NPP VIIRS for Land Studies

(Visible Infrared Imaging Radiometer Suite)

Chris Justice (UMD) and
Robert Wolfe (NASA GSFC)

Land Cover Land Use Change Meeting

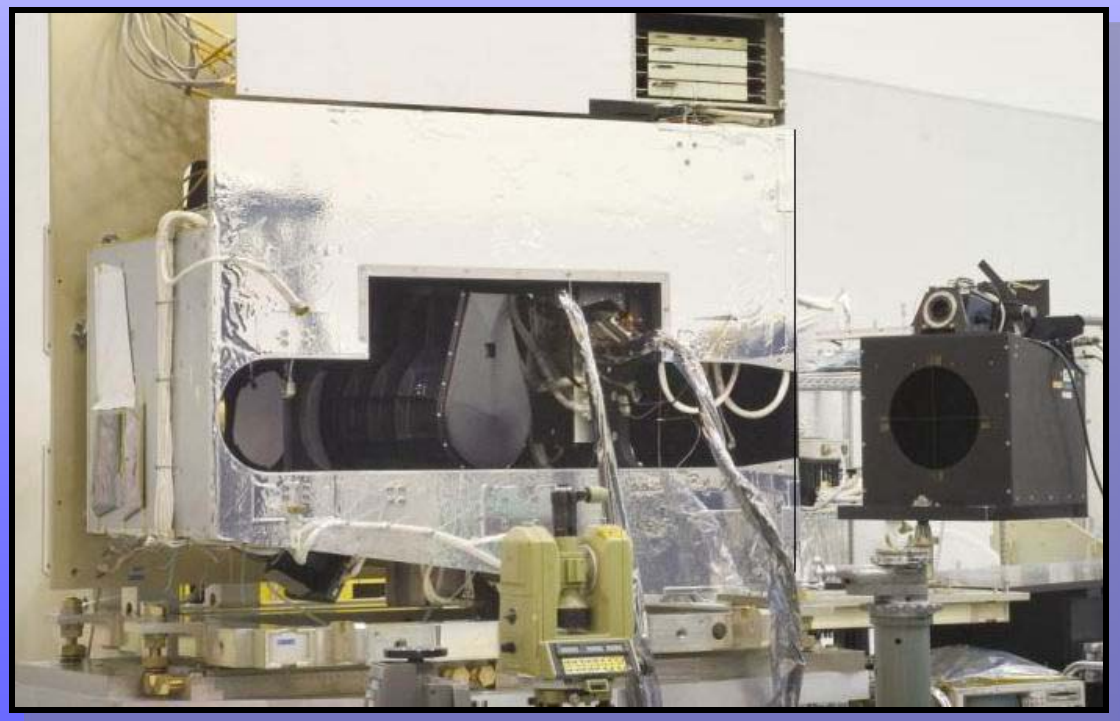
April 1, 2009

Visible Infrared Imaging Radiometer Suite
IPO /NGST/ Raytheon Santa Barbara Remote Sensing

THREE AGENCIES • ONE MISSION

Description

- **Purpose:** Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily)
- **Predecessor Instruments:** AVHRR, OLS, MODIS, SeaWiFS
- **Approach:** Multi-spectral scanning radiometer (22 bands between 0.4 μm and 12 μm) 12-bit quantization
- **Swath width:** 3000 km

