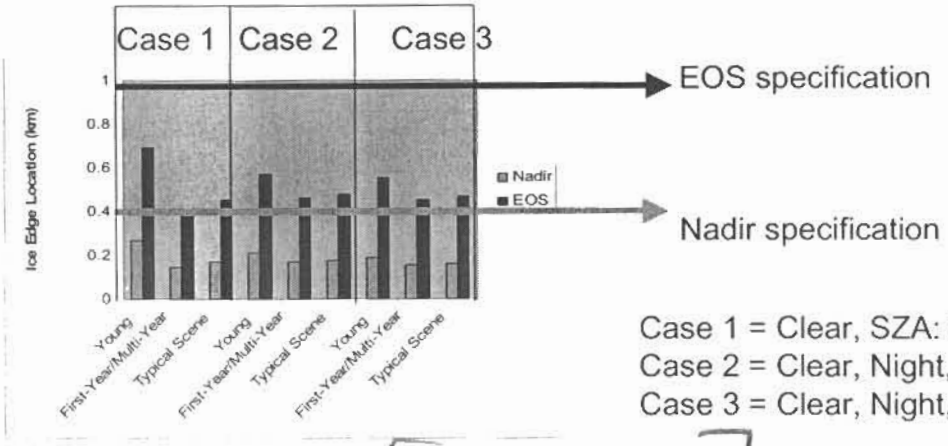
Imagery Ice Edge Location Determined Robustly

Imagery Ice Edge Location	Threshold	Objective	Spec	Spec Perfo
a. Horiz Coverage	N of 36N, S of 50S	N of 36N, S of 50S	N of 36N, S of 50S	N of 36N, S of 50S
b. Measurement Range	Horizontal Coverage	Horizontal Coverage	Horizontal Coverage	Horizontal Coverage
c. Measurement Uncertainty	TBD	TBD		
NADIR			0.4 km	0.35 km
EOS			1.0km	0.9 km



Case 1 = Clear, SZA: 60 degrees
Case 2 = Clear, Night, Tair: -5K
Case 3 = Clear, Night, Tair: -10K

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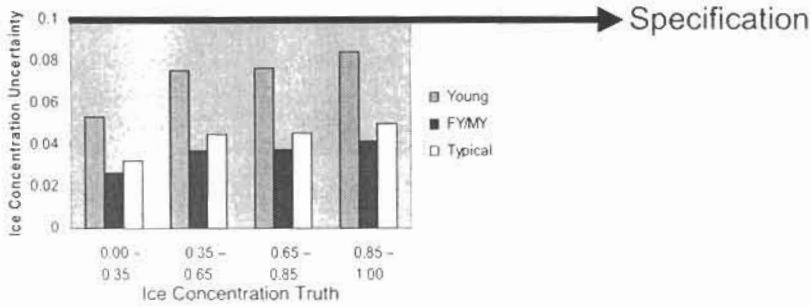
Imagery Ice Concentration Verified over Ice Types and Concentrations

Ice Concentration	Threshold	Objective	Spec	Spec Perfo
d. HCS (km)				
1. Nadir	2	1	0.8	0.75
e. HRI (nadir)	TBD	TBD	0.4	0.37
a. Horiz Coverage	N of 36N, S of 50S	N of 36N, S of 50S	N of 36N, S of 50S	N of 36N, S of 50S
b. Measurement Range	0-1, 0.1 increments	Threshold	0 - 1	0 - 1
c. Measurement Uncertainty	0.1	Threshold	0.1	0.085

Case 1 = Clear, SZA: 60 degrees



- Stressing case for young ice, at EOS
- Full detailed performance across the measurement range and ice type is given in the System Verification Report

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SST System Specification Targets Intermediate Objective

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SST (skin)	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Mod, nadir	3	1	2.5	2.25
2. Mod, worst	4	TBD	3.2	3.2
3. Fine, nadir	1	0.25	0.75	0.75
4. Fine, worst	1.3	TBD	1.3	1.3
b. HRI	TBD	TBD	HCS	HCS
c. Horiz Coverage	Oceans	Oceans	Oceans	Oceans
d. Measurement Range	271-313	271-313	271-313	271-313
e. Uncertainty (K)				
1. Moderate	0.5	0.1	0.35	0.32
2. Fine at NADIR	0.5	0.35	0.35	0.32
f. Accuracy (K)				
1. Moderate	0.2	0.1	0.2	0.19
2. Fine	0.2	0.1	0.2	0.19
g. Precision (K)				
1. Moderate	TBD	0.1	0.27	0.26
2. Fine	TBD	N/A	0.27	0.26
k. Swath width	1700	TBD		
1. Swath width (fine)			2000	2000
2. Swath width (moderate)			2000	2000

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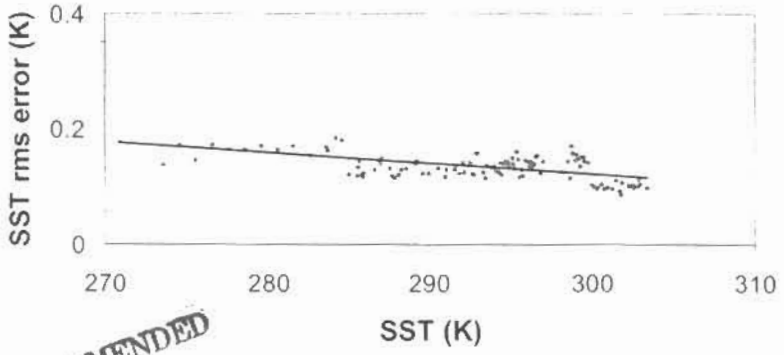
System-Level Modeling Permits Accuracy Specification to be Met With Margin

SST rms accuracy with calibration error



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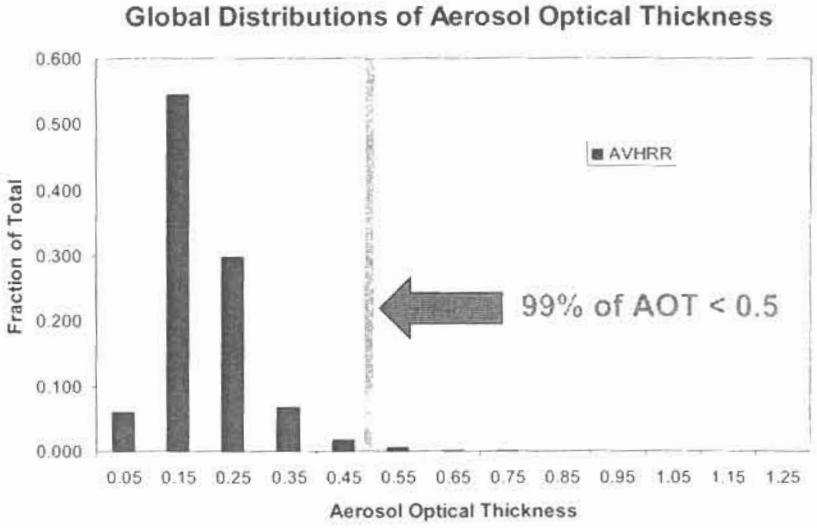
AOT EDR Meets or Beats Threshold 99% of Time Over Ocean



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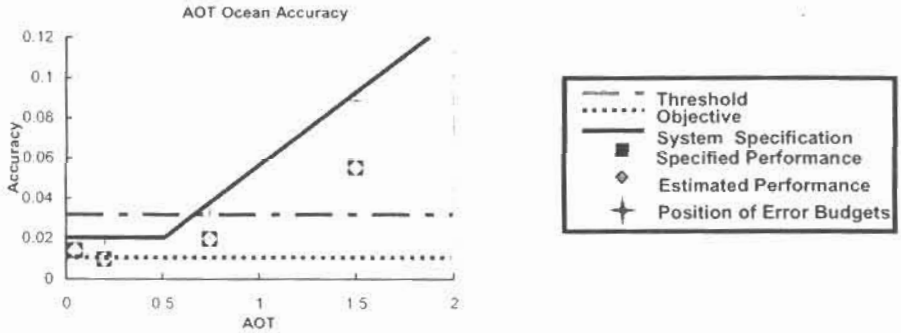
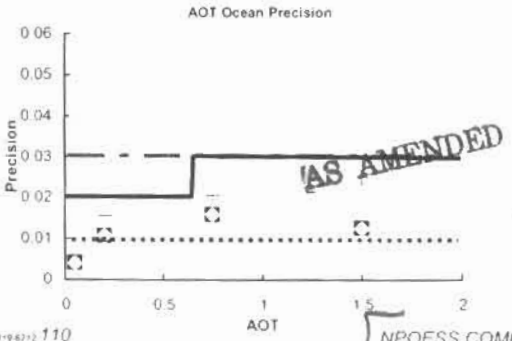
Aerosol Optical Thickness Over Ocean Moves Toward Objective For 99% of Cases





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- Comprehensive error budgets contain additional error sources not found in TDS

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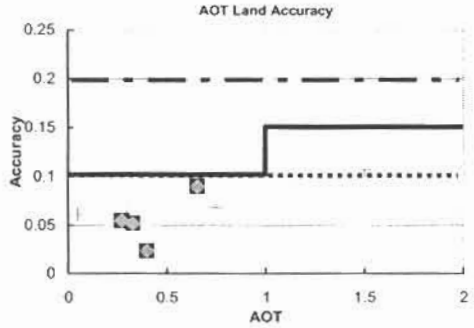
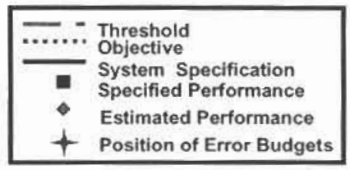
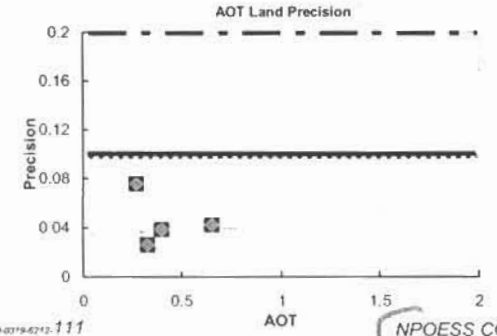
AOT System Specification Over Land: Near Objective Performance in Most Cases







- AOT relies on "Dark Pixel" method over land surfaces

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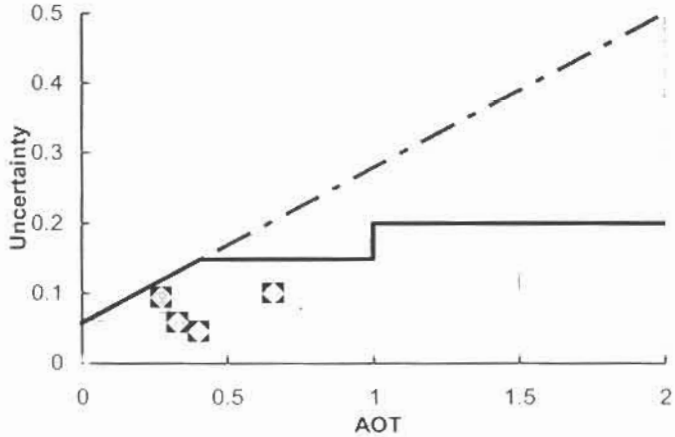
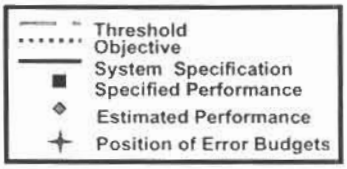
AOT Land Uncertainty





- Significantly better than threshold performance for majority of cases

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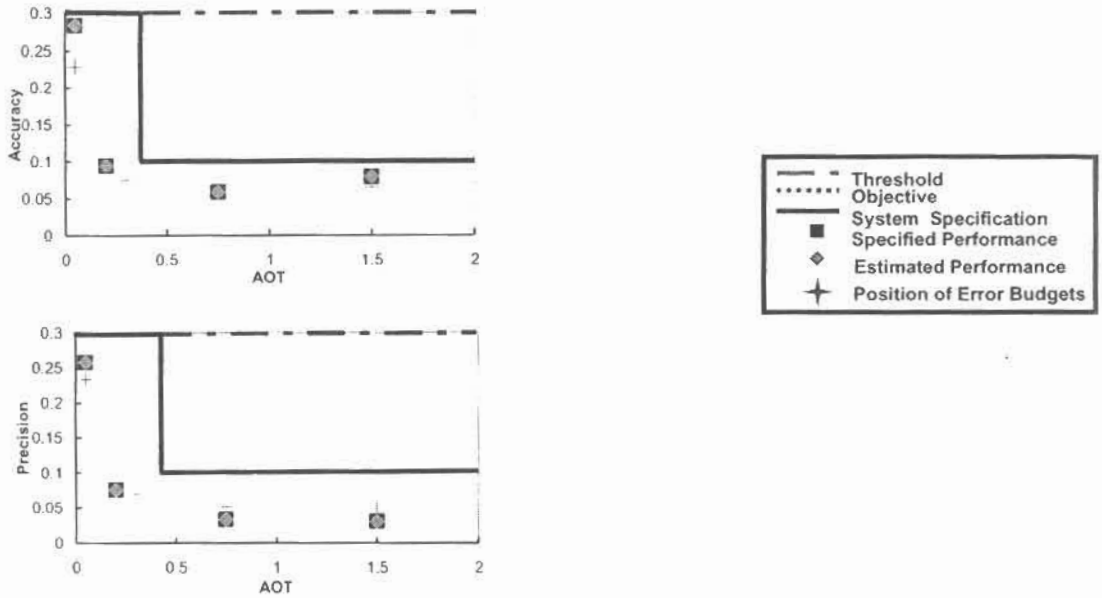
Aerosol Particle Size Over Ocean Substantially Better than Threshold For Larger AOTs



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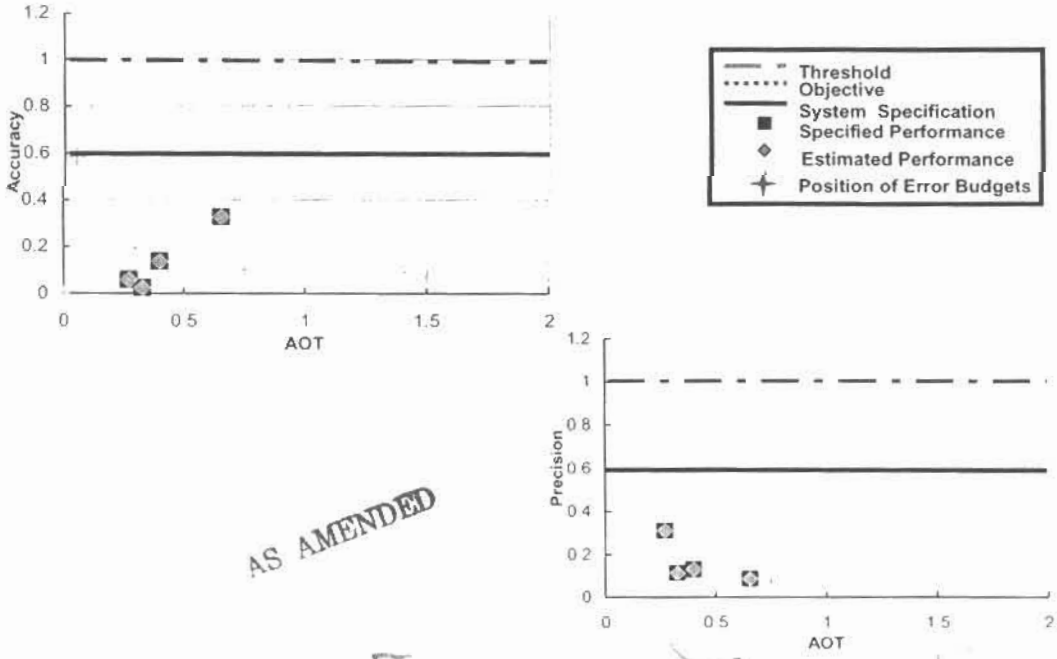
Aerosol Particle Size Over Land Better Than Threshold For Entire Measurement Range



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Suspended Matter Produces Objective Level Flags at High Resolution

Suspended Matter	Threshold	Objective	Spec	Pred Perf
a. HCS (km)	3 km	1 km	1.6 km	1.6 km
b. HRI	TBD	TBD	1.6 km	1.6 km
c. Vertical Cell Size	30 km (Total Column)	0.2 km	Total Col.	Total Col
e. Horiz Coverage	Global	Global	Global	Global
g. Measurement Range				
Detection Flags	N/A			
Suspended Matter present	Flag Suspended matter	Flag layers of SM	Flag Suspended matter	Flag Suspended matter
P(correct flag)	TBD	TBD for classes	90%	90%
Dust/sand present	N/A	Dust/sand	Dust/sand	Dust/sand
P(correct flag)	TBD	TBD for classes	85%	85%
Smoke present	N/A	smoke	smoke	smoke
P(correct flag)	TBD	TBD for classes	85%	85%
Volcanic ash present	N/A	Volcanic ash	Volcanic ash	Volcanic ash
P(correct flag)	TBD	TBD for classes	85%	85%
Sea Salt present	N/A	sea salt	sea salt	sea salt
P(correct flag)	TBD	TBD for classes	85%	85%
Smoke Concentration	N/A	TBD	Smoke concentration	Smoke concentration
Measurement Range	N/A	0 - 100 mic/m^3	0 - 1000 mic/m^3	0 - 1000 mic/m^3
Uncertainty	N/A	TBD	50%	50%
n. Swath Width	3000 km(TBR)	TBD	3000km	3000km

- Threshold Suspended Matter flag is produced, and in addition, five objective level flags and smoke concentration attributes are specified.
- Flag development process based on wide variety of SeaWiFS, AVHRR scenes, therefore no error budget has been derived.

