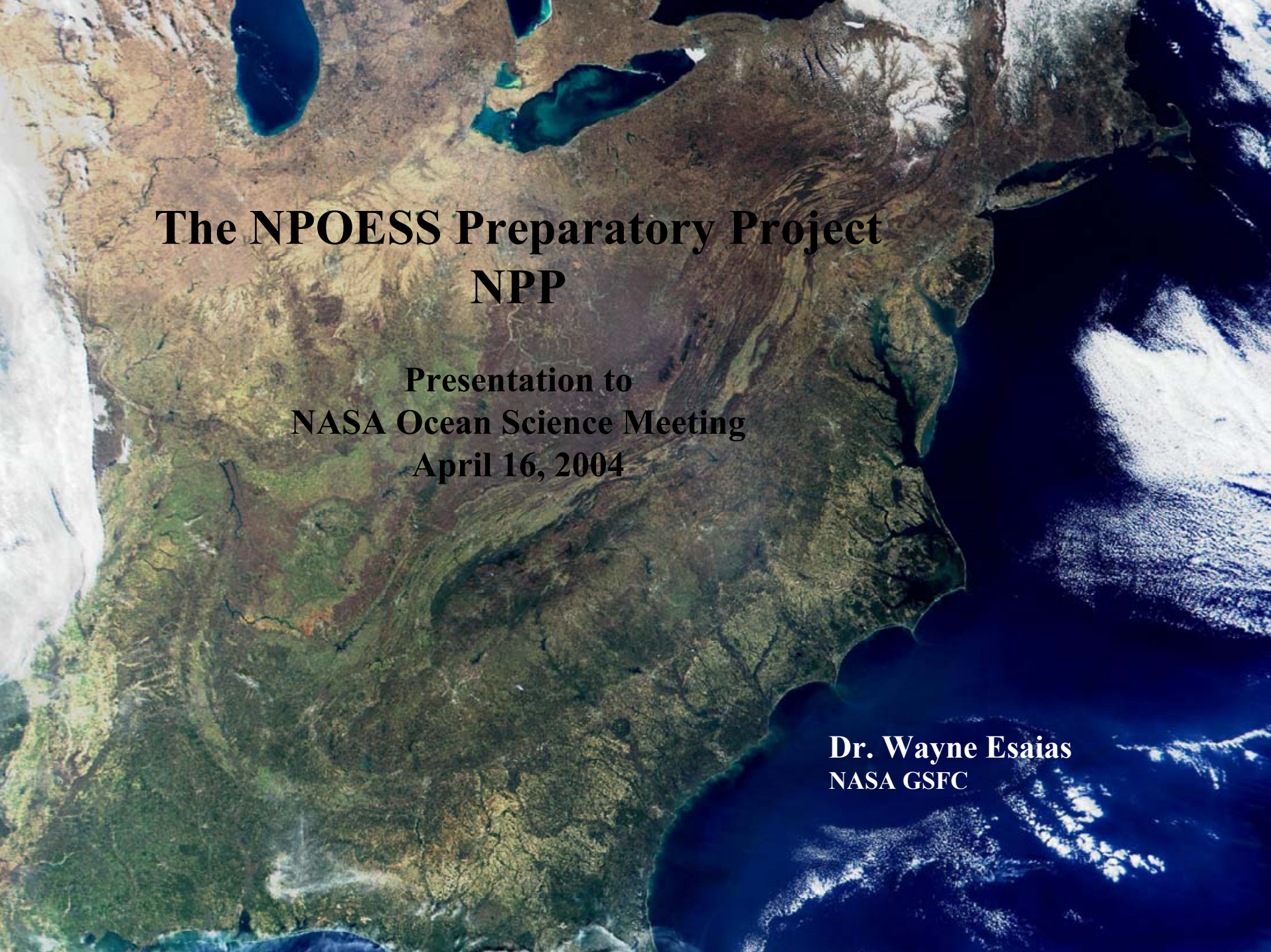


The NPOESS Preparatory Project NPP

Presentation to
NASA Ocean Science Meeting
April 16, 2004

Dr. Wayne Esaias
NASA GSFC

NPP Sensors

- **The Visible Infrared Imaging Spectroradiometer Suite (VIIRS) extends measurement series initiated by MODIS on EOS Terra & Aqua**
  - **Design is evolutionary from MODIS**
- **The Cross-track Infrared Sounder (CrIS) continues measurement series initiated by AIRS on EOS Aqua**
  - **Utilizes a Michelson interferometer in contrast to AIRS, which is a spectrometer**
- **The Advanced Technology Microwave Sounder (ATMS) continues the measurement series initiated by the AMSU on NOAA-15**
  - **MMIC Technology used to reduce mass, power & volume**
- **The Ozone Mapping and Profiling Suite (OMPS) continues the measurement series of SBUV & TOMS and adds a new limb profiler**