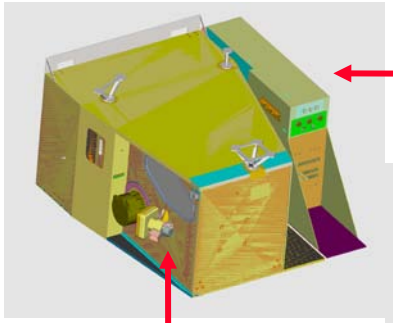


Status

- EDU Finished T/Vac testing
- Flight Unit #1 Development continues

Launch January 2011

VIIRS Sensor Subsystems



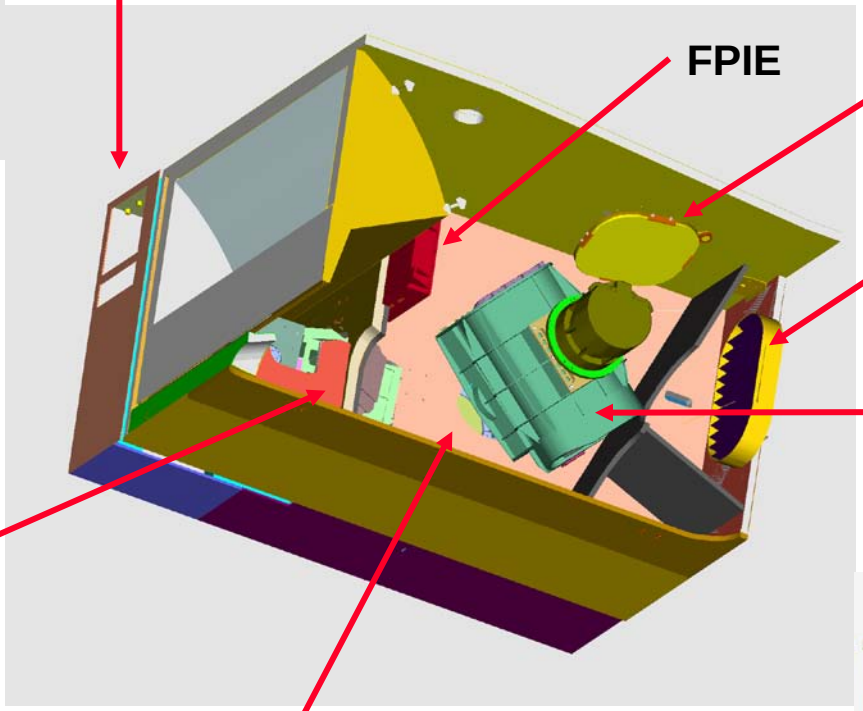
Separately Mounted Electronics Module

Solar Diffuser

FPIE

Blackbody

Solar Diffuser
Stability Monitor



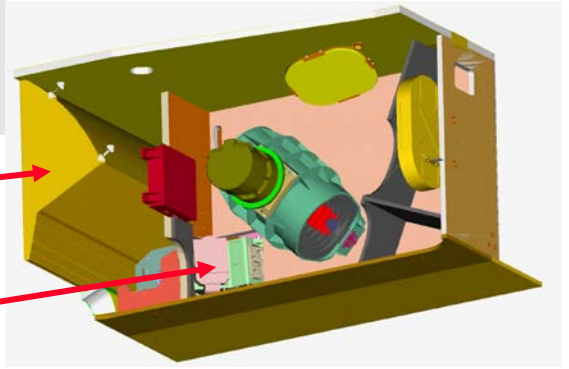
3-Mirror Anastigmat
All reflective
Rotating telescope

4-Mirror Anastigmat
All Reflective
Aft Optics Imager

Cryoradiator

Half-angle Mirror

Cold FPA
Dewar Assembly



MODIS To VIIRS Band Selection

VIIRS Radiometric					VIIRS Geometric			MODIS Radiometric						
Band Name	Band Ctr	Band Width	Ltyp	SNR/ NEDT	GSD Nadir (m)	GSD 850 km (m)	GSD EOS (m)	MODIS Band #	l Min	Band Width	Ltyp	Lmax	NEDL /NEDT	SNR
M1	412 nm	20 nm	155(44.9)	316(352)	742	1093	1597	8	405 nm	15 nm	(44.9)	175	0.051	(880)
M2	445 nm	18 nm	146(40)	409(380)	742	1093	1597	9	438 nm	10 nm	42	133	0.050	176(838)
M3	488 nm	20 nm	123(32)	414(416)	742	1093	1597	10	483 nm	10 nm	5.3 (32)	593	.145/.04	43 (802)
M4	555 nm	20 nm	90(21)	315(362)	742	1093	1597	12	546 nm	10 nm	29	518	.127/.028	28 (750)
I1	640 nm	80 nm	22	119	371	547	799	1	620 nm	50 nm	22			(129)
M5	672 nm	20 nm	68(10)	360(242)	742	1093	1597	13	662 nm	10 nm	9.5	32	0.011	913
M6	746 nm	15 nm	9.6	199	742	1093	1597	15	743 nm	10 nm	10	26	0.017	(600)
M7	865 nm	39 nm	33.4(6.4)	340(215)	742	1093	1597	16	862 nm	15 nm				
I2	865 nm	39 nm	25	150	371	547	799	2	841 nm	36 nm	25	285	0.123	01 (314)
M8	1.24 □	0.020 □	5.4	101	742	1093	1597	5	1.23 □	0.02 □	5.4	110	0.073	74
M9	1.378 □	0.015 □	6	83	742	1093	1597	26	1.36 □	0.030 □	6	90	0.040	150
M10	1.61 □	.06 □	7.3	342	742	1093	1597	6	1.63 □	0.02 □	7.3	70	0.027	270
I3	1.61 □	.06 □	7.3	6	371	547	799							
M11	2.25 □	.05 □	.12	167	742	1093	1597	7	2.11 □	0.05 □	1	22	0.009	111
M12	3.70 □	.18 □	270	0.396	742	1093	1597	20	3.66 □	0.18 □	300K	335	0.050	470
I4	3.74 □	.38 □	270	2.5	371	547	799							
M13	4.05 □	.16 □	380(300)	423(.107)	742	1093	1597	23	4.02 □	0.06 □	300K	328	0.050	364
M14	8.55 □	0.3 □	270	.091	742	1093	1597	29	8.40 □	0.30 □	300K	324	0.050	1065
M15	10.8 □	1.0 □	300K	.070	742	1093	1597	31	10.78 □	0.50 □	300K	324	0.050	1362
M16	12.0 □	1.0 □	300K	.072	742	1093	1597	32	11.77 □	0.50 □	300K	324	0.050	1475
I5	11.5 □	1.9 □	210K	1.5	371	547	799							
DNB	700 nm	400 nm	6.67E-5	6	742	1093	1597							