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Cloud Base Height System Specification Set at Threshold Uncertainty Value

Cloud Base Height	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)	25	10	10	10
b. HRI	TBD	TBD	10	10
c. Horiz Coverage	Global	Global	Global	Global
e. Vertical Reporting Int.	Base of lowest cloud layer	Base of all distinct layers	Base of Highest Cloud and lowest cloud	Base of Highest Cloud and lowest cloud
f. Measurement Range	0-15 km	0-30 km	0-20 km	0-20 km
g. Measurement Uncertainty	2 km (TBR)	0.25 km	2 km	1.5 km
l. Minimum Swath Width	3000 km (TBR)	(TBD)	3000 km	3000 km

- Category III EDR achieves threshold uncertainty at objective level spatial performance
- Specification achieves base of highest and lowest cloud

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Binary Cloud Mask Driven by Worst Case Conditions Over Snow and Ice

Binary Cloud Mask	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
Binary map	N/A	N/A	pixel size	pixel size
b. HRI	TBD	TBD	pixel size	pixel size
e. Horiz Coverage	Global	Global	Global	Global
g. Measurement Range	0-1.	0-1.		
Binary Map	Cloudy/Not Cloudy	Cloudy/Not Cloudy	Cloudy/Not Cloudy	Cloudy/Not Cloudy
n. Probability of Correct Typing	TBD	TBD		
Day, ocean, optical depth < 0.5			92%	98%
Day, ocean, optical depth >0.5			99%	99%
Day, land, optical depth < 1			85%	96%
Day, land, optical depth > 1			93%	98%
Night, ocean, optical depth < 0.5			90%	98%
Night, ocean, optical depth > 0.5			96%	99%
Night, land, optical depth < 1			85%	93%
Night, land, optical depth > 1			90%	94%
m. Minimum Swath Width	3000 km (TBR)	TBD	3000 km	3000 km

SRD requirement is TBD

- Mask based on CLAVR, MODIS heritage with additional Raytheon derived tests
- Detailed stratified results further breakdown specified performances

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Cloud Cover Layers System Specification Achievable at Low Risk Based on Comprehensive Testbed Environment

Cloud Cover Layers			Threshold	Objective	Spec	Spec Perfo
a. HCS (km)						
f. Fractional Cloud Cover			25	2	25	23
b. HRI			TBD	TBD	25	25
d. Vertical Reporting Int.			Up to 4 Layers	0.1 km	4 Layers	5 Layers
e. Horiz Coverage			Global	Global	Global	Global
f. Vertical Coverage			0-20 km	0-30 km	0-20 km	0-20 km
g. Measurement Range			0-1.	0-1		
f. Fractional Cloud Cover			0-1.	0-1	0-1	0-1
h. Measurement Accuracy	Single layers	Nadir	0.10	0.05	0.07	0.02
		Edge of Scan	0.10	0.05	0.10	0.08
	Multiple Layers	Nadir	0.10	0.05	0.07	0.05
		Edge of Scan	0.10	0.05	0.10	0.09
i. Measurement Prec.	Single layers	Nadir	0.15	0.025	0.07	0.03
		Edge of Scan	0.15	0.025	0.15	0.12
	Multiple Layers	Nadir	0.15	0.025	0.07	0.05
		Edge of Scan	0.15	0.025	0.15	0.14
m. Minimum Swath Width			3000 km (TBR)	TBD	3000 km	3000 km

- Specification set at threshold for EOS, better than threshold at nadir

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Cloud Effective Particle Size Based on State-of-the-Art UCLA Algorithm Development

Cloud EPS	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Mod. worst case	50	10	25	25
2. Fine, at nadir	1	TBD	5	5
b. HRI	TBD	TBD	HCS	HCS
1. Mod. worst case	TBD	TBD	25	25
2. Fine, at nadir	TBD	TBD	5	5
d. Vertical Reporting Interval	1.0 km	0.3 km	Up to 4 layers	Up to 4 layers
e. Horiz Coverage	Global	Global	Global	Global
f. Vertical Coverage	0-20 km	0-30 km	0 - 20 km	0 - 20 km
g. Measurement Range	0-50 microns	TBD	0-50 microns	
h. Measurement Accuracy (moderate HCS product)	>10% or 4 um	> 5% or 2um		
OD ≤ 1				
daytime water cloud			5.5 μm	5.0 μm
daytime ice cloud			8 μm	7.9 μm
OD > 1				
daytime water cloud			2 μm	1.35 μm
daytime ice cloud			3.5 μm	2.96 μm
nighttime ice cloud			4 μm	2.8 μm
nighttime water cloud			4 μm	3 μm
i. Measurement Precision (moderate HCS product)	> of 5% or 2um	2%		
OD ≤ 1				
daytime water cloud			1.0 μm	0.70 μm
daytime ice cloud			1.5 μm	0.72 μm
OD > 1				
daytime water cloud			1 μm	0.5 μm
daytime ice cloud			1.5 μm	0.72 μm
nighttime ice cloud			2 μm	1.6 μm
nighttime water cloud			2 μm	2 μm
o. Measurement Uncertainty (fine HCS Product)	>of 10% (TBR) or 2um (TBR)	TBD		
OD ≤ 1				
daytime water cloud			5.5 μm	5 μm
daytime ice cloud			12 μm	11 μm
OD > 1				
daytime water cloud			2.5 μm	2 μm
daytime ice cloud			4 μm	3.9 μm
nighttime ice cloud			4 μm	3. μm
nighttime water cloud			4 μm	3. μm
j. Long term stability	2%	1%	2%	2%
n. Minimum Swath Width	3000 km (TBR)	TBD	3000 km	3000 km

- Stratification by optical depth, cloud type and day or night at two different spatial resolutions
- Fine resolution HCS specified at 5km
- Fine resolution uncertainty specified at 4.5μm for OD > 1

"Nadir HCS and measurement uncertainty thresholds for all fine products that are for augmented applications only are either TBR or TBD. These requirements should not be allowed to significantly drive either the sensor or algorithm designs."

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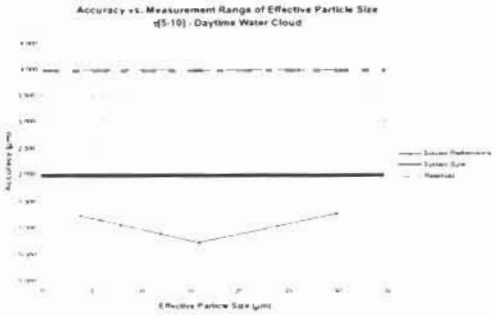
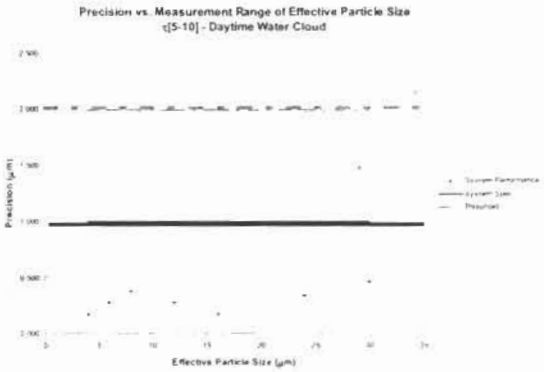
Cloud Effective Particle Size (CEPS) Shows Objective Level Performance

EPS accuracy and precision across measurement range for the 5 –10 optical depth range





CEPS better than threshold for daytime water clouds

- Comprehensive stratified results are given in the System Verification Results

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Cloud Top Height Rigorously Tested to Address Multi-level Objective

Cloud Top Height	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Mod. worst case	25	10	25	25.00
2. Fine, at nadir	5	TBD	5	5.00
b. HRI	TBD	TBD		
1. Mod. worst case			25	25.00
2. Fine, at nadir			5	5.00
c. Horiz Coverage	Global	Global	Global	Global
e. Vertical Reporting Interval	Top of Highest Layer	Top of all Distinct Layers	Up to 4 layers	4 layers
f. Measurement Range	0-20 km	TBD	0 - 20 km	0 - 20 km
g. Measurement Accuracy (moderate HCS product)				
1. Cloud layer optical thickness > 1.0	1 km (TBR)	0.3 km		
Water Cloud- Day			0.50	0.35
Water Cloud- Night			1.00	0.50
Ice Cloud (Day and Night)			1.0 km	0.7 km
1. Cloud layer optical thickness 0.1 < OT < 1.0	1 km (TBR)	0.3 km	2.00	1.00
2. Cloud layer optical thickness <= 0.1	2 km	0.3 km	2.00	1.00
h. Measurement Precision (moderate HCS product)	0.3 km	0.15 km	0.3 km	0.25 km
n. Measurement Uncertainty (fine HCS Product)				
1. Water Clouds	0.5 km (TBR)			
A. Cloud layer optical thickness > 1.0 (TBR)				
Water Cloud - day			0.50	0.40
Water Cloud- Night			1.00	0.70
A. Cloud layer optical thickness 0.1 < OT < 1.0 (TBR)				
Water Cloud- Day			2.00	1.40
Water Cloud- Night			2.00	1.00
B. Cloud layer optical thickness <= 0.1 (TBR)				
Water Cloud- Day			2.00	1.40
Water Cloud- Night			2.00	1.00
2. Ice Cloud (Day and Night)	1 km (TBR)		1.00	0.80
i. Long term stability	0.2 km	0.1 km	0.2 km	0.2 km
m. Minimum Swath Width	3000 km (TBR)	TBD	3000 km	3000 km

"Nadir HCS and measurement uncertainty thresholds for all fine products that are for augmented applications only are either TBR or TBD. These requirements should not be allowed to significantly drive either the sensor or algorithm designs."

Raytheon Stratification break points set at OD = 1.0
System specification generally achieves threshold level performance

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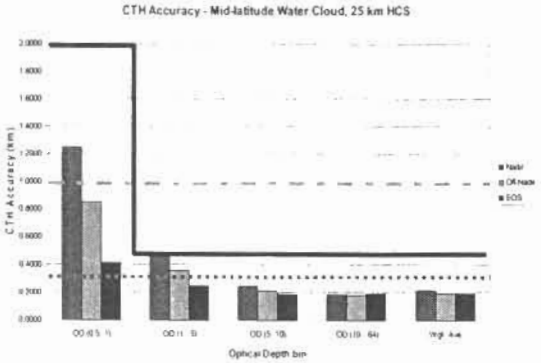
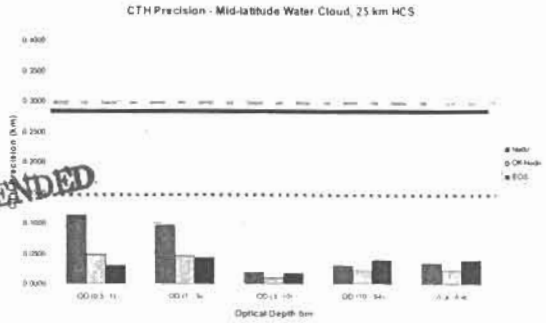
Cloud Top Height Stratified Specification



- **CAIV analysis shows compelling benefit for Raytheon specification at low optical depths**



- **Weighted average performances better than objective requirement for this cloud type.**
- **System Verification Report contains detailed performance for each stratification in the specification**

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Cloud Top Pressure Designed to "Nest" With Other Cloud Top Parameters

Cloud Top Pressure	Threshold	Objective	Spec	Pred Perf
a. HCS (km)				
1. Mod, worst case	15	10	12.5	12.5
2. Fine, at nadir	5	TBD	5	5
b. HRI	TBD	TBD		
1. Mod, worst case			12.5	12.50
2. Fine, at nadir			5	5
c. Horizontal Coverage	Global	Global	Global	Global
d. Measuremetn range	50-1050mb	(TBD)	50 - 1050mb	50 - 1050mb
e. Measurement Accuracy (moderate HCS product)				
1. Surface - 3 km	100 mb	30 mb		
OD ≤ 1				
Daytime Water Cloud			100	90
Nighttime Water Cloud			100	80
OD > 1				
Daytime Water Cloud			40	30
Nighttime Water Cloud			70	60
2. 3-7 km	75 mb	22 mb		
OD ≤ 1			65	55
OD > 1			40	30
3. >7 km	50 mb	15 mb	30	20
f. Measurement Precision (moderate HCS product)				
1. Surface - 3 km	50 mb	10 mb	25	15
2. 3-7 km	38 mb	7 mb	20	10
3. >7 km	25 mb	5 mb	13	7
f. Measurement Uncertainty (fine HCS Product)	50 mb (TBR)	TBD		
1. Surface - 3 km				
OD ≤ 1				
Daytime Water Cloud			130	125
Nighttime Water Cloud			100	80
OD > 1				
Daytime Water Cloud			40	30
Nighttime Water Cloud			80	65
2. 3-7 km				
OD ≤ 1			70	35
OD > 1			45	35
3. >7 km			30	20
g. Long term stability				
1. Surface - 3 km	10 mb (TBR)	3 mb	10 mb	8 mb
2. 3-7 km	7 mb (TBR)	2 mb	7 mb	5 mb
3. >7 km	5 mb (TBR)	1 mb	5 mb	3 mb
k. Minimum Swath Width	3000 km (TBR)	TBD	3000 km	3000 km

- Cloud top EDRs use same algorithm approach and same error budget tree
- Beats threshold for all accuracy and precision requirements

"Nadir HCS and measurement uncertainty thresholds for all fine products that are for augmented applications only are either TBR or TBD. These requirements should not be allowed to significantly drive either the sensor or algorithm designs."

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Cloud Top Temperature Beats Threshold Level Performance

Cloud Top Temperature	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Mod, worst case	25	10	25 km	25 km
2. Fine, at nadir	5 (TBR)	TBD	5 km	5 km
b. HRI	TBD	TBD	HCS	HCS
1. Mod, worst case	25	10	25 km	25 km
2. Fine, at nadir	5 (TBR)	TBD	5 km	5 km
c. Horiz Coverage	Global	Global	Global	Global
d. Measurement Range	180-310K	TBD	175-310K	175-310K
e. Measurement Accuracy (moderate HCS product)				
1. Cloud layer optical thickness > 1.0	3K	1.5K		
Water Cloud-Day			2K	1.6 K
Water Cloud-Night			3K	2.8 K
Ice Cloud (day and Night)			3K	2.8 K
2. Cloud layer optical thickness 0.1 < OT <= 1.0	3K	1.5K	6K	5.3 K
2. Cloud layer optical thickness <= 1.0	6K	TBD	6K	5.3 K
f. Measurement Precision (moderate HCS product)	1.5K	0.5K	1.5 K	1.0 K
g. Long Term Stability	1 K	0.1 K	1 K	1 K
f. Measurement Uncertainty (fine HCS Product)	5K (TBR)	2K		
Water Cloud			3K	2K
Ice Cloud			5K	3K
k. Minimum Swath Width	3000 km (TBR)	TBD	3000 km	3000 km

- CAIV analysis shows compelling benefit for Raytheon specification at low optical depths

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Surface Albedo Optimized Algorithm Operates at High Spatial Resolution

Albedo	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Mod, worst	4	0.5	1.6	1.6
2. Fine, nadir	1	0.5	0.75	0.75
b. HRI	TBD	TBD		
1. Mod, worst			1.6	1.6
2. Fine, nadir			0.75	0.75
c. Horiz Coverage	Global	Global	Global	Global
d. Measurement Range	0-1	0-1	0-1	0-1
e. Accuracy				
Moderate	0.05	0.0125	0.025	
f. Precision				
Moderate	0.02	0.01	0.02	0.02
l. Uncertainty				
Fine	0.03	TBD	0.03	0.03
g. Long-term Stability	0.02	0.01	0.01	0.0075
k. Swath width	3000	TBD	3000	3000

- Obtains threshold for all surface types without requiring direct aerosol retrieval which is problematic for bright surfaces

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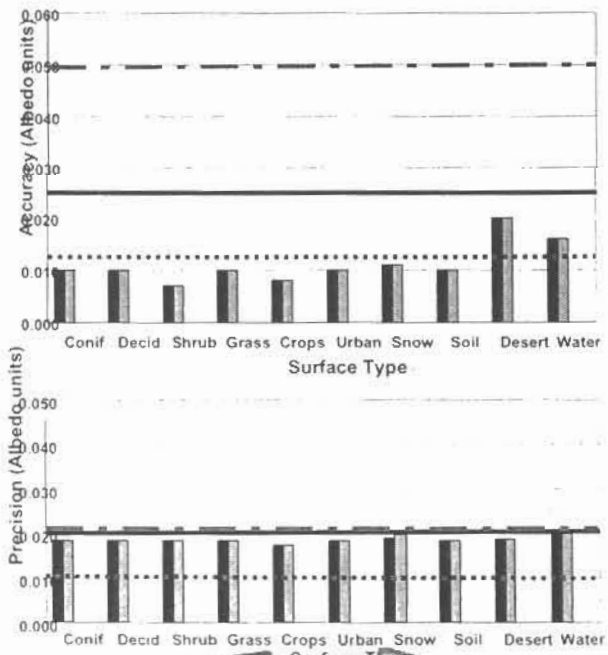
Surface Albedo Accuracy Is Easily Attained Across Measurement Range



Albedo case illustrated:

- Edge of Scan
- Solar Zenith = 30 degrees

Threshold
Objective
System Specification
Specified Performance
Estimated Performance
Position of Error Budgets

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Land Surface Temperature Achieves Threshold Level Performance

Land Surface Temperature	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Nadir	1	TBD	0.75	0.75
2. Intermediate swath			1.3	1.3
3. Worst case	4	1	1.6	1.6
b. HRI	TBD	TBD		
1. Nadir	1	TBD	0.75	0.75
2. Intermediate swath			1.3	1.3
3. Worst case	4	1	1.6	1.6
c. Horiz Coverage	Land	Land	Land	Land
d. Measurement Range	213-343K	213-343K	213-343K	213-343K
f. Accuracy (K) Worst case	2.5	1	2.4	2.1
g. Precision (K)				
1 Intermediate swath	0.50	0.025	0.50	0.42
2. worst case	N/A	N/A	0.52	0.43
e. Uncertainty (K) nadir	2.5	TBD	2.50	2.14
k. Swath width				
1. Swath width (Intermediate)	1700	TBD	2000	2000
2. Swath width (Worst case)	N/A	N/A	2000	2000

- Swath width extended out to 2000km
- Benefits from SST requirements but achieves threshold due to emissivity errors

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NDVI is at Objective Level

Vegetation Index	Threshold	Objective	Spec	Pred Perf	
a. HCS (km)					
1. Mod, worst	4	1	0.8	0.8	Objective Level
2. Fine, nadir	0.5	0.25	0.375	0.375	Near Objective Level
b. HRI	TBD	TBD			
1. Mod, worst			0.8	0.8	
2. Fine, nadir			0.375	0.375	
c. Horiz Coverage	Land	TBD	Land	Land	
d. Measurement Range					
NDVI	-1 to +1	-1 to +1	-1 to +1	-1 to +1	
EVI	TBD	TBD	-1 to +1	-1 to +1	
e. Accuracy					
Mod HCS NDVI	0.05	0.03	0.016	0.006	Objective Level
f. Precision					
Mod HCS NDVI	0.04	0.02	0.020	0.013	Objective Level
I. Uncertainty					
Fine HCS NDVI	0.07	TBD	0.020	0.014	Objective Level
EVI	TBD	TBD	0.110	0.100	
g. Long-term Stability					
NDVI	0.04	0.04	0.01	0.008	Objective Level
k. Swath width	3000	TBD	3000	3000	

- Fine spatial requirement satisfied at near objective level by use of imagery-like resolution bands

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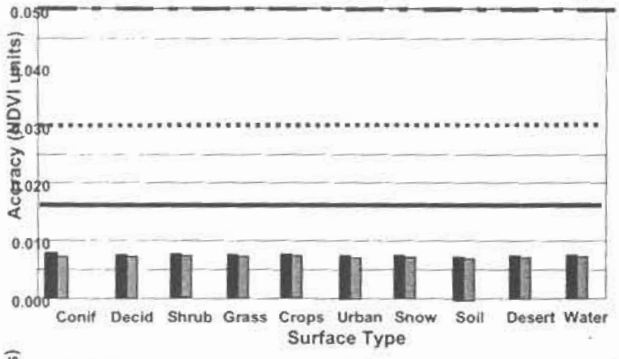
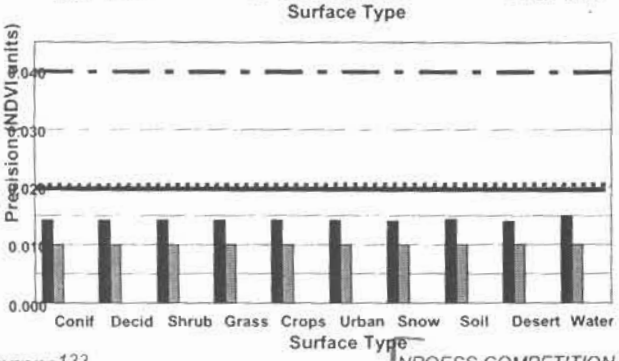
TOA NDVI Accuracy Performance Beats Objective



- Accuracy error is dominated by fixed allocations for misregistration and MTF



TOA NDVI Example,
- Edge of Scan,
- Solar Zenith = 30 degrees

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Snow Cover/Depth EDR Beats Threshold

Snow Binary Map	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Clear-daytime (worst case) binary flag	N/A	N/A	0.8	0.8
2. Clear-daytime (at nadir)	0.5 (TBR)		0.4	0.4
b. HRI	TBD	N/A	HCS	HCS
d. Horiz Coverage	Land	N/A	Land	Land
f. Meas Range	Snow/No snow	N/A	Snow/No snow	Snow/No snow
g. Prob Correct Typing				
1. Clear-daytime	90% (TBR)	N/A	95%	97%
k. Swath width	3000 (TBR)	N/A	3000	3000