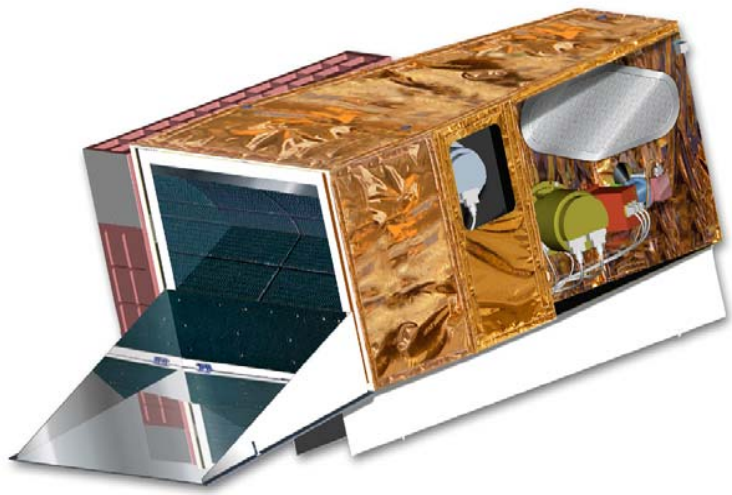
Brief Background

- **Tri Agency (Integrated Program Office) convergence by directive.**
- **Environmental Data Record (EDR) Requirements were generated by operational agencies (NOAA, DOD) for NPOESS.**
- **Multiple Competitive (Algorithm + Instrument) Studies.**
- **Overall system operation and product delivery approach evolved to a shared (gov + contractor) responsibility.**
- **NPOESS Preparatory Project originated (by NASA) as a useful data continuity and risk reduction step.**

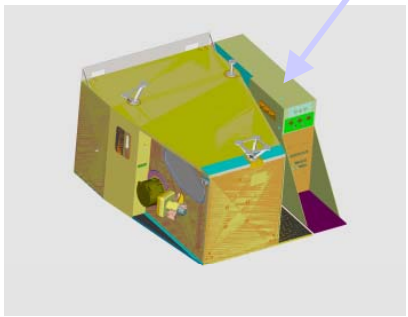
Visible Infrared Imaging Radiometer Suite (VIIRS)

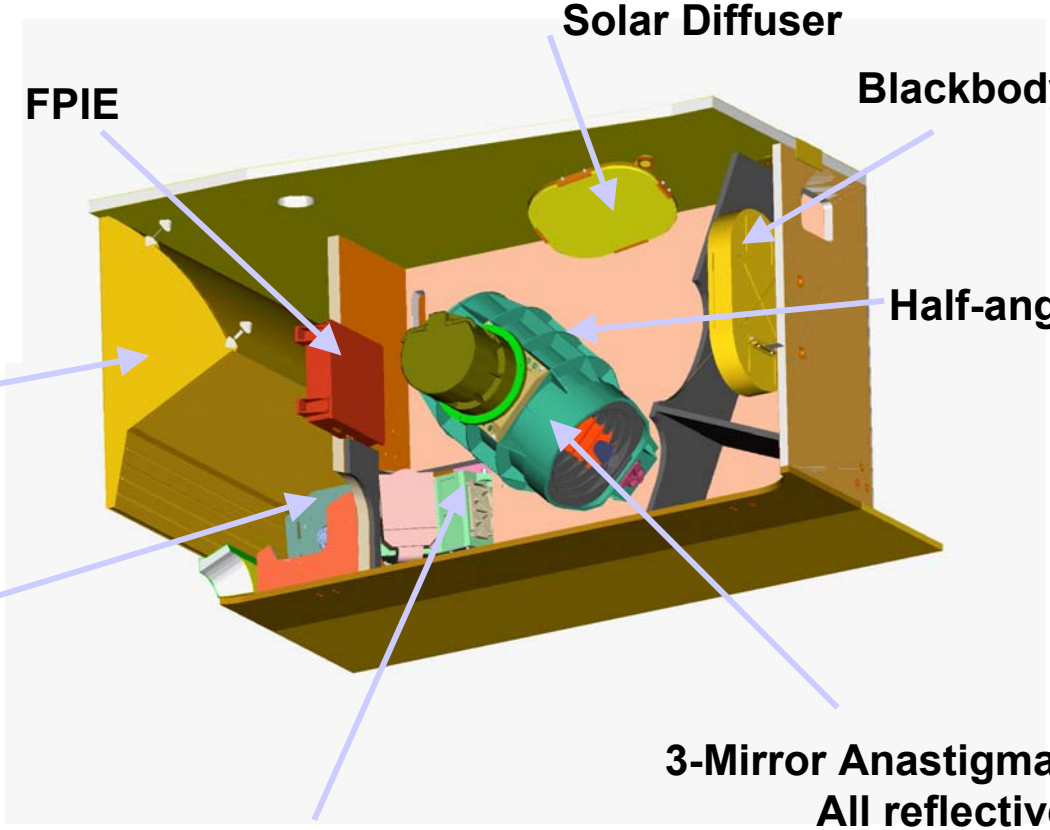
- **Purpose:** **Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily)**
- **Predecessor Instruments: AVHRR, OLS, MODIS, SeaWiFS**
- **Management: Integrated Program Office**
- **Status:Phase C/D (Raytheon)**
- **Approach:** **Multi-spectral scanning radiometer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