MODIS Bands not included in VIIRS	
B11, B14	Ocean color and fluorescence
B17, B18, B19	Precipitble water
B22	SST
B24, B25, B27, B28	Sounding
B30	Ozone
B33, B34, B35, B36	Sounding

Red=Imaging Band

Blue = High Gain Band

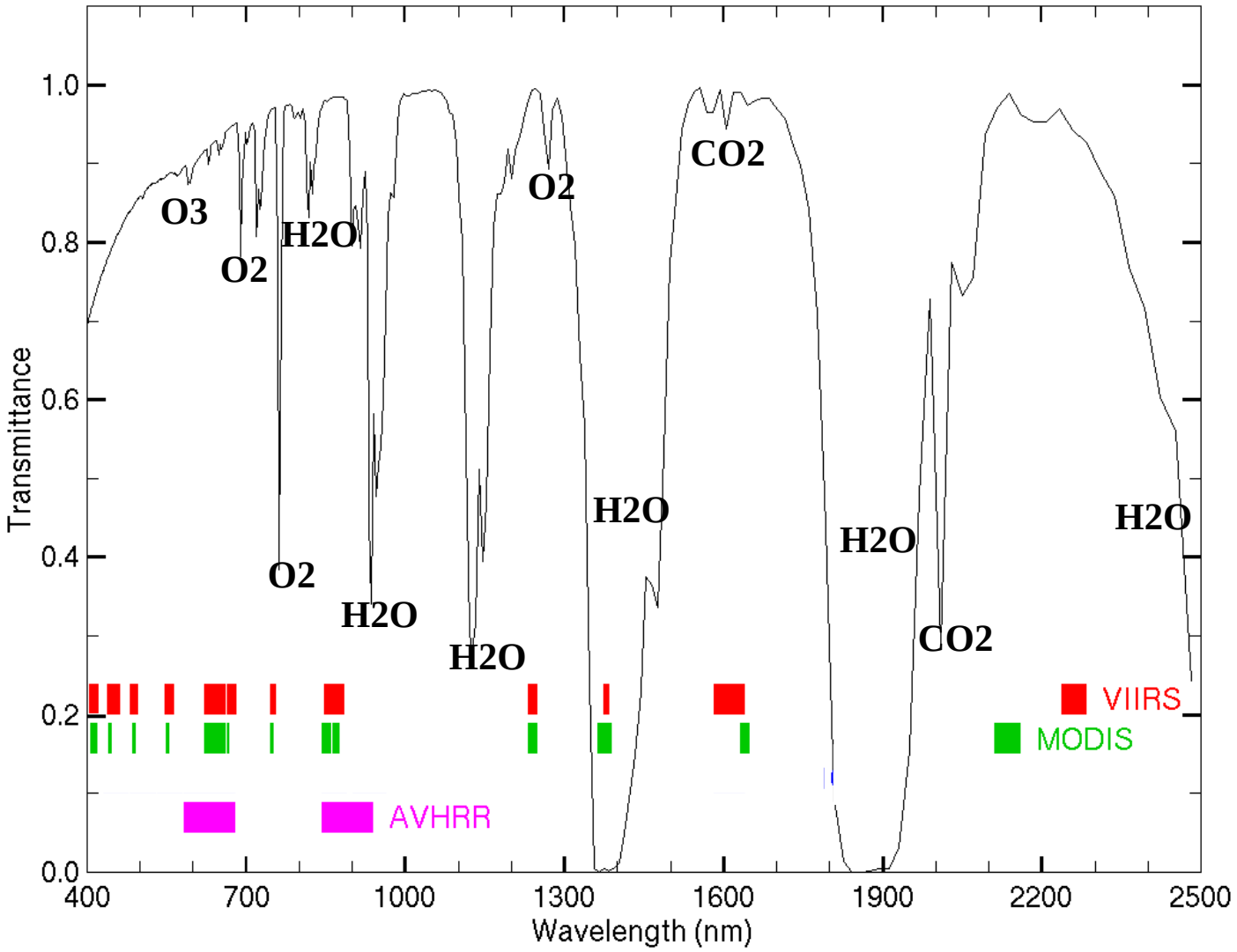
Black= All other Bands

VIIRS Data are from Spec (Jan, 2002)