Snow Fraction	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Clear-daytime (worst case)	1.3 (TBR)	1	1.6	1.6
2. Clear-daytime (at nadir)	N/A	N/A	0.8	0.8
3. Cloudy and/or nighttime	12.5	1	40	CMIS
b. HRI	TBD	TBD		
1. Clear-daytime (worst case)			1.6	1.6
2. Clear-daytime (at nadir)			0.8	0.8
3. Cloudy and/or nighttime			40	CMIS
d. Horiz Coverage	Land	Land/Ice	Land	Land
f. Meas Range	N/A	0-1	0-1	0-1
n. Meas Uncertainty	N/A	10%	0.1	0.1
k. Swath width	3000 (TBR)	TBD	3000	3000

- Imagery-like resolution bands create high resolution binary flag
- Achieving snow fraction is an objective requirement

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Surface Type EDR Has Spatial Resolution to Objective Level

Surface Type	Threshold	Objective	Spec	Pred Perf
a. HCS (km)	20	1	1	1
b. HRI	TBD	TBD	1	1
c. Horiz Coverage	Land	Land	Land	Land
d. Measurement Range				
Surface Type	17 IGBP	17 IGBP	17 IGBP	17 IGBP
Vegetation Cover	N/A	0-100%	0-100%	0-100%
e. Accuracy	N/A	2%	20%	20%
f. Precision	N/A	0.10%	10%	10%
g. Correct Typ. Prob.	70%	TBD	88%	88%
k. Swath width	3000	TBD	3000	3000

- **No error budget has been derived for this EDR**
- **Classification updated on quarterly basis from time series analysis**
- **Instantaneous vegetation cover estimate is draped onto classification**

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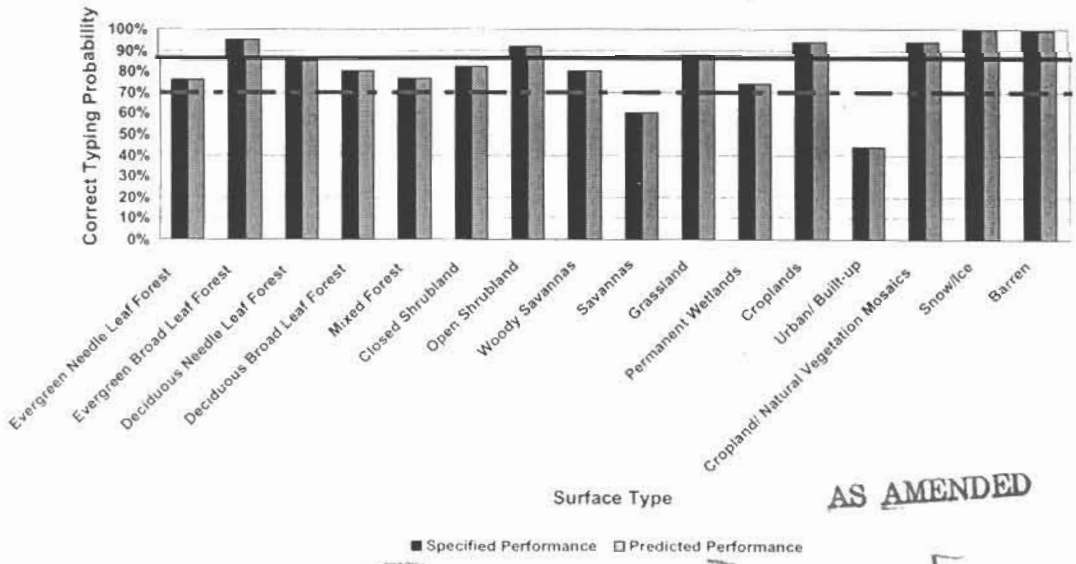
Surface Type Beats 70% Threshold Globally and For 15 of 17 Types

Overall System Spec = 88%, with 95% confidence interval of <2%

Surface Type Correct Typing Probability, Global



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Ocean Currents Satisfied to Objective Level by Use of SST Data

Ocean Currents	Threshold	Objective	Spec	Pred Perf
a. HCS (km)	4 km	1 km		
1. Intermediate swath			1.3 km	1.3 km
2. Worst case			1.6 km	1.6 km
b. HRI	TBD	TBD		
1. Intermediate swath			1.3 km	1.3 km
2. Worst case			1.6 km	1.6 km
c. vertical cell size	5 m	1m	upper layer	upper layer
e. Horiz Coverage	oceans	oceans	oceans	oceans
f. vertical coverage	0 – 10 m	0 – 30 m	upper layer	upper layer
g. Measurement Range				
1 Speed	0 – 5 m/s	0 – 5 m/s	0.01 - 5.0 m/s	0.01 - 5.0 m/sec
2 direction	0 – 360 deg.	0 – 360 deg.	0 - 360 deg.	0 - 360 deg.
h. Accuracy				
1. Speed	0.25 m/s	0.1 m/s	0.1 m/s	.03 m/s
2. Direction	15 deg	5 deg.	15 deg	15 deg.
i. Precision				
1. Speed	0.25 m/s	0.1 m/s	0.1 m/s	0.03 m/s
2. Direction	15 deg.	5 deg.	15 deg.	15 deg.
k. Swath width	1700 km (TBR)	3000 km (TBR)		
1. Intermediate			1700 km	1700 km
2 Worst case			3000 km	3000 km

- **Category III EDR**
- **Spatial resolution, accuracy, precision and swath are all achieved to objective level by use of SST (Category I)**

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Fresh Water Ice: Better Than Threshold Performance For Ice Edge Location

FW Ice	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. At nadir	2 (TBR)	TBD	0.8	0.8
2 Worst case	3.2 (TBR)	2.6	3.2	3.2
b HRI	TBD	TBD		
1. At nadir			0.8	0.8
2. Worst case			3.2	3.2
c. Horiz Coverage	Fresh Water	Threshold	Fresh Water	Fresh Water
d. Meas Range	1/10 to 10/10	0/10 to 1/10	1/10 to 10/10	1/10 to 10/10
e. Meas Uncertainty				
1. Ice Edge (km)	10	5		
Nadir			0.40	0.35
EOS			1	0.9
2 Ice Concentration	1/10 absolute	10% of true value	0.10	0.10
k. Swath width	3000 (TBR)	TBD	3000	3000

- **Nadir HCS specification is much better than threshold**
- **Performance is unstratified in system specification**
- **Fresh Water Ice algorithm used by Imagery ARR shown above**

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Ice Surface Temperature Objective Performance Courtesy of SST Requirements

IST	Threshold	Objective	Spec	Pred Perf
a. HCS (km)	30	10	10	10
b. HRI	TBD	TBD	10	10
c. Horiz Coverage	Ice covered land/water	Ice covered land/water	Ice covered land/water	Ice covered land/water
d. Measurement Range	213-275K	213-293K	213-275K	213-275K
e. Uncertainty (TBR K)	1	TBD	0.50	0.35
k. Swath width	1700	TBD	3000km	3000km

Objective Level

Objective Level

- EDR delivered at objective HCS.
- Used internally at higher spatial resolution to support other EDRs

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Littoral Sediment Transport Attains Threshold Performance

Littoral Sediment Transport	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)	1.3 km (TBR)	0.1 km (TBR)	1.3 km	1.3 km
b. HRI	1.3 km (TBD)	0.1 km (TBD)	1.3 km	1.3 km
c. Horiz Coverage	Rivers, ocean coastal regions	Rivers, ocean coastal regions	Ocean coastal regions	Ocean coastal regions
d. Measurement Range	(TBD)	(TBD)	0-3 m change in depth per day	0-3 m change in depth per day
f. Accuracy	Greater of 30% and (TBD)	Greater of 15% and (TBD)	30%	28%
g. Precision	Greater of 40% and(TBD)	Greater of 15% and (TBD)	40%	38%
k. Swath width	1700 km (TBR)	3000 km (TBD)	1700 km	1700 km

- Performs to threshold only under limited geophysical conditions specified at the system level
- Category III meets threshold

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Net Heat Flux System Specification

NHF	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)	20 km	5 km	20 km	20 km
b. HRI	(TBD)	(TBD)	20 km	20 km
c. Horiz Coverage	Oceans	Oceans	oceans	oceans
d. Measurement Range	0 – 1000 W/m2	0-2000 W/m2	0 to 2000 W/m2	0 to 2000 W/m2
f. Accuracy	10 W/m2	1 W/m2	10 W/m2	10 W/m2
g. Precision	5 W/m2	1 W/m2	25 W/m2	25 W/m2
k. Swath width	3000 km (TBR)	3000 km (TBD)	3000km	3000 km

- Category III EDR
- Precision fails threshold due to inaccuracies in ancillary/auxiliary data

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Ocean Color Specification Meets Threshold For 99% of Ocean Waters

Ocean Color	Threshold	Objective	Spec	Pred Perf
a. HCS (km)				
1. Mod. worst	2.6 km	1 km	2.6	2.3 km
2. Fine, nadir	1 km (TBR)	(TBD)	0.75 km	0.75 km
3. Fine, worst	1.3 km	0.1 km	1.3	1.3 km
b. HRI	(TBD)	(TBD)		
1. Mod. worst			2.6	2.3 km
2. Fine, nadir			0.75 km	0.75 km
3. Fine, worst			1.3	1.3 km
c. Horiz Coverage	oceans	oceans	oceans	oceans
d. Measurement Range	0.05 – 50 mg/m3	0 – 100 mg/m3	0.05-50 mg/m3	0.05 - 50 mg/ m3
e. Accuracy (moderate)	30% or (TBD) mg/m3	30% or TBD mg/m3		
chl < 1.0 mg/m3			15%	11%
1.0 < chl < 10 mg/m3			30%	27%
10 mg/m3 < chl			50%	42%
f. Precision (moderate)	20% or (TBD) mg/m3	10% or TBD mg/m3		
chl < 1.0 mg/m3			20%	18%
1.0 < chl < 10 mg/m3			30%	28%
10 mg/m3 < chl			50%	47%
k. Uncertainty (fine)	30% or (TBD) mg/m3	TBD		
chl < 1.0 mg/m3			20%	16%
1.0 < chl < 10 mg/m3			30%	27%
10 mg/m3 < chl			40%	37%
j. Swath width	1700 km (TBR)	TBD	1700 km	1700 km

- Accuracy, precision and uncertainty are out of threshold for high chlorophyll concentrations due to bio-physical limitations in bio-optical algorithm
- CAIV analysis shows compelling benefit to Raytheon precision specification

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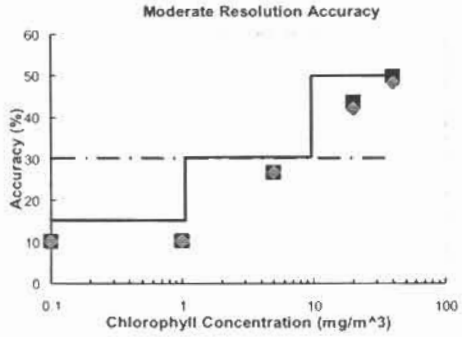
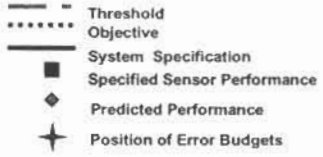
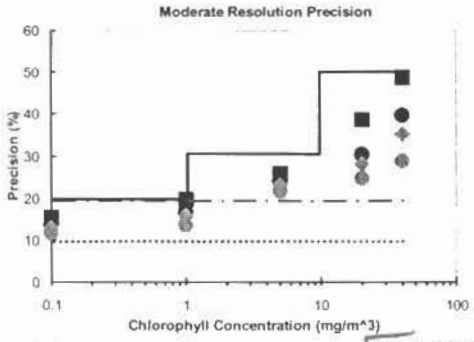
Ocean Color Specification Derived From CAIV Best Value Trade Off





- CAIV analysis shows compelling benefit for Raytheon specification for large chlorophyll concentrations



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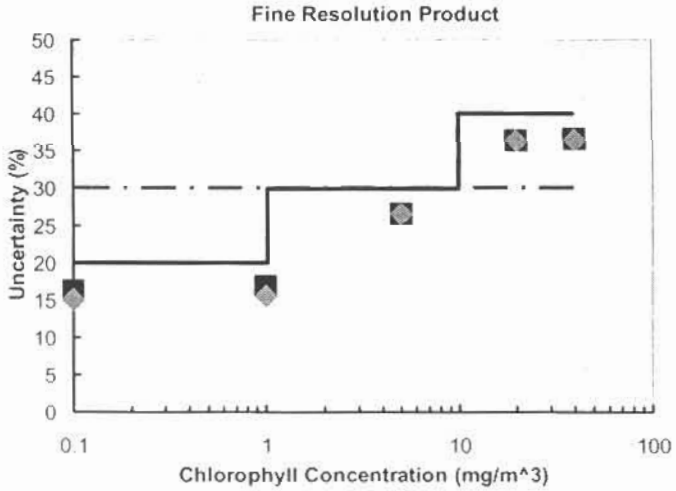
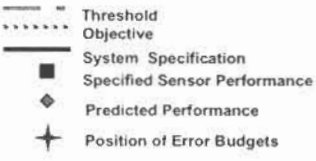
Ocean Color Nadir Fine Requirement Meets Threshold Over Most of Measurement Range





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"Nadir HCS and measurement uncertainty thresholds for all fine products that are for augmented applications only are either TBR or TBD. These requirements should not be allowed to significantly drive either the sensor or algorithm designs."

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Sea Ice Age and Edge Motion: Better than Threshold Specification

Ice Age	Threshold	Objective	Spec	Pred Perf
a. HCS (km)	3	0.1	0.8	0.8
b. HRI	TBD	TBD	0.8	0.8
c. Horiz Coverage	Oceans	Oceans	Oceans	Oceans
d. Measurement Range				
1. Ice Age Classes	First-Year, Multi-Year (TBR)	New, Young, First-Year, Old (TBR)	New/Young, First-Year, Multi-year	New/Young, First-Year, Multi-year
2. Ice Motion (km/day)	0-50	0-50	0-50	0-50
e. Prob Correct Typing (Age)	70%	90%		
First year from Multi-year			80%	82%
New/Young from First year			70%	72%
New/Young from Multi-year			70%	72%
f. Meas Unc (km/day - Motion)	1	0.1	1	0.8
k. Swath width	3000 (TBR)	TBD	3000	3000

- Spatial resolution approaches objective
- Algorithm developed here used in Imagery ARRs
- System recognizes three ice types

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Mass Loading Meets Threshold Over Measurement Range

Mass Loading	Threshold	Objective	Spec	Pred Perf
a. HCS (km)				
1. Mod, worst	2.6 km	1 km	2.6 km	2.3 km
2. Fine, nadir	1 km (TBR)	(TBD)	0.75 km	0.75 km
3. Fine, worst	1.3 km	.25 km	1.3 km	1.3 km
b. HRI	(TBD)	(TBD)	HCS	HCS
c. Horiz Coverage				
1. Moderate	> 370 km from coastline	> 370 km from coastline	oceans	oceans
2. Fine	<370 km from coastline	<370 km from coastline	oceans	oceans
d. Vertical cell size	surface layer (TBD)	(TBD)	surface layer	surface layer
e. measurement range	(TBD)	0-100 mg/l	0.05 - 60 mg/l	0.05 - 60 mg/l
f. Accuracy				
1. Moderate	> of 30% or (TBD)	0.1 mg/l	25%	16%
g. Precision				
1. Moderate	(TBD)	0.1 mg/l	25%	19%
h. uncertainty				
1. fine	> of 30%(TBR) or (TBD)	(TBD)	30%	25%
k. Swath width	1700 km (TBR)	TBD	1700 km	1700 km

- Category III EDR

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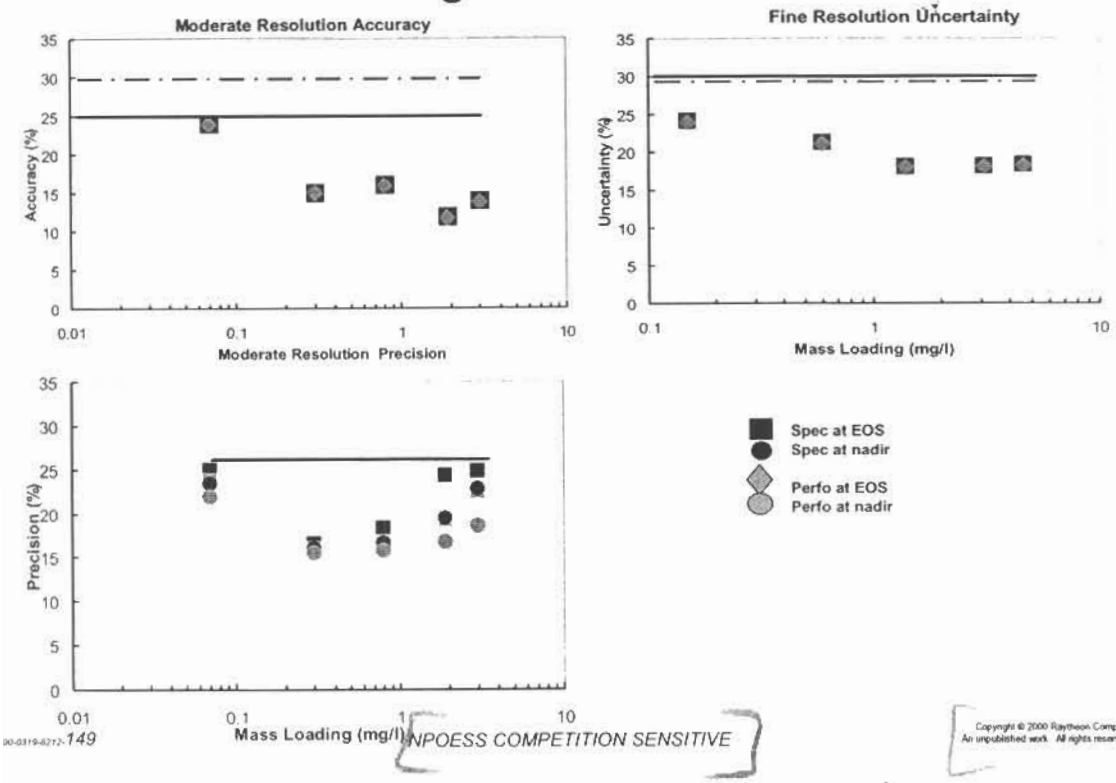
Mass Loading Better Than Threshold



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Active Fires EDR Set to Threshold Performance

Active Fires	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Nadir	1	0.5	0.75	0.75
2. Worst case	2	0.5	1.6	1.6
b. HRI	gapless or near gapless	gapless or near gapless		
1. Nadir			0.75	0.75
2. Worst case			1.6	1.6
c. Horiz Coverage	Land	Land	Land	Land
d. Measurement Range				
1. Subpixel Avg. Temp.	800-1200K	800-1200	800-1200	800-1200
2. Subpixel Area	(100m)^2 to 50m times GSDscar	(50m)^2 to 100m times GSDscar	(100m)^2 to 50m times GSDscar	(100m)^2 to 50m times GSDscar
e. Uncertainty				
1. Subpixel Avg. Temp.	50 K	25 K	50 K	50 K
2. Subpixel Area	30%	15%	30%	30%
f. Swath width	3000	TBR	3000	3000

- No Stratification has been derived
- Error budgets have not been derived

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Total Precipitable Water System Specification Set by SST Requirement

Precipitable Water	Threshold	Objective	Spec	Spec Perfo
a. HCS (km)				
1. Nadir	1	1	0.75	0.75
b. HRI	TBD	TBD	0.75	0.75
c. Horiz Coverage	Global	Global	Global	Global
d. Measurement Range	0-75mm	0-100mm	0-100mm	0-100mm
e. Uncertainty (TBR %)	TBD	TBD		
TPW > 5 mm				
CLEAR, LAND			30%	26%
CLEAR, OCEAN			20%	16%
CLOUD			32%	32%
TPW < 5 mm				
CLEAR			1.5 mm	1.1 mm
CLOUD			1.5 mm	1.5 mm
k. Swath width	3000	TBD	3000	3000