- **Changes to specifics of band dynamic ranges, bandpasses & band centers negotiated**
- **Consideration of adding 6.7 micrometer water vapor band to FU3 & later models**
- **CDR Completed March 2002**



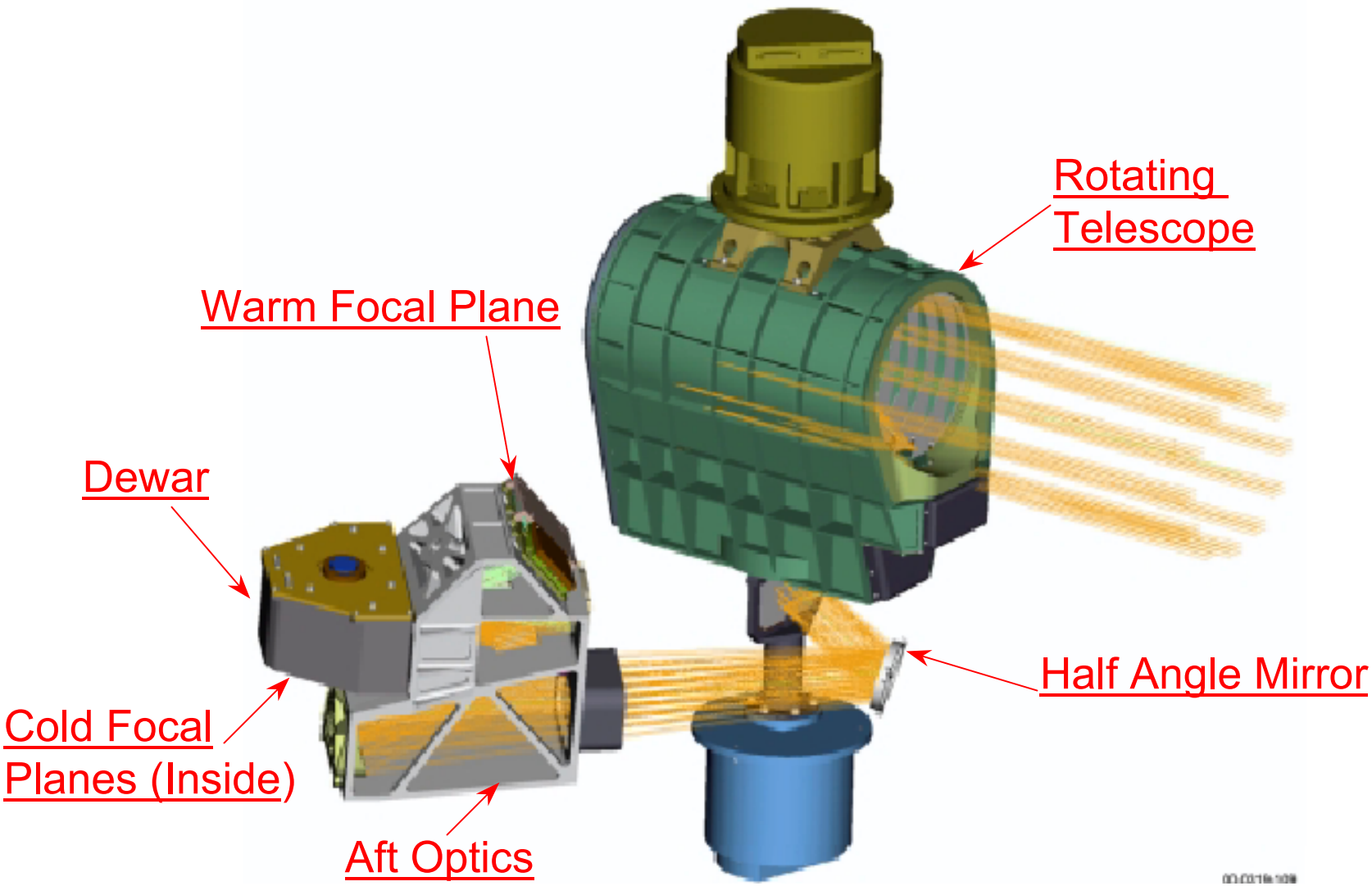
Visible Infrared Imaging Spectroradiometer (VIIRS)