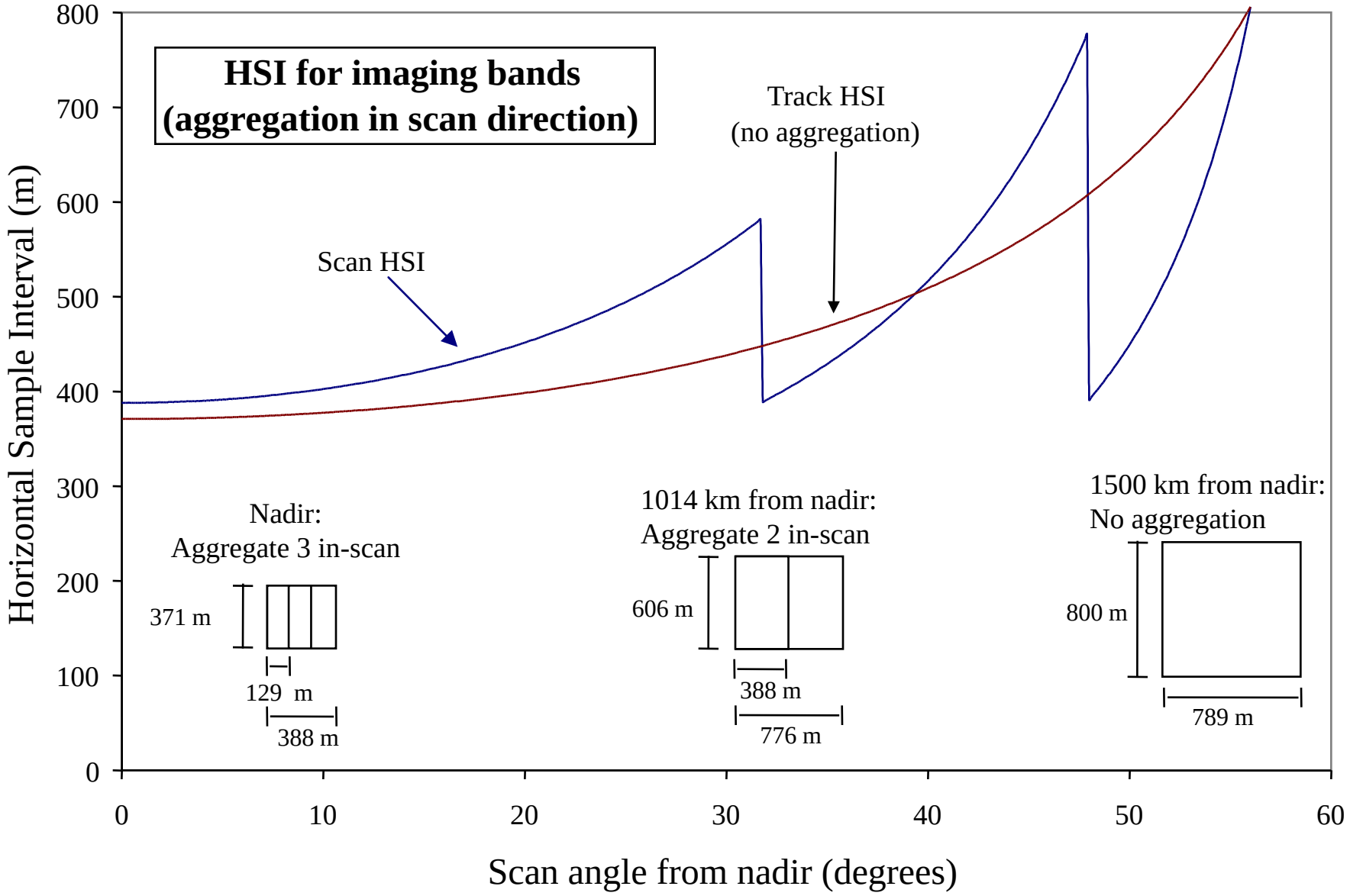
MODIS Data are Spec

Units: W/(m2-sr-µm)

VIIRS Visible, NIR and SWIR Bands



VIIRS Spatial Resolution



FU1 Performance Summary April 2009

- Integ Focal Plane Assembly optical cross-talk present
  - Characterization being done, may be used in look up tables as spectral out of band (ground processing solutions)
    - Doing this in Ocean Color algorithm
    - Confuses spectral and spatial weighting functions
    - Works best in low contrast scenes
- Another cross-talk mechanism present but effects shown by NG analysis to be low
- Gain-change noise and non-linearity present in VisNIR in ~1% of high gain dynamic range
- Scattering, noise and radiometry behaviors generally similar to MODIS in other aspects

Bruce Guenther IPO

Flight Unit 1 – Testing Status

- VisNIR Spectral response testing scheduled as if 31 March for 12 – 16 April (in ambient)
- Close T Vacuum chamber door approximately end April, 2009
- Ground Support Equipment virtually ready for thermal vacuum (but some off Critical Path characterization still needed on spectral test equipment)
- Government Team stepping up to TV F1 data analysis support efforts for mature analysis results in “consent to proceed” meetings
- Delivery to spacecraft still scheduled in 2009

F2 Upgrades

- Already Corrected: Optical Cross-talk on VisNIR focal plane
- Approved for Correction: Gain-switch errors
- Under Study:
  - Down link of M15 pixels unaggregated in both Stored Mission Data and High Rate Data link
  - Calibration over full dynamic range of high radiance IR bands (folding)

Environmental Data Records

By Discipline

★	Atmos Vert Moist Prof
★	Atmos Vert Temp Prof
★	Imagery
★	Sea Surf Temp
★	Sea Surf Winds
★	Soil Moisture
	Aero Opt Thickness
	Aerosol Particle Size
	Albedo (Surface)
	Auroral Boundary
	Auroral Imagery
	Cloud Base Height
	Cloud Cover/Layers
	Cloud Eff Particle Size
	Cloud Ice Water Path
	Cloud Liquid Water
	Cloud Opt Thickness
	Cloud Top Height
	Cloud Top Pressure
	Cloud Top Temp
	Cloud Part Size / Dist