- All SRD uncertainties were TBD

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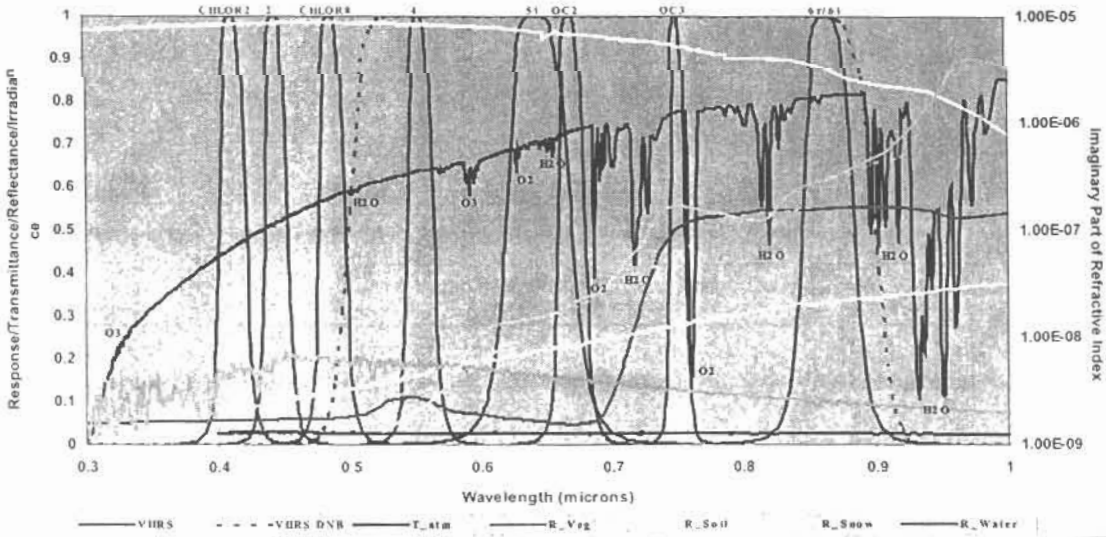
VIS/NIR Bands Combine Ocean and Land Utility into a Single Sensor

Spectral Band Response, Atmospheric Transmittance, Surface Reflectance, Solar Irradiance, and Imaginary Part of Refractive Index for Water and Ice, Visible (VIS) and Near Infrared (NIR)



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Bands Rejected in CAIV Analysis Do Not Address VIIRS' Operational Mission

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	MODIS		Nadir HCS (m)		
Band	l(nm)	AVHRR	MODIS	VIIRS	CAIV Rationale
LLL	500-900	na	na	750	Terminator/moonlight "constant contrast" imagery
1	620-670	1,000	250	375	Daytime imagery, NDVI, red land band
2	841-876	1,000	250	375	NDVI, snow cover, NIR land band
3	459-479	na	500	750 (d)	Blue land atmospheric correction (dual)
4	545-565	na	500	750 (d)	Green land cover classification, snow cover
5	1230-1250	na	500	750	Cloud properties over snow
6	1630-1650	1,000 day	500	375/750	Snow/cloud discrimination
7	2110-2.160	na	500	750	Aerosols over land
8	405-420	na	1,000	750	Ocean color, case 2, accessory pig., smoke
9	438-448	na	1,000	750	Ocean color/chlorophyll for low concentrations
10	483-493	na	1,000	750	Ocean color/chlorophyll for high concentrations
11	526-536	na	1,000	na	Rejected *(Not part of IOCCG)*
12	546-556	na	1,000	750	Ocean color/chlorophyll hinge point
13	662-672	na	1,000	750	Ocean color/atmospheric correction
14	673-683	na	1,000	na	Rejected *(Ocean color/fluorescence research product)*
15	743-753	na	1,000	750	Ocean color/atmospheric correction
16	862-877	na	1,000	750 (d)	Ocean color/atmospheric correction
17	890-920	na	1,000	na	Rejected *(Water vapor research product)*
18	931-941*	na	1,000	na	Rejected *(Water vapor research product)*
19	915-965	na	1,000	na	Rejected *(Water vapor research product)*

* *Rejected due to effect on VIS/NIR optical extent*

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MWIR/TIR Bands Rejected in CAIV Analysis Do Not Address VIIRS' Operational Mission

	MODIS		Nadir HCS (m)		
Band	l(nm)	AVHRR	MODIS	VIIRS	CAIV Rationale
20	3.66-3.84	1,000 night	1,000	375/750	Surface/cloud temperature, stratus discrimination
21	3.93-3.99	na	1,000	750	Surface temperature
22	3.93-3.99	na	1,000	750 (d)	Fire temperature
23	4.02-4.08	na	1,000	750 (incl)	Surface temperature
24	4.43-4.50	na	1,000	na	Rejected *(Atmospheric temperature; Precip. Water is Cat.B*
25	4.48-4.55	na	1,000	na	Rejected *(Atmospheric temperature)*
26	1.36-1.39	na	1,000	750	Cirrus detection/removal
27	6.53-6.90	na	1,000	na	Rejected *(Water vapor profile, achieved by CrIS)*
28	7.18-7.48	na	1,000	na	Rejected *(Water vapor profile, achieved by CrIS))*
29	8.40-8.70	na	1,000	na	Rejected Cloud phase, total precip. water, susp. matter
30	9.58-9.88	na	1,000	na	*(Ozone, achieved by OMPS/CrIS)*
31	10.78-11.28	1,000	1,000	750	Surface/cloud temperature
32	11.77-12.27	1,000	1,000	375/750	Surface/cloud temperature
33	13.18-13.48	na	1,000	na	Rejected *(Cloud-top altitude--CO^2, achieved by CrIS)*
34	13.48-13.78	na	1,000	na	Rejected *(Cloud-top altitude--CO^2, achieved by CrIS)*
35	13.78-14.08	na	1,000	na	Rejected *(Cloud-top altitude--CO^2, achieved by CrIS)*
36	14.08-14.38	na	1,000	na	Rejected *(Cloud-top altitude--CO^2, achieved by CrIS)*

Note that VIIRS footprint growth is 2x track and scan out to 3,000 km EOS; MODIS and AVHRR footprint growth are 6x scan and 2x track for comparable swath

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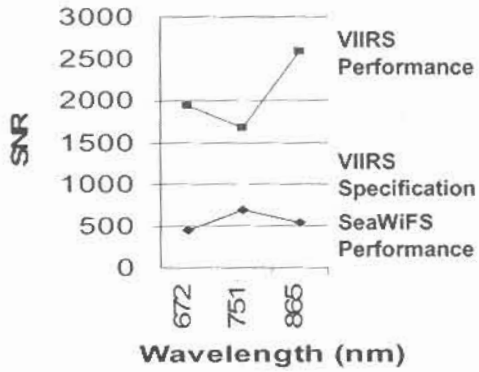
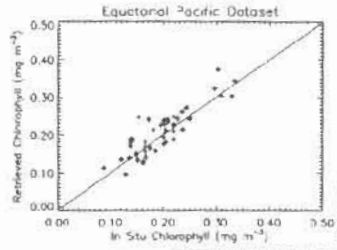
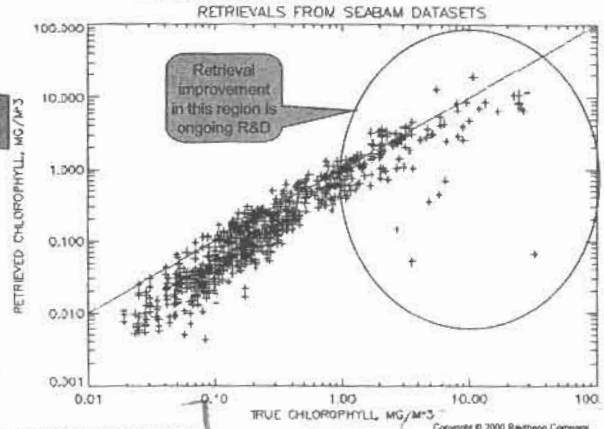
Bio-Optical Algorithm, Information Content, Radiometry Determine Ocean Color/Chlorophyll Quality

SNR calculated at VIIRS Ltyp





Improved bio-optical algorithm allocations (e.g., 18% uncertainty) achieved when pigment packaging is parameterized



- High spatial resolution
  - VIIRS nadir HSR 75% of MODIS
  - Scan growth rate 66% of MODIS at 2,000 km EOS
- Permits 3x3 NIR-band pixel aggregation
- Achieves 1,000<SNR<2,000

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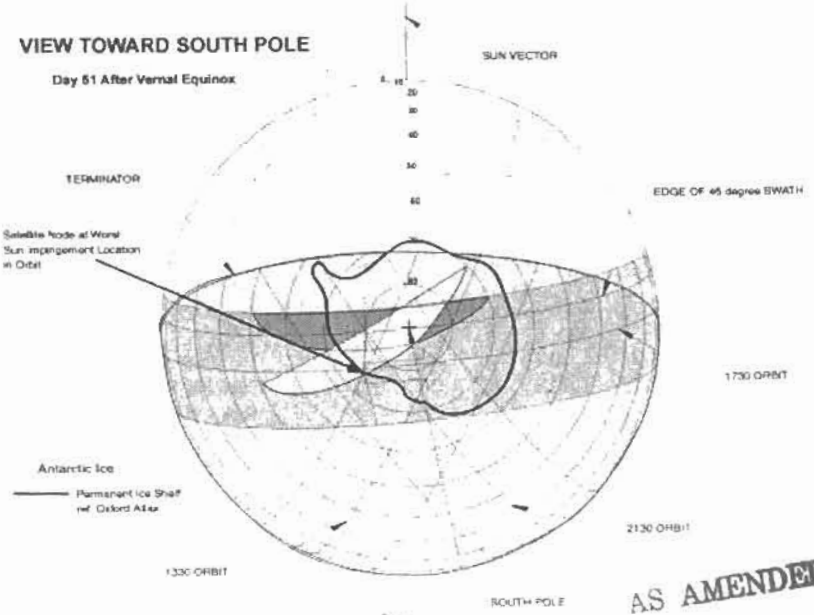
Sensor Provides Optimum Coverage in Terminator Orbits

Baffled telescope has low sensitivity to far field glare and solar impingement

Data available from preceding orbit and/or Sensors in mid-day orbits can fill-in gap



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Telescope Designed to Limit Periods of Solar Impingement

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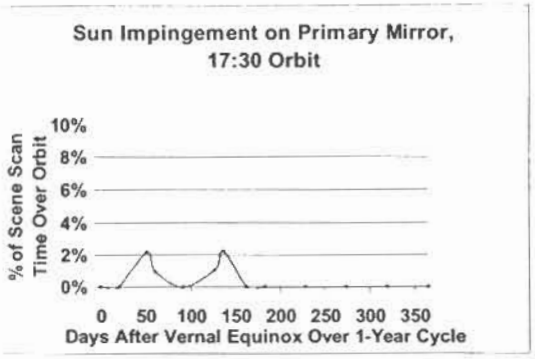

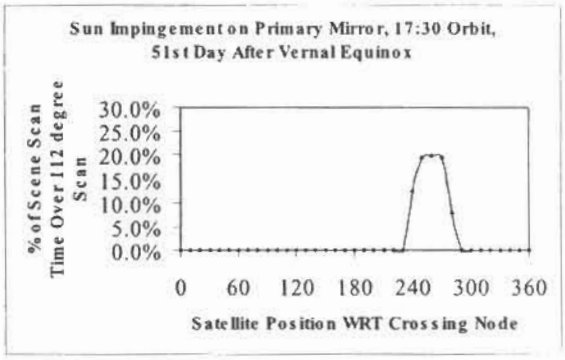

- In terminator orbit, direct solar illumination of primary mirror occurs during small fraction of an orbit for approximately 25 days twice each year.
- Approximately 2.2% of orbit affected (worst case) during each period.
- < 0.4 % data loss over 1 year period

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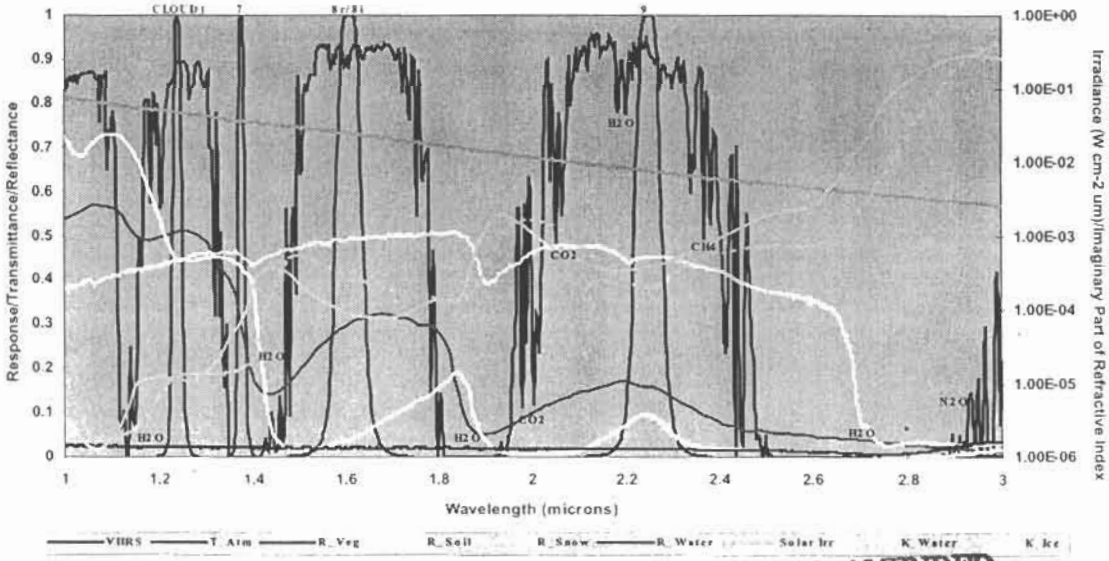
SWIR Bands Provide Pivotal Information About Cloud Optical Properties and Snow

Spectral Band Response, Atmospheric Transmittance, Surface Reflectance, Solar Irradiance, and Imaginary Part of Refractive Index for Water and Ice, Short Wave Infrared (SWIR)



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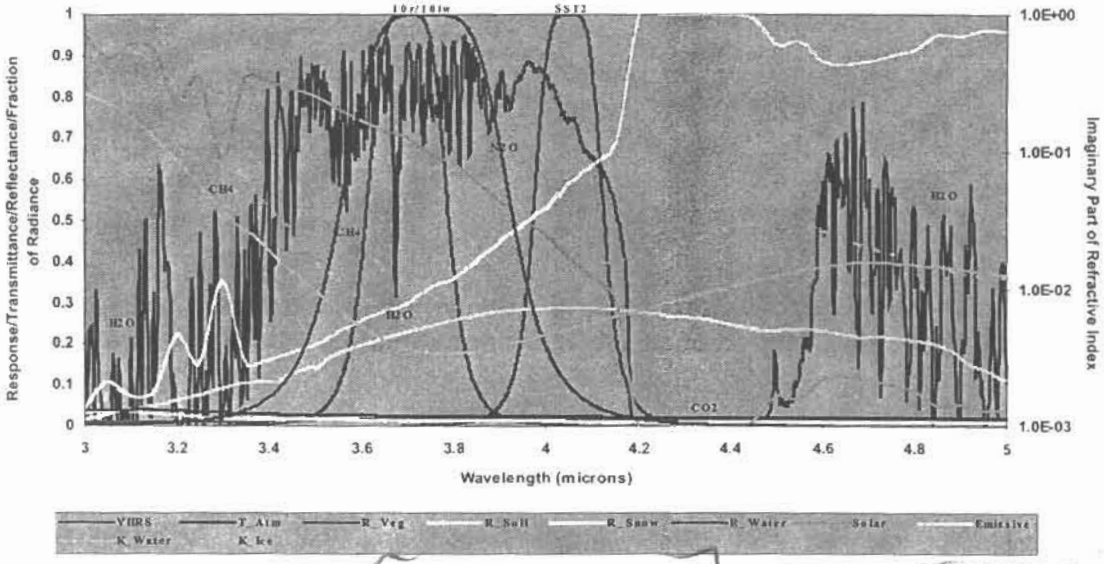
MWIR Bands Bridge Gap Between Reflectance Bands and Thermal IR; Provide Cleanest Tropical SST Window

Spectral Band Response, Atmospheric Transmittance, Surface Reflectance, Solar/Emissive Radiance Fraction for Cloud, and Imaginary Part of Refractive Index for Water and Ice, Mid Wave Infrared (MWIR)



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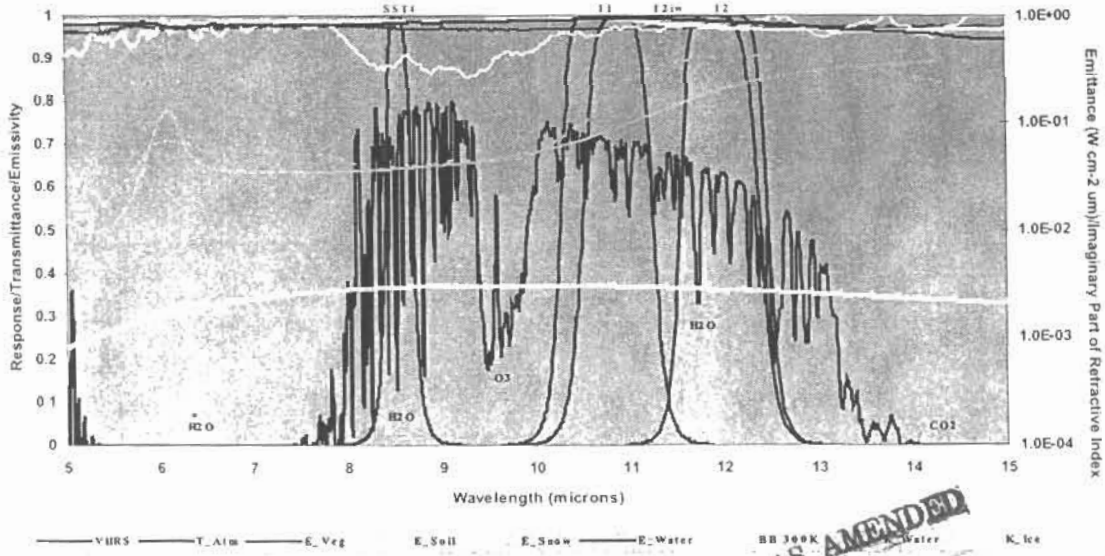
LWIR Bands Targeted Toward Both VIIRS Category I EDRs

Spectral Band Response, Atmospheric Transmittance, Surface Emissivity, Blackbody Emittance (300 K), and Imaginary Part of Refractive Index for Water and Ice, Long Wave Infrared (LWIR)



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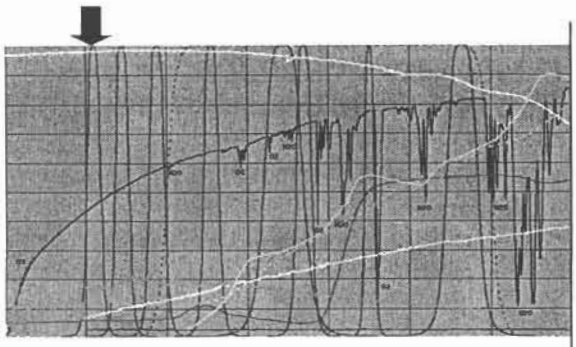
CHLOR2 - 412 nm Essential Ocean Color Band for Case 2 Waters



- Driving EDRs: Ocean Color, Suspended Matter, Net Heat Flux, Mass Loading
- Heritage: MODIS, SeaWiFS
- Rationale:
  - ocean chlorophyll absorption through ratioing with 445 nm
  - sensitivity to both water and smoke for suspended matter

- Phenomenology:
  - strong chlorophyll absorption
  - absence of any significant atmospheric absorption features
  - volatile spectral behavior for solar irradiance
  - must be kept sufficiently separate from 445-nm band to allow extraction of independent signals