Compact, All Reflective Optical Design

Yields Lower Scattered Light than MODIS



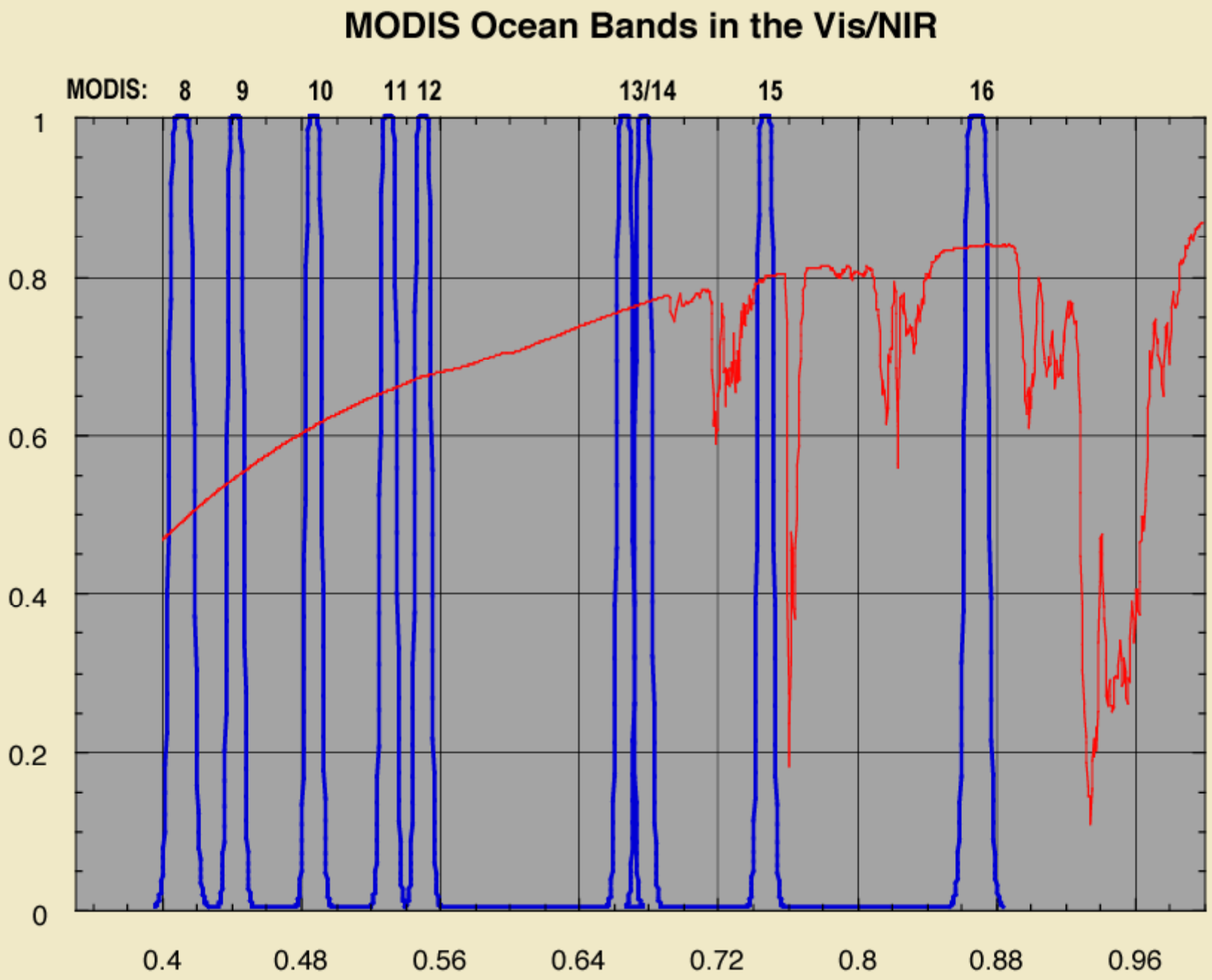
VIIRS Spectral Bands

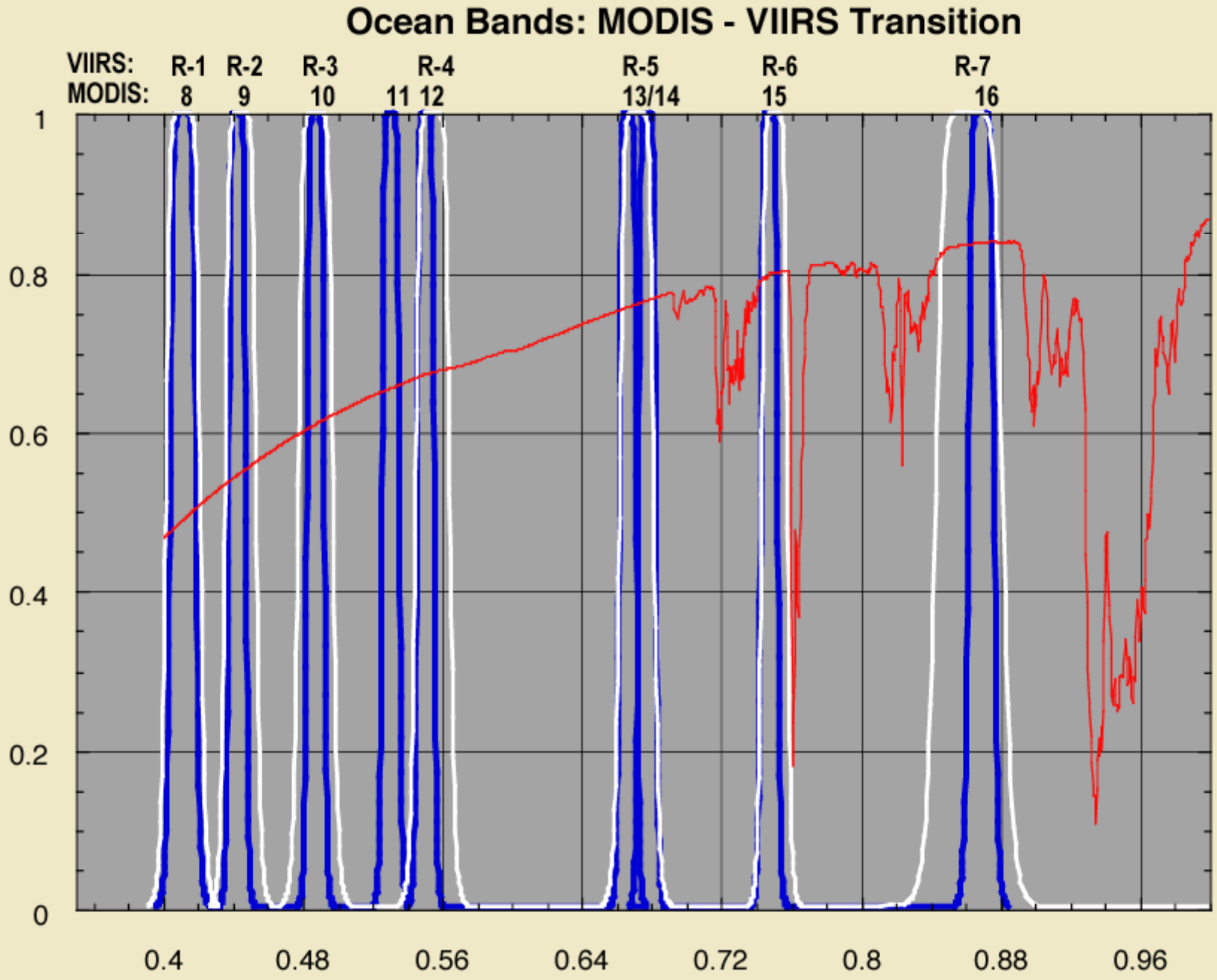
- **22 Bands**
  - **Subset of MODIS bands plus day-night panchromatic band**
- **Two spatial resolutions**
  - **Imagery resolution bands: 370 m at nadir**
  - **Moderate resolution bands: 740 m at nadir**
- **Features**
  - **8 (Moderate) or 16 (Imagery) detectors per scan**
  - **Bands spatially nested**
  - **Some bands have dual gain**
    - **> Maximize dynamic range without precision penalties**
- **Constrained pixel growth with scan angle**
- **Ocean bands derived from OCCG recommendations**