Dn Lwave Rad (Sfc)
Electric Field
Electron Density Prof
Aero Refractive Index
Geomagnetic Field
Ice Surface Temp
Energetic Ions
In-situ Plasma Fluct
In-situ Plasma Temp
Downward Swave Rad
Med Energy Particles
Ionospheric Scint
Land Surface Temp
Surface Type
Net Heat Flux
Net Solar Rad (TOA)
Neutral Density Profile
Total Water Content
Vegetation Index
Ocean Color / Chlor
Ocean Wave Char

Ozone-Tot Col/Profile
Precipitable Water
Precip Type / Rate
Pressure (Surf/Profile)
Sea Ice Age Char
Sea Surface Hgt/Topo
Snow Cover/Depth
Solar Irradiance
ST- Auroral Particles
Surface Wind Stress
Suspended Matter
Auroral Energy Depos
Out Lwave Rad (TOA)
Atmospheric
Oceanic
Terrestrial
Space Environment
Climate

LEGEND

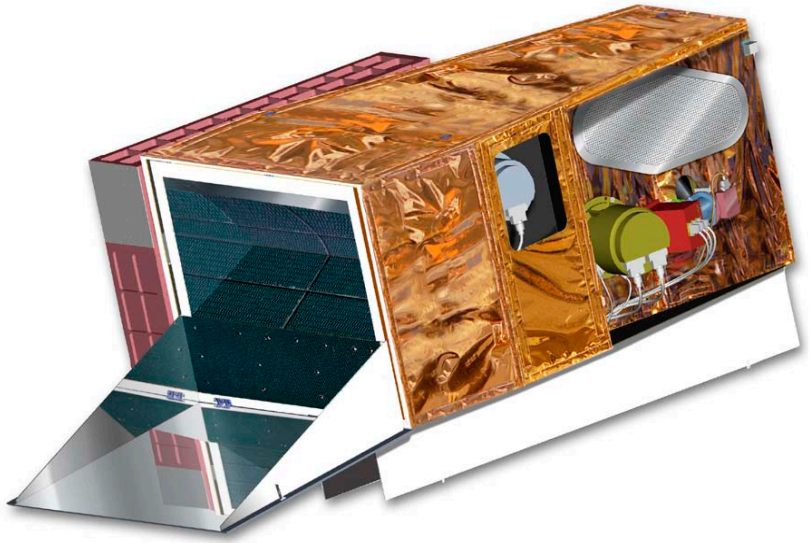
★ **- Key Performance Paramss**

VIIRS Land Bands

	M1	M2	M3	M4	I1	M5	M7	I2	M8	M10	I3	M11	M12	M13	M15	I5	M16
Wavelength (um)	0.412	0.445	0.488	0.555	0.64	0.672	0.865	0.865	1.24	1.61	1.61	2.25	3.7	4.05	10.76	11.45	12.01
Land Surface Temp.													x	x	x		x
Active Fires						x	x					x		x	x		x
Vegetation Index			x		x			x									
Snow Cover (Binary)					x			x			x					x	
Snow Cover (Fraction)	x	x	x	x			x		x	x		x					
Surface Type	x	x	x	x		x	x		x	x		x	x	x	x		x
Surface Albedo	x	x	x	x	x	x	x		x	x		x					
Ice Surface Temp.															x	x	x
Sfc Reflectance (IP)	x	x	x	x	x	x	x	x	x	x	x	x					

VIS	NIR	SWIR	MWIR	LWIR

x	Imagery Resolution
x	Moderate Resolution



Land/Cryosphere Products

Discipline	Sensor	General Product	Priority Category for NPP*	Number of VIIRS-based Products
Land/ Cryosphere	VIIRS	Land Surface Temperature (LST)	II-A	1
		Surface Type	II-A	2^
		Albedo (Surface)	II-A	1#
		Vegetation Index	II-A	2
		Sea Ice Characterization* (age, motion, edge, concentration)	II-A*	1*
		Ice Surface Temperature (IST)	II-A	1
		Snow Cover/Depth	II-A	3
		Active Fires ARP	II-B	2
		Surface Reflectance IP	N/A	1

Summary Product Specs

EDR	Horizontal Cell Size (nadir) [km]	Precision	Accuracy	Uncertainty
Land Surface Temperature	0.75	0.5 K	2.4 K	N/S
Surface Type	1.0	N/S	N/S	70% (PCT*)
Albedo	0.75^	0.02	0.035	0.03
Active Fires (ARP)	0.75	N/S	N/S	50 K (subpixel temperature) 30% (subpixel area)
Vegetation Index	0.375**	0.02**	0.016 (NDV) 0.11 (EVI)	0.02 (TOA NDI) 0.11 (TOC EVI)
Surface Reflectance IP &&	0.375 (I##), 0.75 (M)	N/S	N/S	<0.01#
Snow Cover/Depth	0.4 (binary) 0.8 (% cover)	N/S	N/S	90% (binary PCT*) 10% (% cover)
Ice age	2.4	N/S	N/S	70% PCT (ice free, new/young, other)
Ice concentration (MIS)	20	N/S	N/S	1/10
Ice surface temperature (IST)	30	N/S	N/S	1 K
Ice motion	3	N/S	N/S	1 km/day

Surface Albedo EDR

- The VIIRS EDR Surface Albedo algorithm consists of two sub-algorithms, bright pixel sub-algorithm (BPSA). The BPSA is a regression approach and is the Default Algorithm.
- The dark pixel sub-algorithm (DPSA) is broadly based on the MODIS approach, is the backup.