- Spectral Parameters:
  - Band Center: 412 nm (± 2 nm)
  - Band Width: 20 nm (± 2 nm)
  - 1% Response Pts.: 376-444 nm
  - Max. OOB Response: 1.0%

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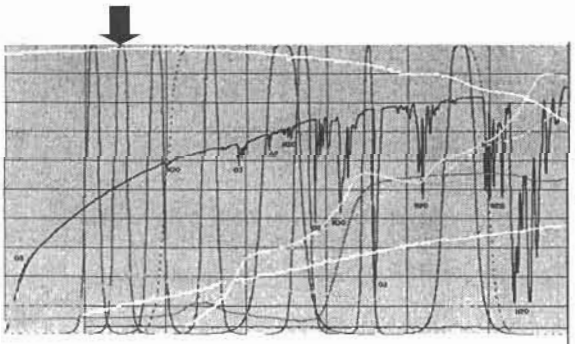
2 - 445 nm Essential Blue Band For Ocean Color/Chlorophyll



- Driving EDRs: Ocean Color, Suspended Matter, Net Heat Flux, Mass Loading
- Heritage: MODIS, SeaWiFS
- Rationale:
  - ocean chlorophyll absorption via ratios with 410 nm and 555 nm
  - typical of "blue" wavelengths for multispectral algorithms

- Phenomenology:
  - strong chlorophyll absorption
  - absence of any significant atmospheric absorption features
  - dynamic spectral behavior for solar irradiance
  - must be kept sufficiently separate from 410-nm band to allow extraction of independent signals

- Spectral Parameters:
  - Band Center: 445 nm (± 3 nm)
  - Band Width: 18 nm (± 2 nm)
  - 1% Response Pts.: 417-473 nm
  - Max. OOB Response: 1.0%

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CHLOR8 - 488 nm Essential Blue Ocean Color Band (High Chlorophyll)

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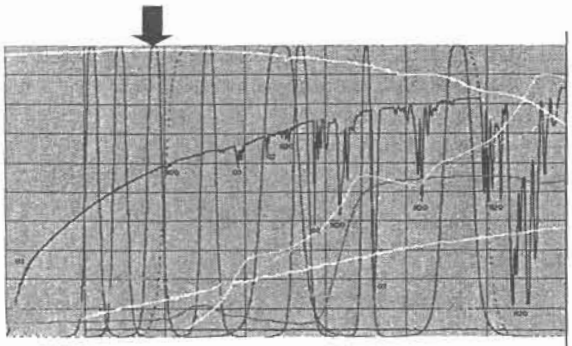

- Driving EDRs: Ocean Color, EVI, Surface Type, Aerosols, Suspended Matter, Net Heat Flux, Mass Loading
- Heritage: MODIS, SeaWiFS, TM
- Rationale:
  - chlorophyll absorption, Case 1 waters
  - pivotal location for reporting or correction of aerosols and smoke

- Phenomenology:
  - strong chlorophyll absorption
  - minor water vapor feature toward longwave (minimal concern)
  - dynamic spectral behavior for solar irradiance

- Spectral Parameters:
  - Band Center: 488 nm (± 4 nm)
  - Band Width: 20 nm (± 3 nm)
  - 1% Response Pts.: 455-521 nm
  - Max. OOB Response: 0.7%

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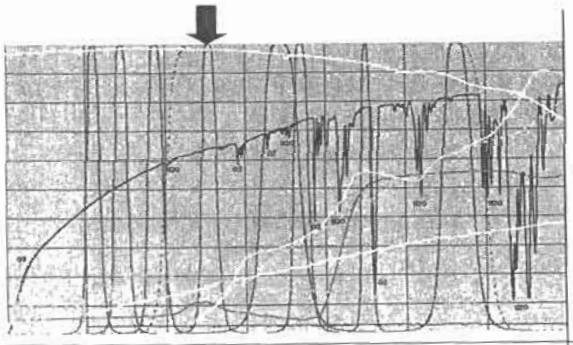
4 - 555 nm Essential Green Band (Chlorophyll Absorption Minimum)



- Driving EDRs: Ocean Color, Surface Type, Suspended Matter, Net Heat Flux, Mass Loading
- Heritage: MODIS, SeaWiFS, TM
- Rationale:
  - ratio with 445-nm for Case 2 waters, fairly transparent in shallow water
  - chlorophyll absorption minimum

- Phenomenology:
  - slight respite in chlorophyll absorption
  - minor water vapor feature toward longwave (minimal concern)
  - variable spectral behavior for solar irradiance
  - slightly stronger absorption in ice than in liquid water

- Spectral Parameters:
  - Band Center: 555 nm (± 4 nm)
  - Band Width: 20 nm (± 3 nm)
  - 1% Response Pts.: 523-589 nm
  - Max. OOB Response: 0.7%

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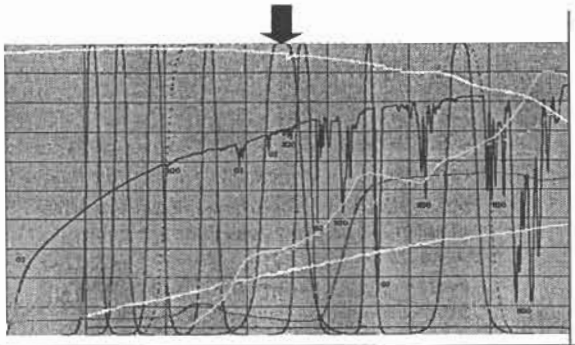
5i - 645 nm - Essential Heritage Imagery NDVI Band



- Driving EDRs: Imagery, NDVI, Cloud Mask/Cover, Cloud Optical Properties, Surface Type, Albedo, Snow/Ice, Soil Moisture
- Heritage: OLS, AVHRR, MODIS, TM
- Rationale:
  - rich heritage as typical visible band
  - near chlorophyll absorption maximum

- Phenomenology:
  - very strong chlorophyll absorption
  - significant water vapor feature within band
  - minor oxygen feature within band
  - fairly well-behaved spectral solar irradiance
  - stronger absorption in liquid water than in ice

- Spectral Parameters:
  - Band Center: 645 nm (± 6 nm)
  - Band Width: 50 nm (± 3 nm)
  - 1% Response Pts.: 570-720 nm
  - Max. OOB Response: 0.7%

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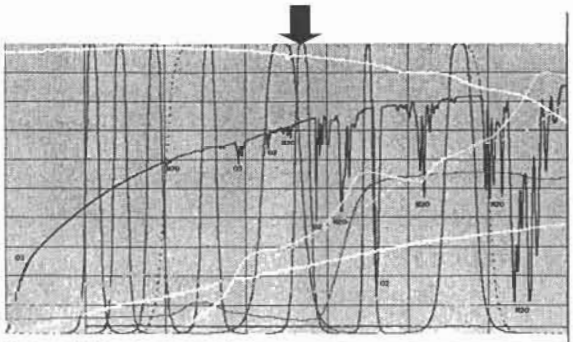
OC2 - 672 nm Essential Deep-Ocean Atmospheric Correction Band



- Driving EDRs: Ocean Color, Aerosols, Suspended Matter, Net Heat Flux, Littoral Transport, Mass Loading
- Heritage: MODIS, SeaWiFS
- Rationale:
  - avoids water vapor, oxygen features
  - centered on chlorophyll absorption maximum

- Phenomenology:
  - very strong chlorophyll absorption
  - significant water vapor features to either side
  - fairly well-behaved spectral solar irradiance
  - stronger absorption in liquid water than in ice

- Spectral Parameters:
  - Band Center: 672 nm (± 5 nm)
  - Band Width: 20 nm (± 3 nm)
  - 1% Response Pts.: 638-706 nm
  - Max. OOB Response: 0.7%

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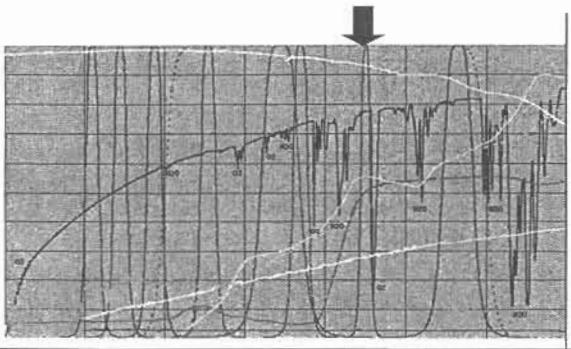
OC3 - 751 nm Essential All-Ocean Atmospheric Correction Band



- Driving EDRs: Ocean Color, Mass Loading
- Heritage: MODIS, SeaWiFS
- Rationale:
  - black ocean allows for sensing and removal of aerosols as precursor to ocean color retrieval
  - avoids oxygen feature in corresponding SeaWiFS band

- Phenomenology:
  - extremely low reflectance over water
  - very strong oxygen feature toward longwave
  - significant water vapor absorption toward shortwave
  - OOB response must be minimized due to low signal, surrounding absorption features

- Spectral Parameters:
  - Band Center: 751 nm (± 2 nm)
  - Band Width: 15 nm (± 2 nm)
  - 1% Response Pts.: 726-776 nm
  - Max. OOB Response: 0.8%

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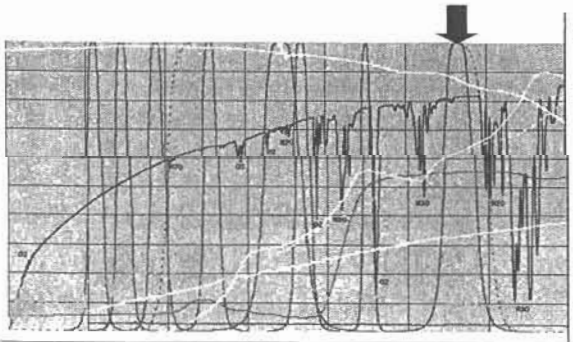
6r - 865 nm Essential Ocean Color Atmospheric Correction Band



- Driving EDRs: Ocean Color, Cloud Mask/Cover, Aerosols, Soil Moisture, Net Heat Flux, Mass Loading
- Heritage: AVHRR, MODIS, SeaWiFS, TM
- Rationale:
  - black ocean for sensing and removal of aerosols

- Phenomenology:
  - extremely low water reflectance
  - strong water vapor absorption to either side
  - slightly stronger absorption in liquid water than in ice
  - minimal OOB response important for ocean

- Spectral Parameters:
  - Band Center: 865 nm (± 8 nm)
  - Band Width: 39 nm (± 5 nm)
  - 1% Response Pts.: 801-929 nm
  - Max. OOB Response: 0.7%

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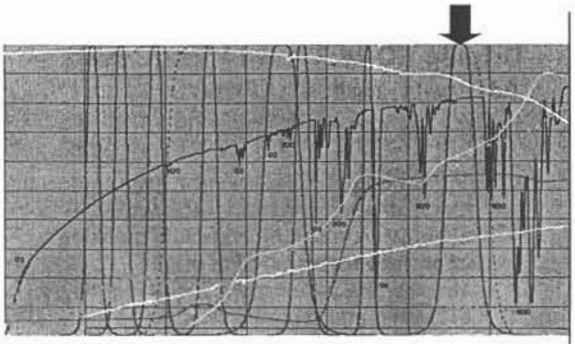
6i - 865 nm Essential NDVI Heritage Band



- Driving EDRs: NDVI, Snow/Ice, Surface Type, Albedo
- Heritage: AVHRR, MODIS, SeaWiFS, TM
- Rationale:
  - reflectance plateau for healthy vegetation

- Phenomenology:
  - extremely low reflectance over water
  - strong scattering through vegetation canopies leads to high reflectances compared with that for visible wavelengths
  - strong water vapor absorption to either side

- Spectral Parameters:
  - Band Center: 865 nm (± 8 nm)
  - Band Width: 39 nm (± 5 nm)
  - 1% Response Pts.: 801-929 nm
  - Max. OOB Response: 0.7%

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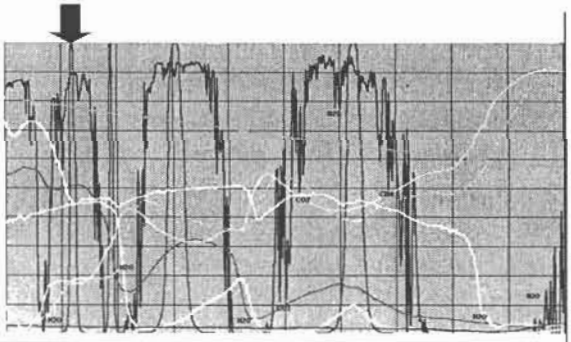
CLOUD1-1.24 μm Essential For Cloud Properties Determination Over Snow/Ice



- Driving EDRs: Cloud Optical Properties, Active Fires
- Heritage: MODIS
- Rationale:
  - very low surface signal for snow/ice allows more accurate retrieval of cloud optical properties
  - large fire sensing without saturation

- Phenomenology:
  - low reflectance for snow/ice
  - significant water vapor absorption to either side
  - strong, localized oxygen feature to longwave
  - slightly stronger absorption in ice than in liquid water

- Spectral Parameters:
  - Band Center: 1.24 μm (± 0.005 μm)
  - Band Width: 0.02 μm (± 0.004 μm)
  - 1% Response Pts.: 1.205-1.275 μm
  - Max. OOB Response: 0.8%

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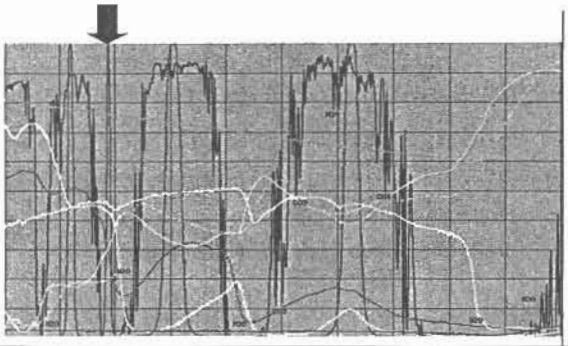
Band 7-1.378 μm Essential For Thin Cirrus Detection and Mitigation



- Driving EDRs: Cloud Mask/Cover, Aerosols, Net Heat Flux
- Heritage: MODIS
- Rationale:
  - black atmosphere from water vapor absorption, allowing complete masking of surface for retrieval of upper atmosphere parameters, including cirrus detection and stratospheric aerosols

- Phenomenology:
  - total absorption by water vapor within band
  - surface signal emerges to either side
  - stronger absorption in ice than in liquid water than in ice
  - narrower bandwidth chosen to avoid surface signal leakage in MODIS band

- Spectral Parameters:
  - Band Center: 1.378 μm (± 0.004 μm)
  - Band Width: 0.015 μm (± 0.003 μm)
  - 1% Response Pts.: 1.351-1.405 μm
  - Max. OOB Response: 1.0%

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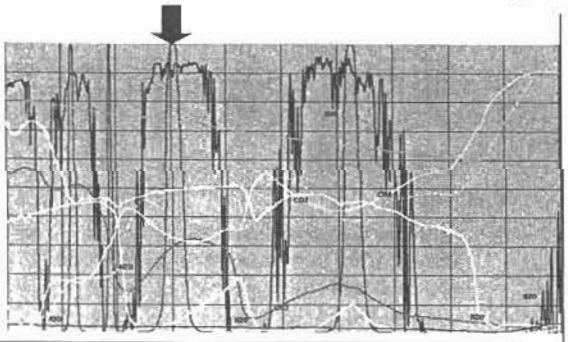
Band 8r-1.61 μm Essential For Differentiating Cloud and Snow



- Driving EDRs: Aerosols, Cloud Optical Properties, Cloud Mask/Cover, Active Fires, Soil Moisture, Net Heat Flux
- Heritage: AVHRR, MODIS
- Rationale:
  - lower reflectance for snow/ice than for vegetation, soil, and clouds
  - excellent cloud phase discriminator

- Phenomenology:
  - extremely low reflectance for snow/ice
  - slightly increased reflectance for vegetation and soil
  - surrounded by minor carbon dioxide and methane features
  - stronger absorption in ice than in liquid water

- Spectral Parameters:
  - Band Center: 1.61 μm (± 0.014 μm)
  - Band Width: 0.06 μm (± 0.009 μm)
  - 1% Response Pts.: 1.509-1.709 μm
  - Max. OOB Response: 0.7%

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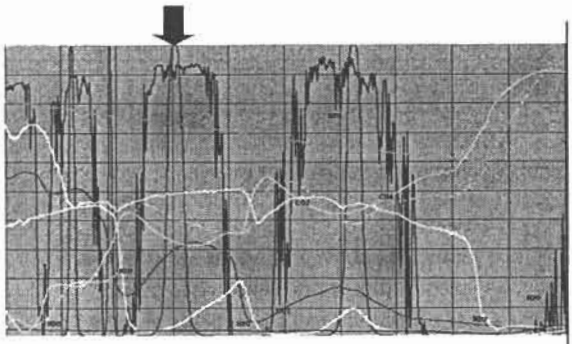
8i - 1.61 μm Essential For Differentiating Cloud and Snow



- Driving EDRs: Snow/Ice, Surface Type, Albedo
- Heritage: AVHRR, MODIS
- Rationale:
  - lower reflectance for snow/ice than for vegetation, soil, and clouds
  - excellent phase discriminator for clouds

- Phenomenology:
  - extremely low reflectance for snow/ice
  - slightly increased reflectance for vegetation and soil
  - surrounded by minor carbon dioxide and methane features
  - stronger absorption in ice than in liquid water

- Spectral Parameters:
  - Band Center: 1.61 μm (± 0.014 μm)
  - Band Width: 0.06 μm (± 0.009 μm)
  - 1% Response Pts.: 1.509-1.709 μm
  - Max. OOB Response: 0.7%

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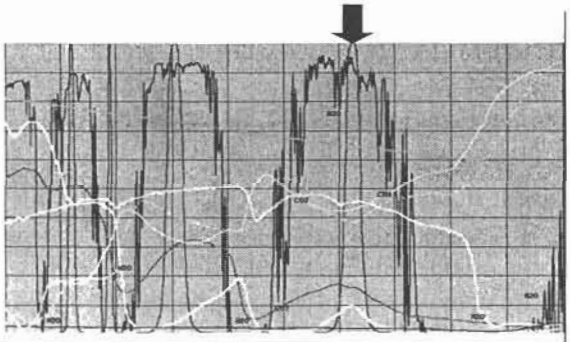
Band 9-2.25 μm Essential For Optimal Aerosol Optical Thickness Over Land



- Driving EDRs: Aerosols, Cloud Optical Properties, Surface Type, Active Fires, Net Heat Flux
- Heritage: MODIS, TM
- Rationale:
  - dark pixel detection for aerosol optical thickness retrieval
  - reversed phase difference for water from that in 1.61 μm band

- Phenomenology:
  - low reflectance for vegetation and water
  - enhanced water vapor and methane absorption to either side
  - stronger absorption in liquid water than in ice

- Spectral Parameters:
  - Band Center: 2.25 μm (± 0.013 μm)
  - Band Width: 0.05 μm (± 0.006 μm)
  - 1% Response Pts.: 2.167-2.333 μm
  - Max. OOB Response: 1.0%

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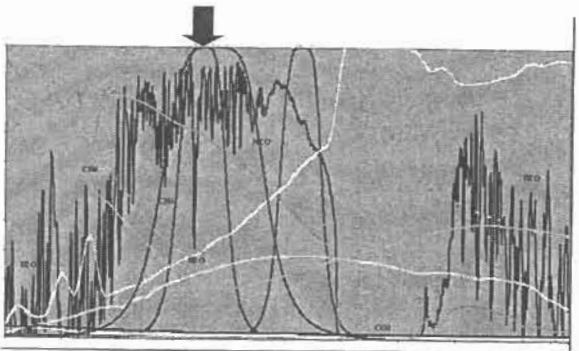
Band 10r-3.7 μm Essential Heritage Band