VIIRS' 0ptimized Bandset Provides Rich Data for All EDRs

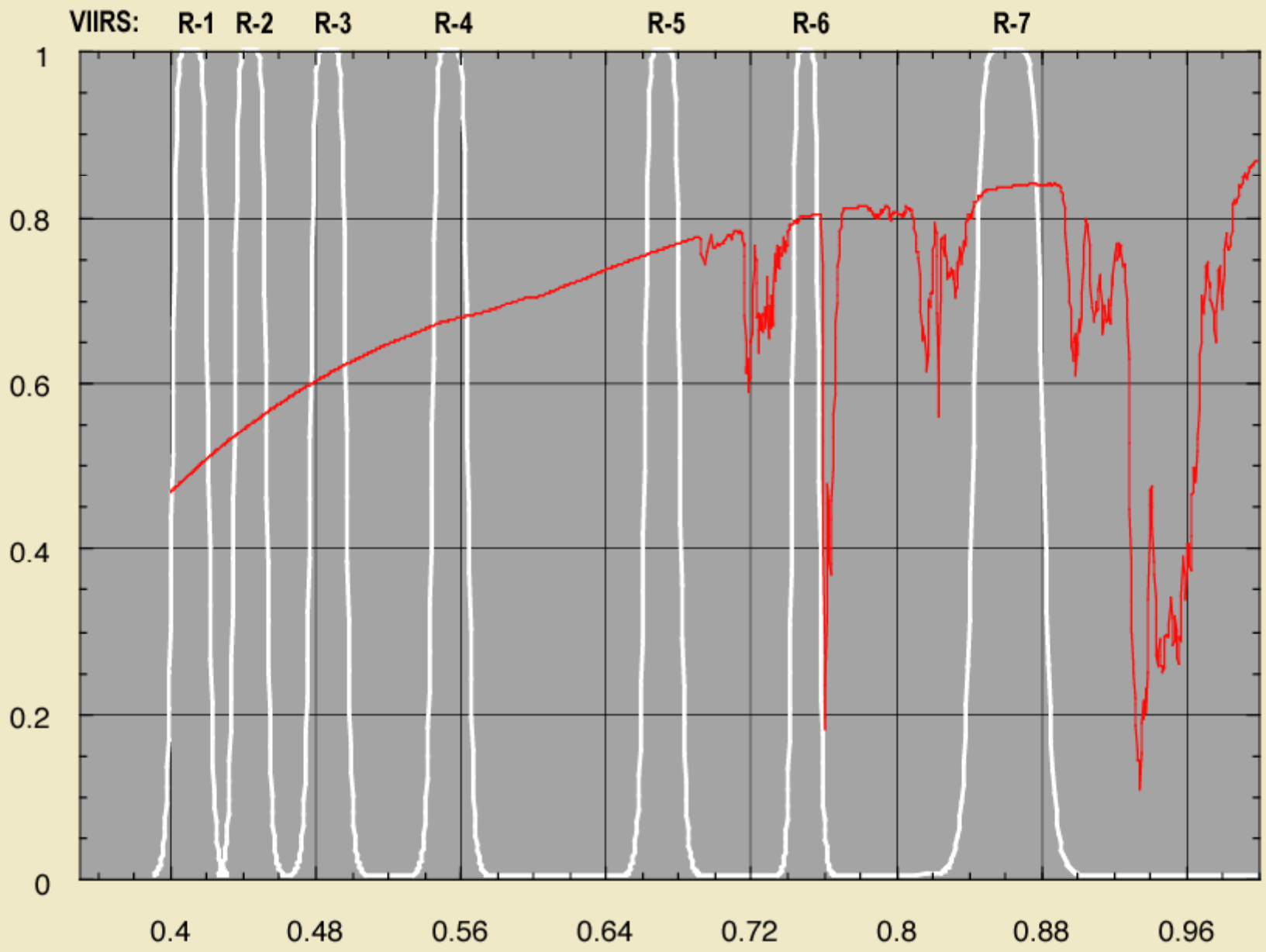
nm/μm

Band name	DNB	M1	M2	M3	M4	I1	M5	M6	M7	I2	M8	M9	M10	I3	M11	M12	I4	M13	M14	M15	I5	M16
Band position	700	412	445	488	555	645	672	751	865	865	1.2	1.4	1.6	1.6	2.3	3.7	3.7	4.1	8.6	10.8	11.5	12.0
Band width	400	20	18	20	20	50	20	15	39	39	0.02	0.015	0.06	0.06	0.05	0.18	0.38	0.16	0.30	1.00	1.90	0.95
Imagery	■		■			■				■		■		■	■		■	■	■	■	■	■
Sea Surface Temp.																■		■		■		■
Soil Moisture							■		■													
Cloud Base Height																						
Cloud Cover/Layers	■					■	■		■	■		■	■	■	■	■	■	■	■	■	■	■
Cloud Partical Size							■				■		■			■				■		
Cloud Thickness							■				■		■			■				■		
Cloud Top Height							■									■				■		
Cloud Top Pressure							■									■				■		
Cloud Top Temp.							■									■				■		
Land Surface Temp.																■		■		■		■
Fire											■		■		■		■	■		■	■	
Vegetation Index				■	■	■				■				■								
Snow Cover (Binary)						■				■				■								
Snow Cover (Fraction)		■	■	■	■	■	■		■	■			■	■	■							
Vegetation/Type			■		■	■				■	■			■	■	■				■		■
Albedo		■	■	■	■	■				■	■			■	■							
Fresh Water Ice						■				■											■	
Ice Surface Temp.																				■		■