EDR/Attribute	Appendix D EDR Requirements
Horizontal Reporting Interval	
1. Edge of Swath	1.6 km
2. Nadir	0.75 km
Horizontal Cell Size	4 km (TBR)
Horizontal Coverage	Global
Measurement Range	0 - 1.0 Units of Albedo
Measurement Accuracy	0.03 Units of Albedo
Measurement Precision	0.02 Units of Albedo
Long Term Stability	0.01 Units of Albedo
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	24 hrs, Daytime and Clear Only
Latency	NPP - 150 min.
	NPOESS - 28 min.
Degraded Measurement Conditions:	
1. Measurement Accuracy If Solar Zenith Angle 65 to 85 deg	0.04 Units of Albedo
2. Measurement Precision If Solar Zenith Angle 65 to 85 deg	0.04 Units of Albedo
3. Over Ocean, the ratio of the Rayleigh-corrected radiance of Band M2 to Band M4 is greater than or equal to 0.95 (TBR).	0.1 Units of Albedo (TBR)
4. Regions containing sea ice	0.3 Units of Albedo (TBR)
Excluded Measurement Conditions:	
1. Solar Zenith Angle > 85 deg	
2. Aerosol Optical Thickness > 1.0	
3. With scattering error greater than what would exist at a point 6 milliradians away from the VIIRS Bright	

Land Surface Temperature EDR

- The VIIRS dual split window day/night LST algorithm establishes one equation for each IGBP surface type by using 4 Moderate Resolution VIIRS brightness temperatures at 10.8, 12.0, 3.8, and 4.0 mm (M12, M13, M15, and M16), and a solar zenith angle correction during the daytime. In sun glint regions, the fallback split window algorithm is employed using only M15 and M16.
- Measurement Precision spec of 0.5K is considered unattainable given current state of available land emissivity models.

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	
1. Nadir	0.75 km
2. Edge of Swath	1.3 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	213 K - 343 K
Measurement Accuracy	2.4 K
Measurement Precision	0.5 K
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	6 hrs
Latency	NPP - 140 min.
	NPOESS - 28 min.
Clear Measurement Precision Degradation Condition: Satellite Zenith Angle greater than 40 degrees	1.5 K (TBR)
Excluded Measurement Condition:	
1. Aerosol Optical Thickness > 1.0	
2. Thin cirrus as indicated by Cloud Mask Think Cirrus Flag	
3. Fire as indicated by Cloud Mask Fire Flag	

Surface Type EDR

- At the global scale, the VIIRS Surface Type algorithm will map 17 IGBP surface types. The Surface Type EDR algorithm, consists of extracting:
  1. Surface type according to the Quarterly Surface Type IP, snow mask and fire masks,
  2. Computing the Green Vegetation Fraction, which uses the internally computed Vegetation Index.

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	1 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	
1. Vegetation/Surface Type	17 Types
2. Vegetation Cover	0 - 100 %
Measurement Accuracy (Vegetation Cover)	20%
Measurement Precision (Vegetation Cover)	10%
Correct Typing Probability (Vegetation /Surface Type)	70%
Mapping Uncertainty, 3 Sigma	1.5 km
Max Time Between Local EDR Updates	24 hrs
Latency	NPP - 140 min.
	NPOESS - 28 min.
Excluded Measurement Condition: Aerosol Optical Thickness > 1.0	

Vegetation Index EDR

- The VIIRS Vegetative Index EDR produces a (TOA) NDVI and a (TOC) Enhanced Vegetation Index.
- The TOA NDVI calculation uses NDVI formulation with TOA reflectance inputs. It combines the 375 m resolution red (640 nm – I1) and near infrared (865 nm – I2) band TOA reflectances.

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	
1. Edge of Swath	0.8 km
2. Nadir	0.375 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	
1. NDVI Units	-1 to +1
2. EVI Units	-1 to +1
Measurement Accuracy	0.016 NDVI Units
Measurement Precision	0.02 NDVI Units
Long Term Stability	0.01 NDVI Units
Mapping Uncertainty, 3 Sigma	
1. Nadir	0.4 km
2. Edge of Swath	1.5 km
Max Local Average Revisit Time	24 hrs, Daytime Only
Measurement Uncertainty for EVI	0.11 Units of EVI
Long Term Stability	0.01 NDVI Units
Latency	NPP - 140 min. NPOESS - 28 min.
Measurement Degradation Conditions:	
1. EVI Measurement Uncertainty if Solar Zenith Angle 65 to 85 deg	0.2 EVI Units
Measurement Exclusion Conditions:	
1. Solar Zenith Angle > 85 deg, for both NDVI and EVI	
2. Aerosol Optical Thickness > 1.0, for EVI	