- Driving EDRs: Sea Surface Temperature, Cloud Mask/Cover, Cloud EDRs, Surface Type, Land/Ice Surface Temperature, Aerosols
- Heritage: AVHRR, MODIS
- Rationale:
  - contains solar and emissive info
  - differential water vapor absorption
  - T_b differences w/ thermal for clouds

- Phenomenology:
  - strong solar/emissive components
  - water vapor absorption throughout at a fairly constant average level
  - stronger absorption in ice than in liquid water
  - separation with 4.05 μm band critical for calculations of SST

- Spectral Parameters:
  - Band Center: 3.7 μm (± 0.032 μm)
  - Band Width: 0.18 μm (± 0.02 μm)
  - 1% Response Pts.: 3.41-3.99 μm
  - Max. OOB Response: 1.1%

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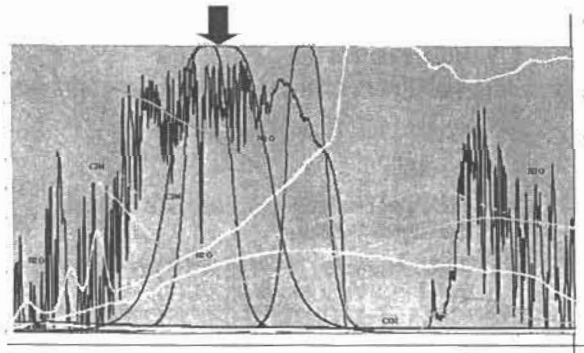
Band 10i--3.74 μm Essential For Identifying Low (Dark) Stratus



- Driving EDRs: Imagery, Active Fires
- Heritage: AVHRR, MODIS, (MOLS)
- Rationale:
  - contains solar and emissive info
  - differential water vapor absorption
  - differences in T_b with thermal for clouds
  - proxy for 4.05 μm band at imagery resolution (fire detection)

- Phenomenology:
  - strong solar/emissive components
  - water vapor absorption throughout at a fairly constant average level
  - stronger absorption in ice than in liquid water
  - separation with 4.05 μm band critical for calculations of SST

- Spectral Parameters:
  - Band Center: 3.74 μm (± 0.040 μm)
  - Band Width: 0.38 μm (± 0.03 μm)
  - 1% Response Pts.: 3.34-4.14 μm
  - Max. OOB Response: 0.5%

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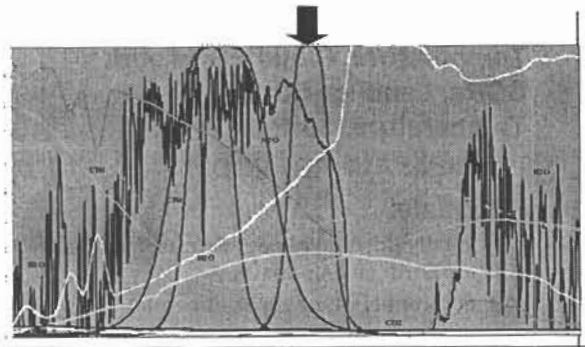
SST2-4.05 μm Essential For Skin SST in Tropics, and During Daytime



- **Driving EDRs: Sea Surface Temperature, Land Surface Temperature, Active Fires, Precipitable Water**
- **Heritage: MODIS**
- **Rationale:**
  - **differential water vapor absorption for surface temperature retrievals**
  - **optimal location for fire detection**

- **Phenomenology:**
  - **strong solar/emissive components**
  - **stronger absorption in ice than in liquid water**
  - **carbon dioxide absorption to longwave**
  - **separation with 3.7 μm band critical for calculations of SST**

- **Spectral Parameters:**
  - **Band Center: 4.05 μm (± 0.034 μm)**
  - **Band Width: 0.155 μm (± 0.02 μm)**
  - **1% Response Pts.: 3.79-4.31 μm**
  - **Max. OOB Response: 1.3%**

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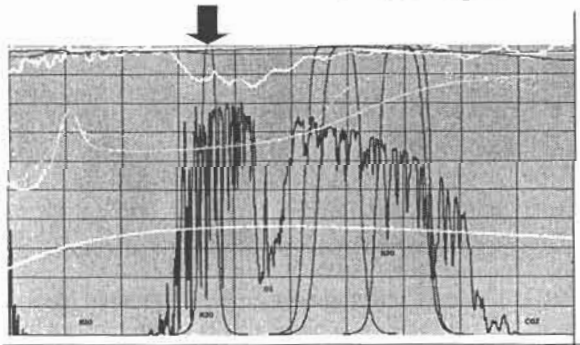
SST4 - 8.55 μm Essential For Cloud Phase and Optical Properties



- **Driving EDRs: Cloud Mask/Cover, Cloud Optical Properties**
- **Heritage: MODIS**
- **Rationale:**
  - **pivotal longwave band for phase detection in clouds at night**

- **Phenomenology:**
  - **water vapor absorption throughout and beyond band to either side - large fluctuations, but not much of a spectral trend**
  - **stronger absorption in ice than in liquid water**
  - **spectral signature for quartz/sand makes band useful for suspended matter, soil discrimination**

- **Spectral Parameters:**
  - **Band Center: 8.55 μm (± 0.07 μm)**
  - **Band Width: 0.3 μm (± 0.04 μm)**
  - **1% Response Pts.: 8.05-9.05 μm**
  - **Max. OOB Response: 0.9%**

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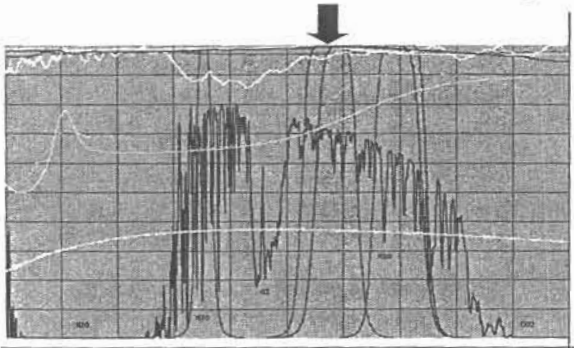
11 - 10.763 μm - Essential Heritage Band (Split Window)



- Driving EDRs: Sea Surface Temperature, Cloud EDRs and SDRs, Land/Ice Surface Temperature, Surface Type
- Heritage: AVHRR, MODIS
- Rationale:
  - ideally positioned near thermal maximum for Earth and clouds
  - differential water vapor absorption

- Phenomenology:
  - fairly strong water vapor absorption within band -
  - prominent ozone feature to shortwave
  - stronger absorption in ice than in liquid water
  - located near the thermal emission maximum for most objects on Earth or in atmosphere

- Spectral Parameters:
  - Band Center: 10.763 μm (± 0.112 μm)
  - Band Width: 1.0 μm (± 0.1 μm)
  - 1% Response Pts.: 9.7-11.74 μm
  - Max. OOB Response: 0.4%

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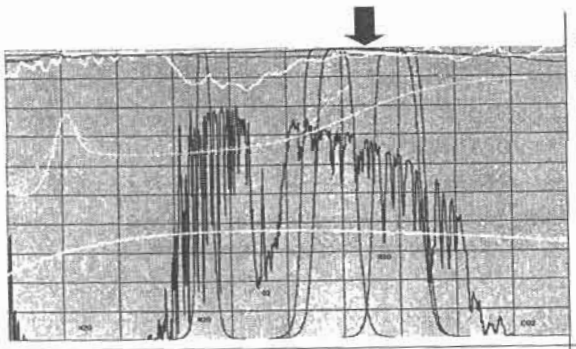
12i - 11.45 μm - Essential Heritage Nighttime Imagery Band



- Driving EDRs: Imagery
- Heritage: OLS, TM
- Rationale:
  - positioned near thermal maximum for Earth and clouds
  - 1.9 μm width allows stronger signal, continuity with OLS and TM heritage
  - gives VIIRS potential for three-band separation of cloud phase in the thermal window (AGI study)

- Phenomenology:
  - complete carbon dioxide absorption to longwave
  - significant ozone feature to shortwave
  - stronger absorption in ice than in liquid water
  - located near the thermal emission maximum for most objects on Earth or in atmosphere

- Spectral Parameters:
  - Band Center: 11.45 μm (± 0.1 μm)
  - Band Width: 1.9 μm (± 0.1 μm)
  - 1% Response Pts.: 9.9-12.9 μm
  - Max. OOB Response: 0.4%

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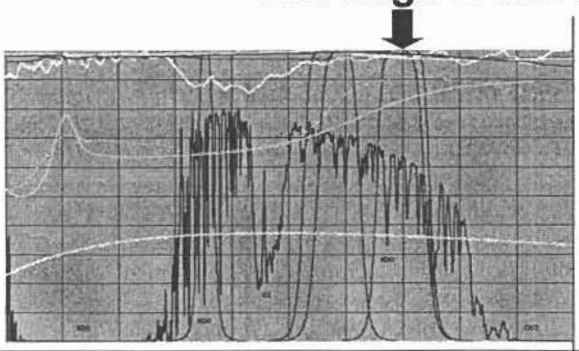
12r - 12.013 μm - Essential Heritage Band (Split Window)



- Driving EDRs: Sea Surface Temperature, Cloud Mask/Cover, Land/Ice Surface Temperature, Surface Type
- Heritage: AVHRR, MODIS
- Rationale:
  - ideally positioned near thermal maximum for clouds
  - differential water vapor absorption

- Phenomenology:
  - fairly strong water vapor absorption within band
  - carbon dioxide absorption to longwave
  - stronger absorption in ice than in liquid water
  - located near the thermal emission maximum for most objects in Earth's atmosphere

- Spectral Parameters:
  - Band Center: 12.013 μm (± 0.088 μm)
  - Band Width: 0.95 μm (± 0.05 μm)
  - 1% Response Pts.: 11.06-13.05 μm
  - Max. OOB Response: 0.4%

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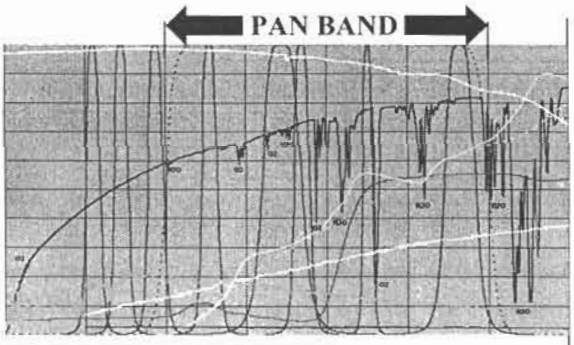
DNB - Pan Band -Essential Nighttime Reflected Band



- Driving EDRs: Imagery
- Heritage: OLS
- Rationale:
  - utility of a band using reflected moonlight has been demonstrated by OLS for detection of oil fires, city lights, and some types of clouds
  - broad spectral bandwidth maximizes signal

- Phenomenology:
  - contains both visible and near infrared signals
  - numerous absorption features within band, however each is fairly minor compared to band width
  - scattering in shortest wavelengths avoided

- Spectral Parameters:
  - Band Center: 700 nm (± 14 nm)
  - Band Width: 400 nm (± 20 m)
  - Edge Range (5%-80%): 15-27 nm

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Mission Modes & Activities Similar To Previous Raytheon Space Sensors

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MISSION MODES & ACTIVITIES
LAUNCH
No power, Mechanisms caged
ACTIVATION
Warmup & Operation of One-Time Mechanisms (cooler door, nadir door/sunshade, scan system launch pin)
DIAGNOSTIC
Sensor configuration, data taking, data processing & formatting all configured by ground command as needed for Sensor characterization
OPERATIONAL (Includes calibration)
Daytime: All spectral bands
Nighttime: DNB & Bands >1 micron
Terminator: All spectral bands, swath widths selectable by band
SAFE HOLD
Telescope stopped facing in, telemetry packets generated

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Bandset & Data Parameters Derived By System Simulations: VNIR FPA

Original Band Name/No.	Day/ Night	chlr2	2	chlr8	4	5 image	OC2	OC3	6 image	6 rad
Focal Plane/Spectral Region	CCD	VIS	VIS	VIS	VIS	VIS	VIS	NIR	NIR	NIR
Detector Material	CCD	Si	Si	Si	Si	Si	Si	Si	Si	Si
New Band Designator April 2000	**DNB**	**M1**	**M2**	**M3**	**M4**	**I1**	**M5**	**M6**	**I2**	**M7**
Central Wavelength (µm)	0.70	0.412	0.445	0.488	0.555	0.645	0.672	0.751	0.865	0.865
Bandwidth (µm)	0.40	0.02	0.018	0.02	0.02	0.05	0.02	0.015	0.039	0.039
In-Track Projected Det (IGFOV=HSI=GSD - km)										176
Nadir	0.742	0.7420	0.742	0.742	0.742	0.371	0.742	0.742	0.371	0.742
55.8 deg	0.742	1.6000	1.600	1.600	1.600	0.800	1.600	1.600	0.800	1.600
Crosstrack Sample Spacing (HSI - km) Min posible @ Nadir		0.2621	0.262	0.262	0.262	0.131	0.262	0.262	0.131	0.262
Nadir	0.742	0.2586	0.259	0.259	0.259	0.129	0.259	0.259	0.129	0.259
55.8 deg	0.742	1.5784	1.578	1.578	1.578	0.789	1.578	1.578	0.789	1.578
Gain States (2 = bilinear)	3	2	2	2	2	1	2	1	1	2
Number of Detectors In TDI	Var	1	1	1	1	1	1	1	1	1
Sample Interval per Det (µsec)	253.3	88.259	88.26	88.26	88.26	44.13	88.26	88.26	44.13	88.26
Integration Time (µsec)	253.3	78.453	78.45	78.45	78.45	39.23	78.45	78.45	39.23	78.45
Data Rate (Per Nominal Altitude)										
NetData Rate - Mbps	0.506954	0.731	0.731	0.731	0.731	1.361	0.731	0.340	1.361	0.731
Daytime Bands	1	1	1	1	1	1	1	1	1	1
Nighttime Bands	1	0	0	0	0	0	0	0	0	0
Twilight Bands	1	1	1	1	1	1	1	1	1	1
Regional Day Raw Data Rate (Mbps)	0.507	0.731	0.731	0.731	0.731	1.361	0.731	0.340	1.361	0.731
Regional Night Raw Data Rate (MBPS)	0.507	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Regional Twilight Raw Data Rate (MBPS)	0.507	0.731	0.731	0.731	0.731	1.361	0.731	0.340	1.361	0.731

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Bandset & Data Parameters Derived By System Simulations: MWIR & LWIR

Original Band Name/No.	cloud1	7	8 image	8 rad	9	10 image	10 rad	ss12	ss14	11	12 image	12 rad
Focal Plane/Spectral Region	SWIR	SWIR	SWIR	SWIR	SWIR	MWIR	MWIR	MWIR	LWIR	LWIR	LWIR	LWIR
Detector Material	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT	PVHCT
New Band Designator April 2000	**M8**	**M9**	**I3**	**M10**	**M11**	**I4**	**M12**	**M13**	**M14**	**M15**	**I5**	**M16**
Central Wavelength (µm)	1.24	1.378	1.61	1.61	2.25	3.74	3.70	4.05	8.55	10.7625	11.45	12.01
Bandwidth (µm)	0.02	0.015	0.06	0.06	0.05	0.38	0.18	0.155	0.30	1.00	1.90	0.95
In-Track Projected Det.(IGFOV=HSI=GSD - km)												240
Nadir	0.742	0.742	0.371	0.742	0.742	0.371	0.742	0.742	0.742	0.742	0.371	0.742
55.8 deg.	1.600	1.600	0.800	1.600	1.600	0.800	1.600	1.600	1.600	1.600	0.800	1.600
Crosstrack Sample Spacing (HSI - km) Min posible @ Nadir	0.262	0.262	0.131	0.262	0.262	0.131	0.262	0.262	0.262	0.262	0.131	0.262
Nadir	0.259	0.259	0.129	0.259	0.259	0.129	0.259	0.259	0.259	0.259	0.129	0.259
55.8 deg.	1.578	1.578	0.789	1.578	1.578	0.789	1.578	1.578	1.578	1.578	0.789	1.578
Gain States (2 = bilinear)	1	1	1	1	1	1	1	2	1	1	1	1
Number of Detectors In TDI	1	1	1	1	1	1	1	1	1	1	1	2
Sample Interval per Det. (µsec)	88.26	88.26	44.13	88.26	88.26	44.13	88.26	88.26	88.26	88.26	44.13	88.26
IntegrationTime (µsec)	76.00	76.00	38.00	76.00	76.00	39.23	78.45	78.45	78.45	78.45	39.23	78.45
Data Rate (for Nominal Altitude)												
NetData Rate - Mbps	0.340	0.340	1.361	0.340	0.340	1.361	0.340	0.731	0.340	0.340	1.361	0.340
Daytime Bands	1	1	1	1	1	1	1	1	1	1	1	1
Nighttime Bands	1	0	0	1	1	1	1	1	1	1	1	1
Twilight Bands	1	1	1	1	1	1	1	1	1	1	1	1
Regional Day Raw Data Rate (Mbps):	0.340	0.340	1.361	0.340	0.340	1.361	0.340	0.731	0.340	0.340	1.361	0.340
Regional Night Raw Data Rate (MBPS):	0.340	0.000	0.000	0.340	0.340	1.361	0.340	0.731	0.340	0.340	1.361	0.340
Regional Twilight Raw Data Rate (MBPS):	0.340	0.340	1.361	0.340	0.340	1.361	0.340	0.731	0.340	0.340	1.361	0.340

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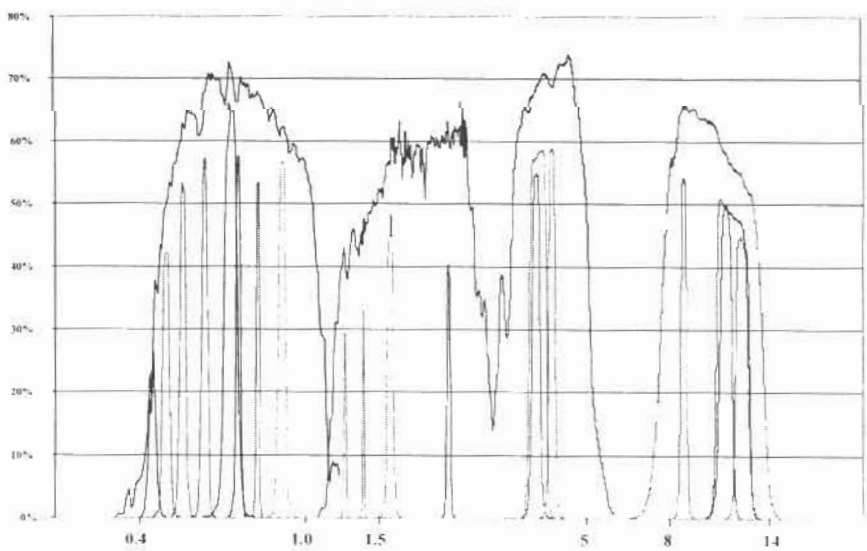
3 Focal Planes (4 FPAs) Cover VIIRS Spectrum



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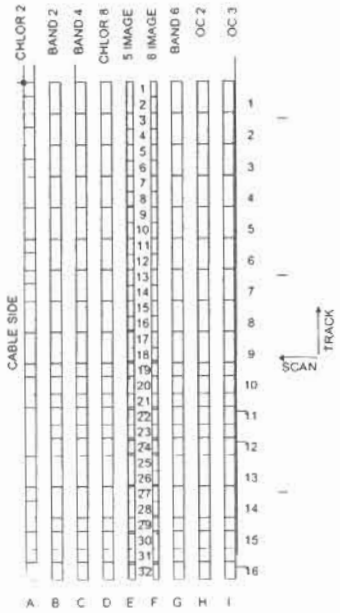
Vis-Nir FPA: MODIS Heritage Technology



- VisNIR PIN Diode Array/ROIC Hybrid
  - 7 radiometric bands and 2 imaging bands
  - Covers 0.4 to 0.88 microns
  - Proven MODIS technology
  - Excellent blue response with AR coating
  - Very low crosstalk
  - Provides common hybrid approach for all spectral FPAs
  - Fabricated at Raytheon IR CoE