Active Fires ARP

- The current implementation of the VIIRS Active Fires ARP is a "sparse array" fire product consisting only of the LAT/LON of fire locations. Area and Temp spec will not be met
- Science Team is developing a MODIS continuity product

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size (HCS)	
1. At Nadir	0.75 km
2. Worst Case	1.6 km
Horizontal Reporting Interval	HCS
Horizontal Coverage	Land
Measurement Range	
1. Sub-pixel Average Temperature of Active Fire	800 K - 1200 K
2. Sub-pixel Area of Active fire	From 1000 m^2 to 50 m Times Ground Sample Distance in Scan Direction
Measurement Uncertainty	
1. Sub-pixel Average Temperature of Active Fire	50 K
2. Sub-pixel Area of Active Fire when computed for total area of contiguous fires	30%
Mapping Uncertainty, 3 Sigma	1.5 km
Maximum Local Average Revisit Time	6 hrs
Latency	NPP - 140 min NPOESS - 28 min
Exclude Measurement Condition	
Aerosol Optical Thickness > 1.0	

2007/296 - 10/23 at 18 :25 UTC, Ca
http://rapidfire.sci.gsfc.nasa.gov/gallery/2007296-1825/California.A2007296.1825.1km.jpg

Snow Cover EDR

- The VIIRS Snow Cover EDR provides the extent of snow cover. Additionally Snow Fraction and Binary Snow /No Snow products will be produced. VIIRS EDR does not provide sub-pixel snow fractional coverage

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size	
1. Nadir	0.8 km
2.Edge of Swath	1.6 km
Horizontal Reporting Interval	HCS
Snow Depth Ranges	Snow/No Snow
Horizontal Coverage	Land
Measurement Range	0 - 100% of HCS
Measurement Uncertainty	10% of HCS (Snow/No Snow)
Mapping Uncertainty, 3 Sigma	1.5 km
Max Local Average Revisit Time	24 hrs Daytime Only
Binary HCS	
1. Nadir	0.4 km
2. Edge Of Swath	0.8 km
Long Term Stability	10%
Latency	NPP - 140 min.
	NPOESS - 28 min.
Binary Map- Measurement Range	Snow/No Snow
Binary Map- Probability of Correct Typing	90%
Measurement Uncertainty Degradation If Solar Zenith Angle 70 to 85 deg	40% of HCS (Snow/No Snow)
Measurement Exclusions:	
1. Snow Fraction Measurement Exclusion Condition: Horizontal Cell Contains Forest Canopy	
2. Binary Map Probability of Correct Typing Exclusion Condition: Snow Fraction 0.2 to 0.7 or Solar Zenith Angle > 60 deg	
3. All Measurements If Aerosol Optical Thickness > 1.0	
4. All Measurements If Solar Zenith Angle > 85 deg	

Ice Surface Temperature EDR

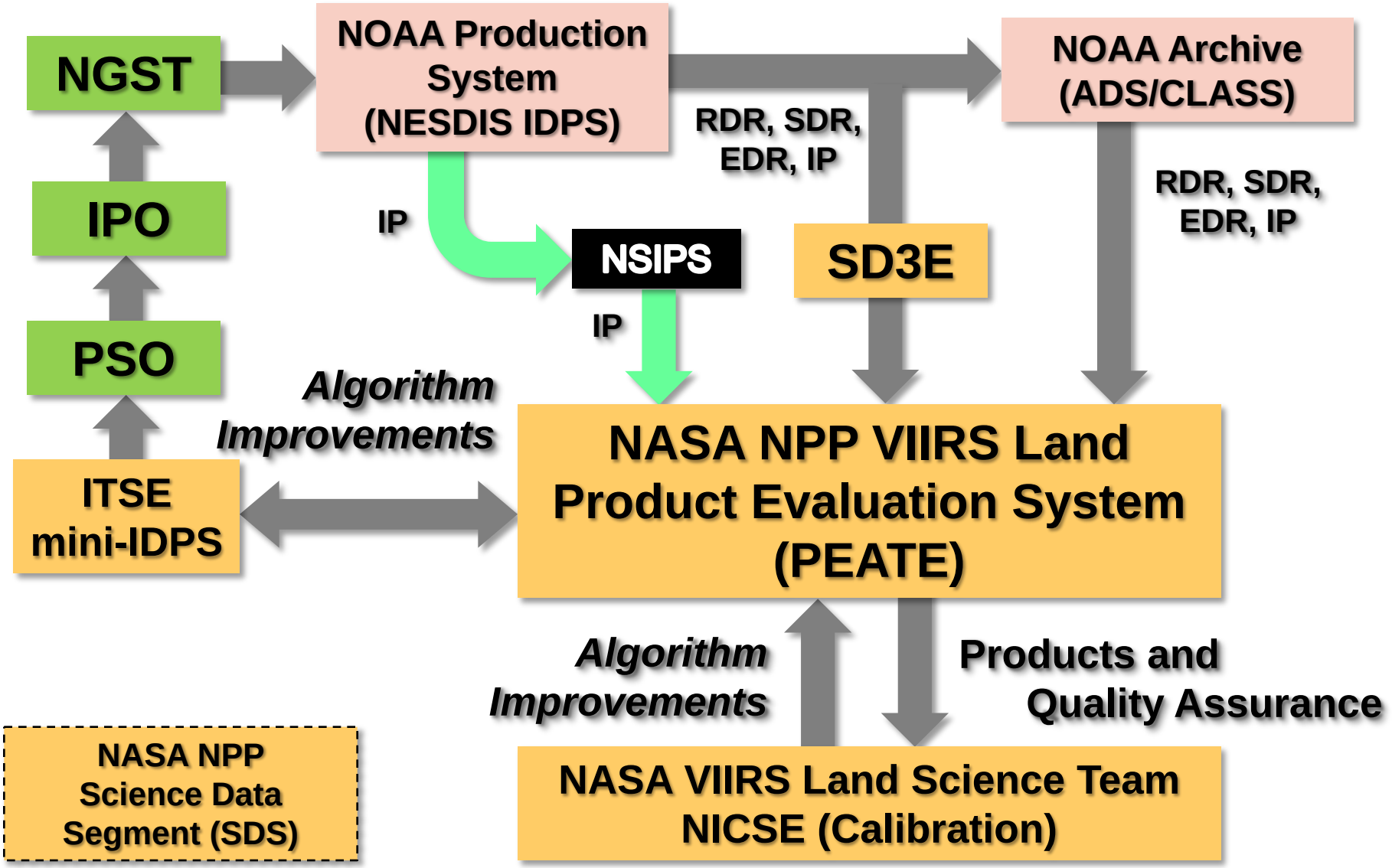
- The VIIRS algorithm is a regression technique and employs a two-band split-window water vapor correction method using brightness temperatures from two 750 m resolution bands in the LWIR, 10.76 and 12.01 microns (M15 and M16).