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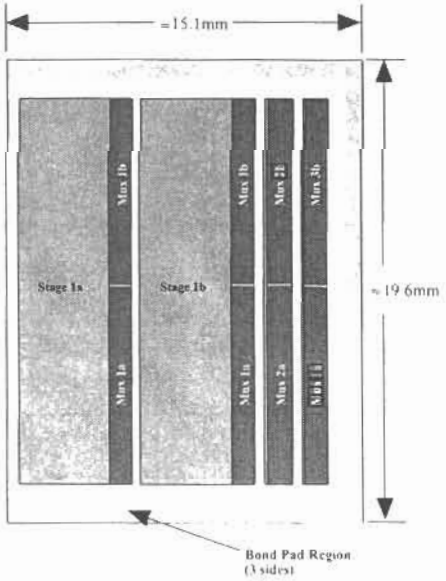
DNB CCD Detector - Excellent SNR, Near-Objective Sample Spacing



- Spectral Range 0.5-0.9 μm
- 4 Light-Sensitive Areas
  - 2 with 250 In TDI
  - 1 With 3 In TDI
  - 1 With 35x ND Filt & No TDI
- 742-meter constant HSI with near-rectangular Sampling Direct From CCD
  - Sample spacing post-launch programmable
- Performance margin at EOS & SNR improvement at center of scan allow night imaging well into high latitudes
- CCD CDR Complete

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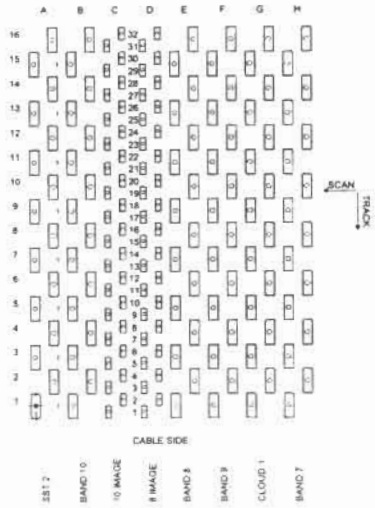
Short/Midwave IR Focal Plane Uses Routine Raytheon Technology



- Spectral Range 1.24 - 4.05 μm
- 6 Radiometric Bands Plus 2 Imaging Bands, 1.124 - 3.7 microns
- Low risk - Wavelength Range same as many Raytheon Space FPAs
- Field "microlens" array improves SNR
  - Smaller, lower-noise detector
  - Restricts imaged area to telescope aperture
- 2 PV HgCdTe Chips hybridized to single readout
  - Smaller detector chip improves yield

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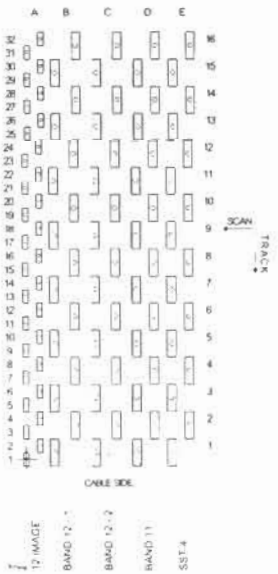
LWIR Focal Plane: Second-Generation Technology Provides Cost Savings



- Spectral range 8.55 to 12.01 μm
- Two detector hybrid uses different detector material cutoffs to optimize performance
- Improved PV HgCdTe Extends Second-Generation FPA Technology to 12 μm
  - Tests demonstrate performance per VIIRS requirements at 80 Kelvin
- Readout IC (2nd gen.) provides improved noise, built-in offset correction
- Field "microlens" array also used on LWIR FPA
- Hardware and interfaces much simpler than previous Photoconductive HgCdTe LWIR focal planes

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VIIRS Electronics Block Diagram

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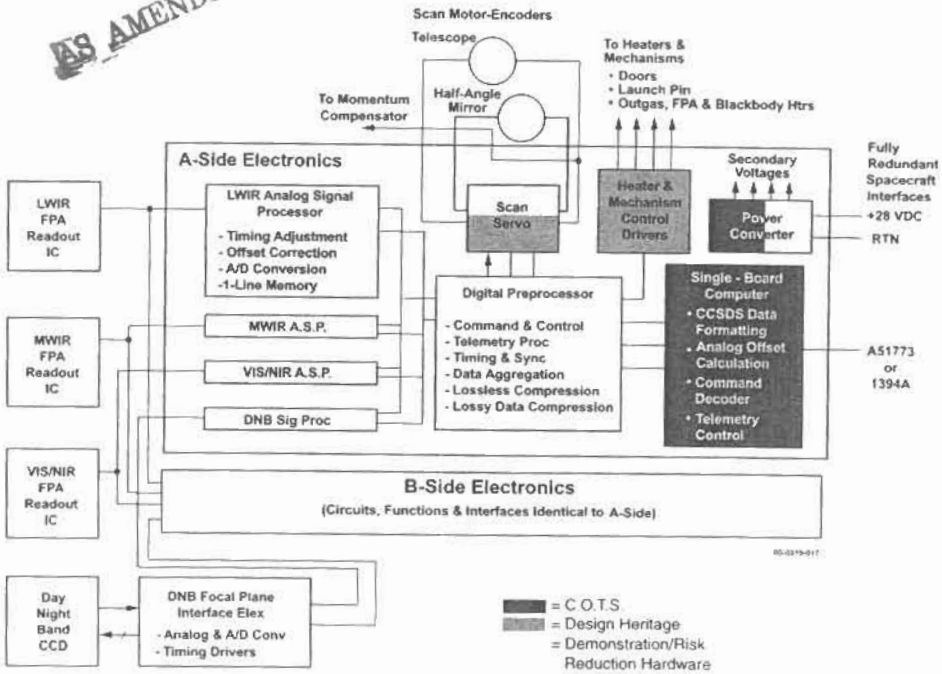

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Flight Software Adds Flexibility and Capability to VIIRS Sensor

- Spacecraft Command and Telemetry Interface
  - Flexible command structure offers individual component commands and Macro commands (stored multi-command sequences)
  - Mode changes need only a single ground command
- Provides flexible diagnostic features
  - Reconfigurable Telemetry sampling
  - Processing functions can be selectively disabled
  - Self Test capability for Analog and Processing chains
- Provides 30-day autonomous operation
- On-orbit Software Maintenance capability AS AMENDED
- Meets flexible formatting needs of three data streams to the Spacecraft (High Rate, Low Rate, Telemetry)

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On-Board Data Processing Preserves Data Integrity & Serves Mission Needs

- Generates RDRs with all Sensor data needed for SDRs,
  - Aggregates Imaging and Single-gain Radiometric bands to preserve data bandwidth while meeting HRI requirements
  - Performs lossless compression of HDR data, lossy compression of LDR data
- Updates ASP analog offsets each scan to optimize use of ADC dynamic range
- Provides versatile control of all processing functions to facilitate diagnostic mode operations
  - Band-by-band selection of swath width & location
  - Selective enable/disable of all aggregation, compression
- Processor provides >100% performance margins; open architecture allows for upgrades, PPPI

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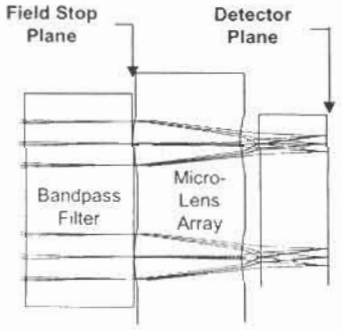
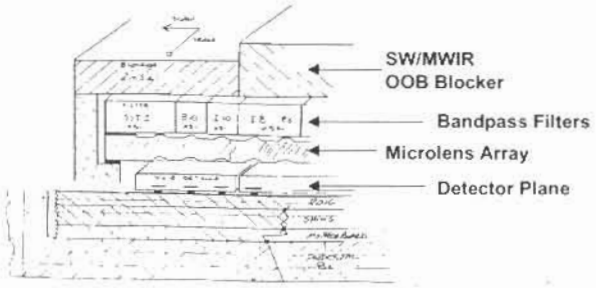
Low Cost Microlens Array Optimizes Radiometric Performance





- Microlenses Reimage Exit Pupil of Aft Imager onto Detectors
- F/0.8 Microlenses Minimize Detector Area and Reduce Noise
- Meniscus Design Minimizes Aberrations
- Microlenses for Each Band Optimized Separately to Accommodate Band-to-Band Chromatic Focal Shifts
- Monolithic Microlens Array Simplifies Dewar Assembly and Alignment
- Limits View of Non-Scene Energy
- Si Substrate for SW\MWIR FPA
- Ge Substrate for LWIR FPA

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Polarization Requirement Met With Increased Margin Using Two Fold Mirrors

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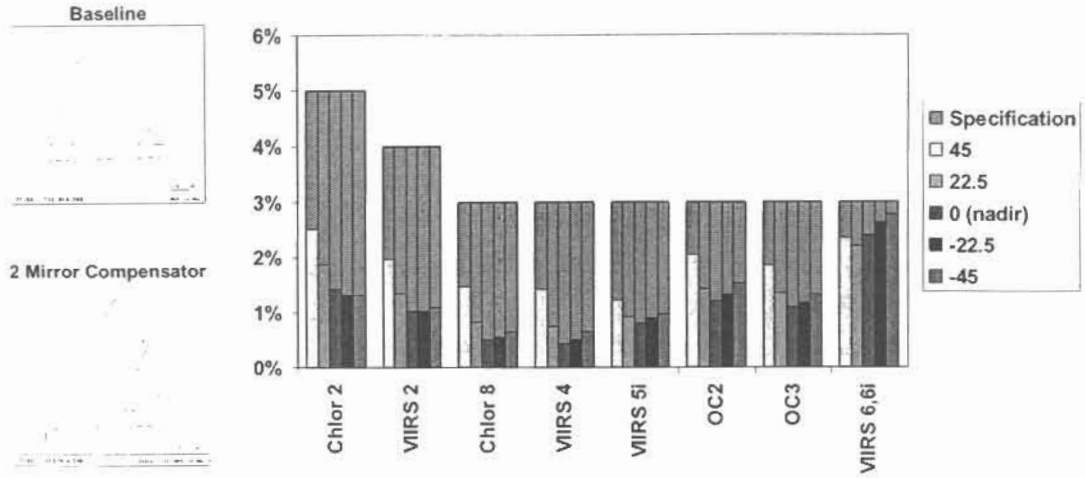

- Dual Fold Preserves Image Orientation and Minimizes FPA Displacement

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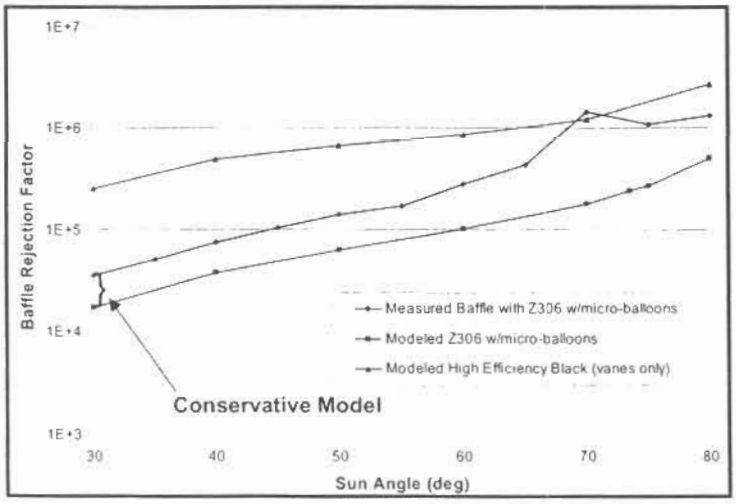
Measured Baffle Data Validates Stray Light Model – Reduces Risk to Low



- Stray Light from Solar Glare Modeled Using ASAP
- Reflectance Properties Assigned Using Measured BRDF Data
- Lab Measurements Within 2X of Modeled Values
- Correlation Between Stray Light Model and Lab Measurements Lends Confidence to Detailed Analysis

Sun Angle is Measured Relative to Telescope Line-of-Sight

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Outgassing Capability Is Built Into VIIRS Cryogenic Module

- Outgas capability exists if needed
  - To drive off molecular contaminants from thermal control surfaces of cryoradiator
  - To maintain transmission through dewar optics
- MLI thermal blankets
  - Primary source of contaminant (water vapor)
  - Used in cryoradiator for improved isolation
  - Excluded from FPA dewar to keep windows clear
- Outgas heaters are located in cryoradiator
- Thermal link transfers outgassing power from cryoradiator to FPA dewar assembly
- Vent path from cryoradiator is directly to space

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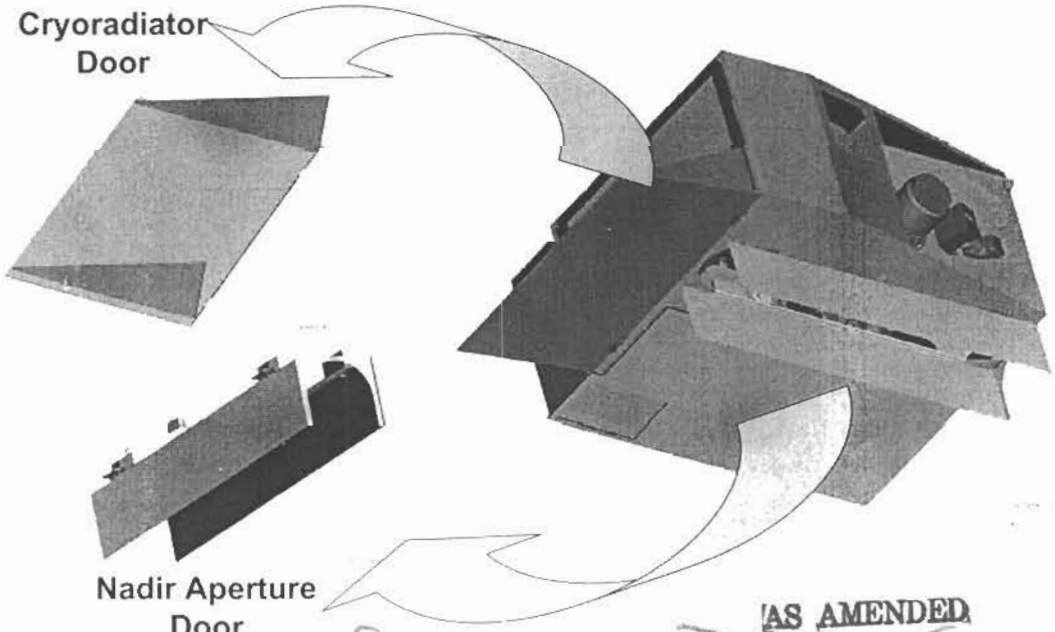
VIIRS Has Two Deployable Door Assemblies



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Nadir Aperture Doors Shield Telescope from Solar Exposure

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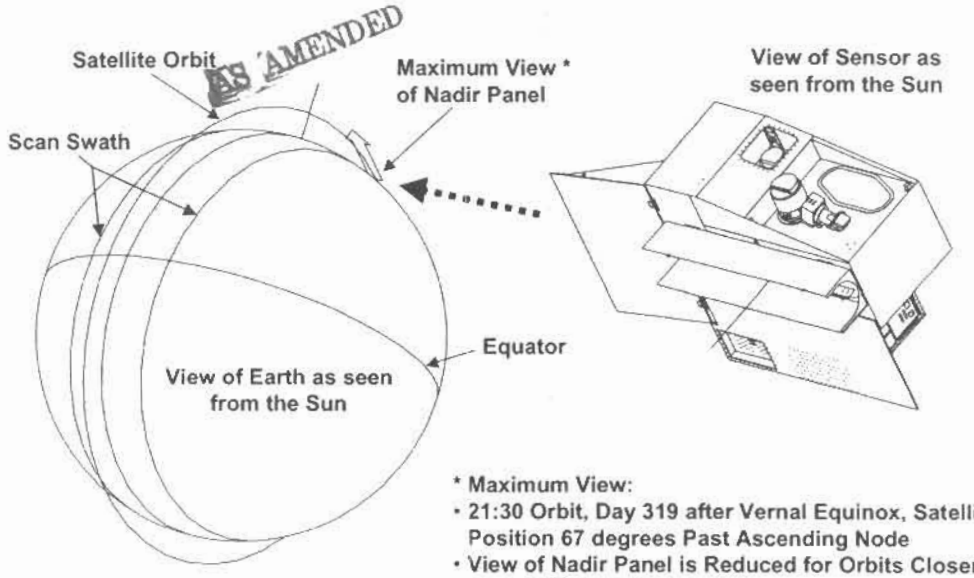

* Maximum View:
- 21:30 Orbit, Day 319 after Vernal Equinox, Satellite Position 67 degrees Past Ascending Node
- View of Nadir Panel is Reduced for Orbits Closer to Noon or Midnight

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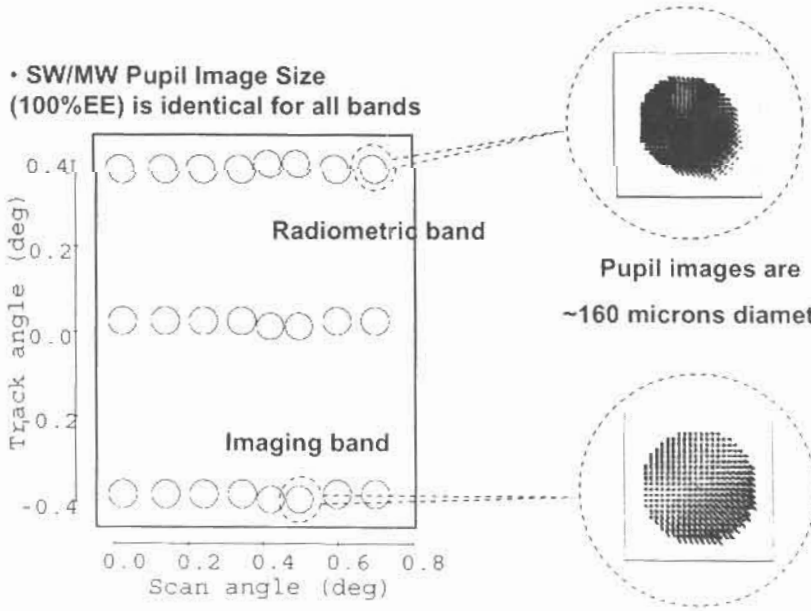
Microlens Design Maximizes Margin for 100% Energy on Detector

- SW/MW Pupil Image Size (100%EE) is identical for all bands



Pupil images are ~160 microns diameter

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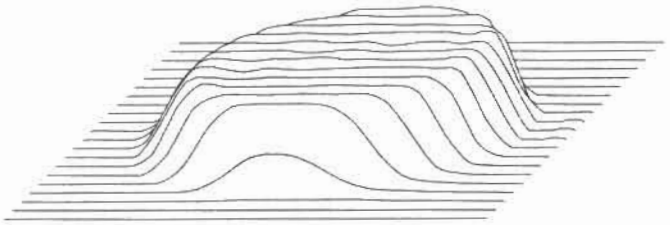
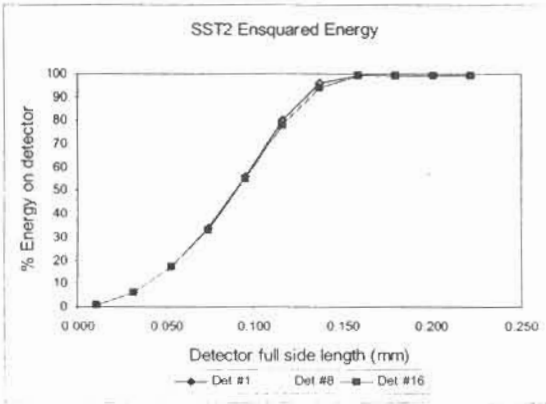
Detectors are sized to pupil images