EDR/Attribute	Appendix D EDR Requirements
Horizontal Cell Size (HCS)	
1. Nadir	0.8 km
2. Worst Case	1.6 km
Horizontal Reporting Interval	1.0 km
Horizontal Coverage	Ice-covered Oceans
Measurement Range	213 K - 275 K
Measurement Uncertainty at Horizontal Reporting Interval	0.5 K
Mapping Uncertainty, Nadir, 3 Sigma	0.4 km
Maximum Local Average Revisit Time	24 hrs
Latency	NPP - 140 min.
	NPOESS - 28 min.
Measurement Exclusion Condition:	
1. Aerosol Optical Thickness > 1.0	
2. Inland waters	
3. Coastal waters	
4. Thin cirrus as indicated by Cloud Mask Thin Cirrus Flag	

NPP VIIRS Current Status

- **Land EDR's**
  - Code developed by NGST – being inserted into operational chain and tested in the IDPS
- **VIIRS Land Processing System** (Land PEATE) **established at GSFC** (Masuoka et al)
  - collocated with the MODIS Land Processing System – builds on MODAPS experience
  - Currently testing operational code
- **NASA NPP Science Team** – Land Subgroup
  - Science team has identified a number EDR limitations for science use , continued evaluation underway
  - Science team algorithms in development for comparison evaluation
- **IPO reviewing plans for EDR Validation inc. Land**
  - IPO funding in process for developing some validation infrastructure
  - Validation Session at the **Montana Global Vegetation Workshop, June 13-15 2009**

Product Evaluation Flow



NASA NPP Land Science Team

Science Team Members	Product
R. Wolfe	Geolocation
E. Vermote, A. Lyapustin	Land Surface Reflectance
C. Schaaf	Albedo
Z. Wan, S. Hook	Land Surface Temperature
D. Hall, J. Maslanik	Snow Cover
M. Friedl	Surface Type
I. Csiszar, C. Justice	Active Fires, (Burned Area)
D. Hall, J. Maslanik	Ice Surface Temperature
A. Huete, R. Myneni	Vegetation Indices, (LAI)

Land Earth Science Data Records

- VIIRS ESDR's that are now in development by the Team (last round of proposals)
  - LST
  - S. Ref > Composited NDVI and EVI
  - Fire (w. IPO support)
  - LAI
  - Land Cover and Phenology
  - Sea Ice Cover
- Most will use MODIS C6 code

VIIRS Land

- Land Team Coordination
  - Telecons every two weeks
    - include other agencies, IPO and VOAT – no longer have separate interagency coordination telecon
- NPP Science Team Meeting

  - probably in the Fall jointly with MODIS, after FU1 comes out of TVac
- Need to look ahead to the second VIIRS launch decisions getting made now
  - What are the instrument upgrades needed to meet science needs - a list was developed at the last ST Meeting (Jim Butler) - is NASA currently advocating any changes?
  - The product specs (IORD) were developed prior to the launch of MODIS - they need to be revisited – is NASA advocating any changes?

NPP VIIRS Outstanding Issues

- EDR validation planning and prototyping underway – some IPO support in process – focused land community effort needed
- Land PEATE Budget Post Launch (staffing)
- NASA plans for ESDR generation
- FU2 Changes – NASA's must have changes?
- Revisit the IORD (NASA recommendations?)
- Data System Lessons Learned - need to continue to be shared