Pupil image irradiance is uniform across detector active area

Ensquared Energy distribution reaches 100% well inside detector edge



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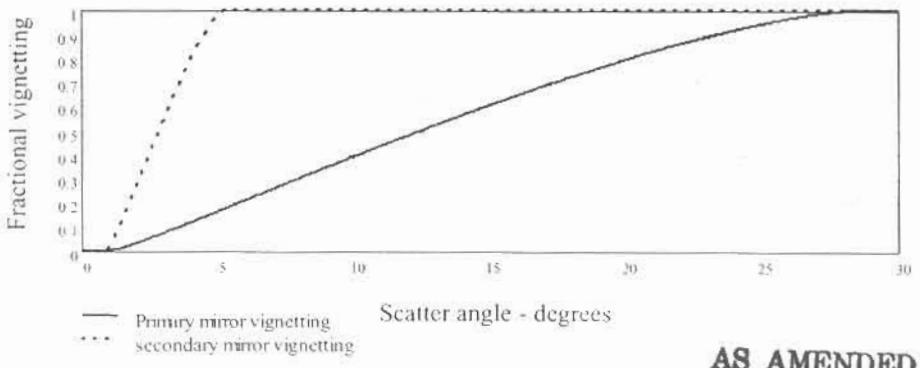
VIIRS rotating telescope reduces scatter at larger angles

- Primary mirror vignetting is convolution of projected telescope tube and primary mirror
- Secondary mirror vignetting is the convolution of entrance aperture projected to secondary mirror



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Additional comments on models

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- Scatter model uses two nodes: fore and aft optics
- Harvey Shack coefficients
  - VIIRS used THEMIS secondary mirror BRDF for all powered mirrors
  - MODIS PFM used near field response fitted data
  - MODIS FM1 used near field response fitted data (TBR)
- Eight VIIRS bands were compared to nearest MODIS bands
- Cloud size: 12 mr square
- Field baffle size:
  - VIIRS - 26 mr by 16 mr
  - MODIS 50 mr by 16 mr
- Scatter angular step size: 1 mr

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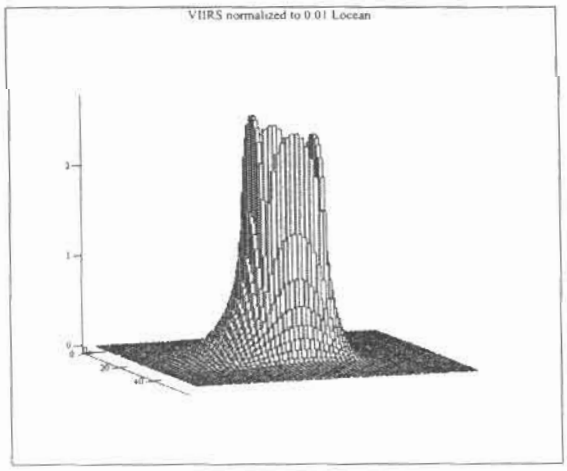
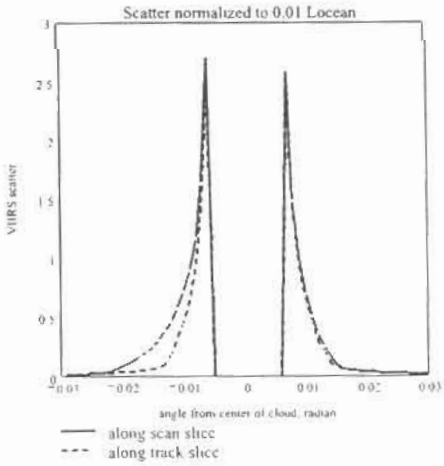
OC 3 has the most critical scatter when normalized to typical scene radiance



VIIRS



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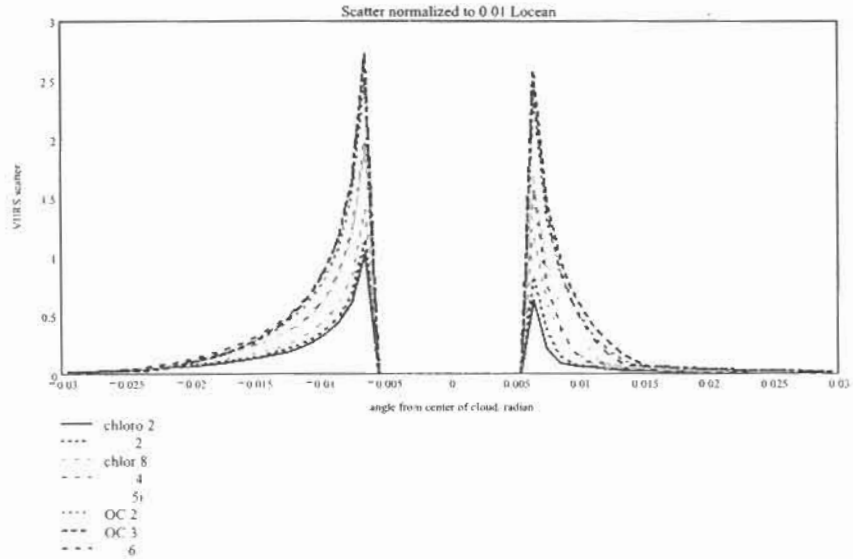
VIIRS scatter model predicts all bands meet 0.01 albedo in presence of 10 km cloud > 6 mr



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Revised SRD Structured Scene Specifications

Structured scene type	SRD requirement
I. Single cloud	
Cloud: size, radiance	10 km square, Lmax
Surround: radiance	Ltyp
Scatter effect	>0.006 mr, effect < 0.01 Ltyp
	>0.003 mr, 0.5 K SST
II. Hole in cloud	
Hole: size, radiance	200 p by 200 , Ltyp
Surround radiance	Lmax
Map cal accuracy-knowledge	% of pixels inside Ltyp region that meets cal accuracy
III. Multiple clouds	
Cloud: size, radiance	50 p square, Lmax
Surround: spacing, radiance	300 p, Ltyp
Map cal accuracy-knowledge	% of pixels in Ltyp region that meets cal accuracy

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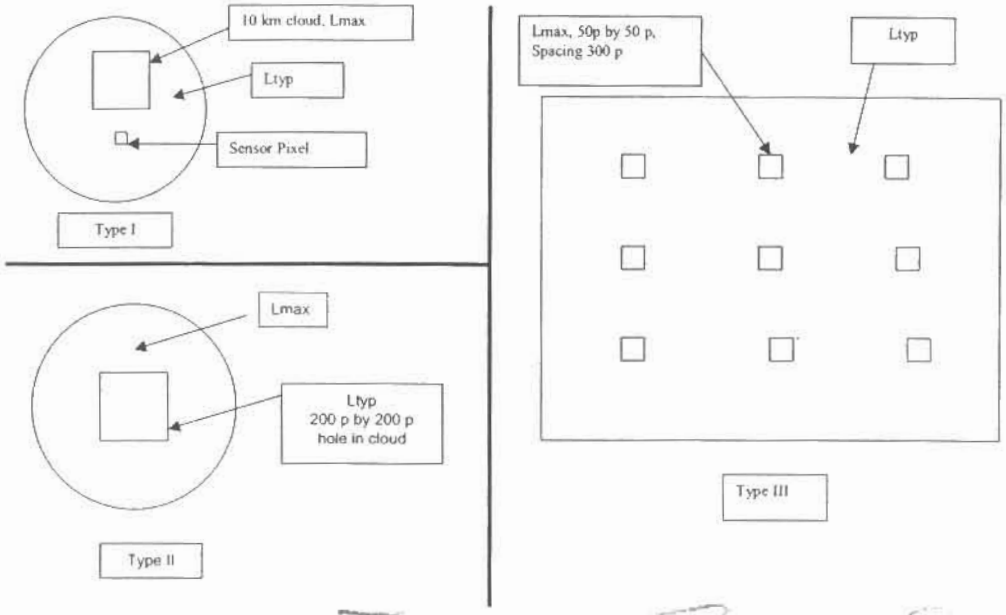
Illustration of Three Types of Structured Scenes



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Structured Scene Test Methodology

- Test methodology is driven by technical feasibility and cost
- Approach uses a suite of system and subsystem characterization
  - Component BRDF (0.2 to 80 deg) along and cross track - primary, secondary of fore optics TMA; other components BRDF (0.2 to 5 deg)
    - Scattering goniometer - 0.63, 3.39, and 10.6 μm lasers
  - VIIRS system level characterization near field cross track (± 6 deg)
  - VIIRS system level characterization near field along track - as needed
  - Far field response within SNR constraints
  - Radiometric calibration (uniform scene)
  - Assessment of uniform scene calibration accuracy

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Validation of VIIRS Sensor Scattering Model

- VIIRS scattering model will be developed based upon optical component BRDF measurements
- This model will be compared with system level near field response
- In the overlapping regions scattering model and near field response need to be consistent
  - System near field response measurements will be assumed correct within SNR constraints
  - Significant differences, if present, need to be understood
  - Model will be adjusted where necessary
- Scattering model will be used to predict VIIRS sensor performance in extended angular regions
- Scattering model will be used in design phase; e.g., adequacy of optical system, FPA layout

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Scatter Model Illustrates Feasibility of Using Diamond Turned Post Polished Mirrors

- Parametric scatter model illustrates the effect of structured scene (Type I) on reflectance accuracy
- THEMIS TMA telescope - Al substrate, Ni plated, diamond turned, post polished has mirror roughness of < 25 A
- Secondary mirror measured roughness agrees with roughness obtained using BRDF data
- Scatter model indicates structured scene reflectance specification will be met
  - Equivalent BRDF used in conjunction with intermediate field baffle and appropriate band placement on FPA

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Dichroic Transmittance Ratio: VIIRS Risk Reduction vs. MODIS FM1

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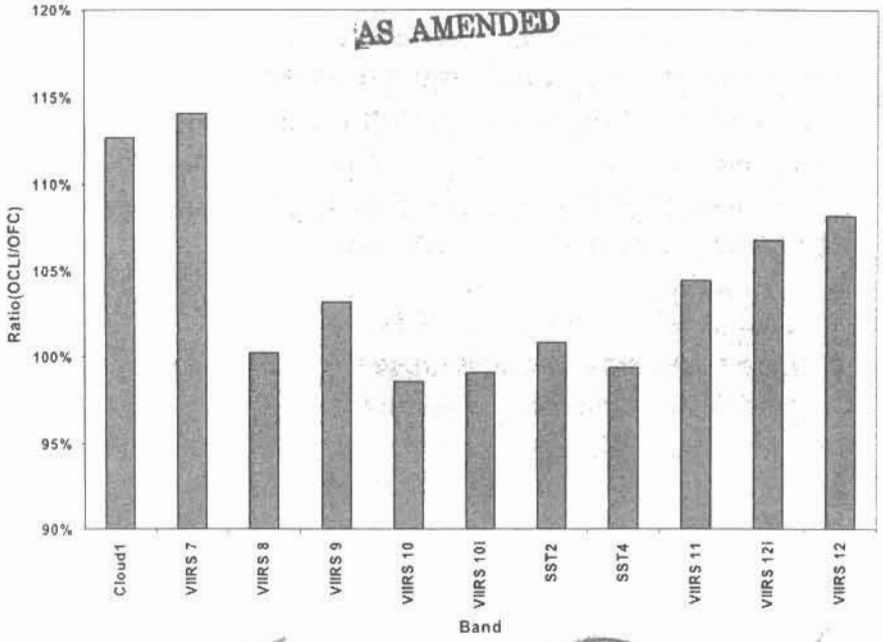

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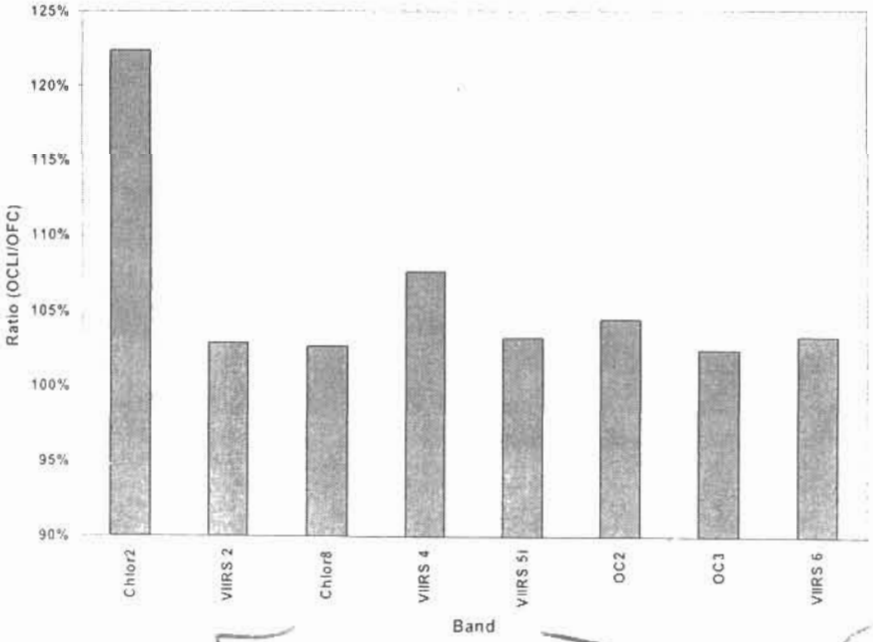
Dichroic Reflectance Ratio: VIIRS Risk Reduction vs. MODIS FM1



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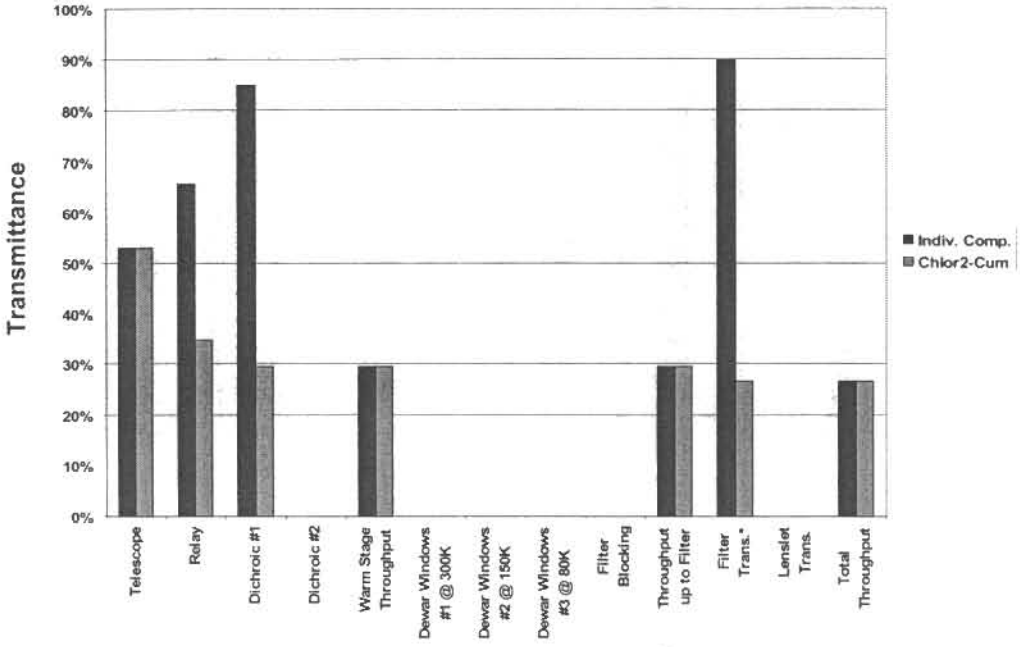
Chlor2 System Transmittance



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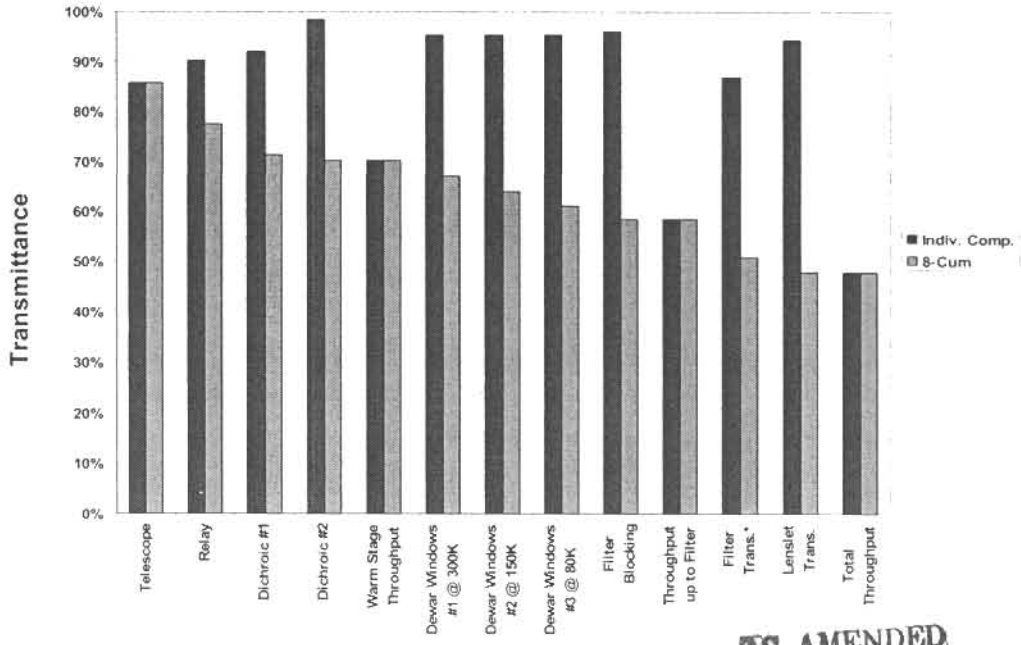
Band 8 System Transmittance



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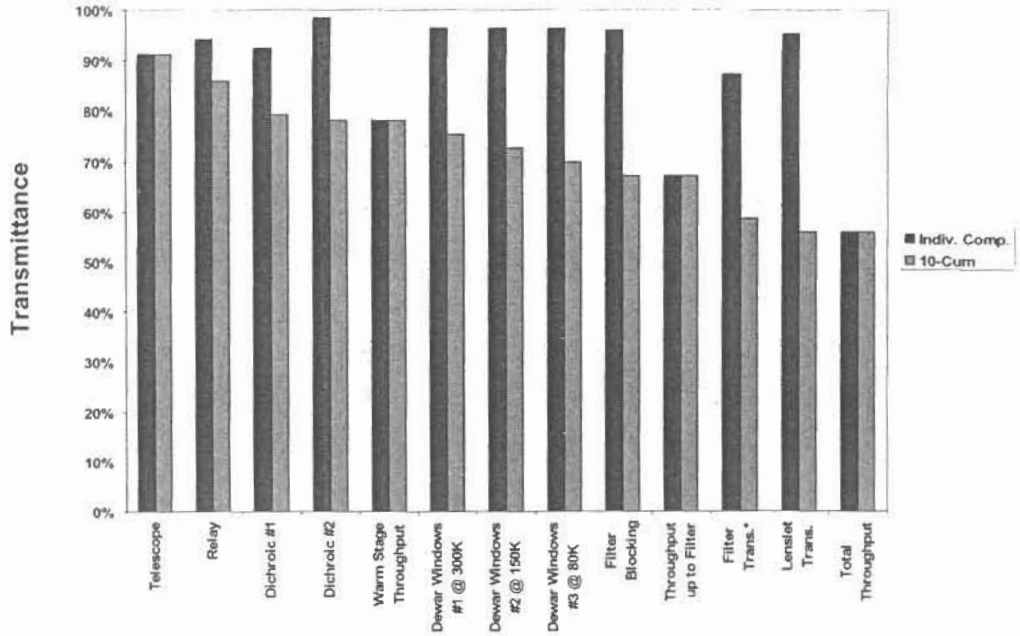
Band 10 System Transmittance



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