Littoral Transport					■		■															
Net Heat Flux		■	■	■	■		■	■	■			■	■		■							
Sea Ice age/motion		■	■	■	■	■	■		■	■			■	■	■							
Mass (turbidity)		■	■	■	■		■	■	■													
Ocean Currents																						
Aer Opt Thick (Ocean)		■	■	■	■		■		■				■		■	■						
Aer Opt Thick (Land)		■	■	■	■		■								■	■				■		■
Aer Part Size (Ocean)		■	■	■	■		■		■				■		■	■						
Aer Part Size (Land)		■	■	■	■		■								■	■				■		■
Suspended Matter		■	■	■	■		■									■		■	■	■		■
Total Prec. Water																■		■	■	■		■
Cloud Mask	■					■	■		■	■		■	■	■	■	■	■	■	■	■	■	■


MODIS Ocean Bands in the Vis/NIR
MODIS:
8
9
10
11
12
13/14
15
16
1
0.8
0.6
0.4
0.2
0
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96


Ocean Bands: MODIS - VIIRS Transition
VIIRS:
MODIS:
R-1
8
R-2
9
R-3
10
11
R-4
12
R-5
13/14
R-6
15
R-7
16
1
0.8
0.6
0.4
0.2
0
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96

VIIRS Ocean Bands in the Vis/NIR



Detector Aggregation Reduces Pixel Growth

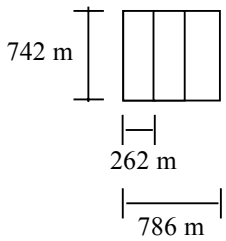
VIIRS Reduces Pixel Size Along Scan:

Much Better HSR, SNR Toward Nadir

Radiometric ("Moderate-Resolution") Bands

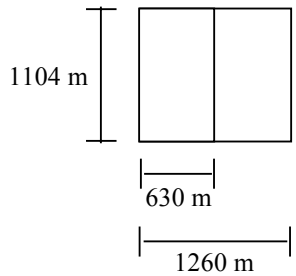
Nadir to 1060km

- aggregate 3 samples
- SNR increases by sqrt(3)



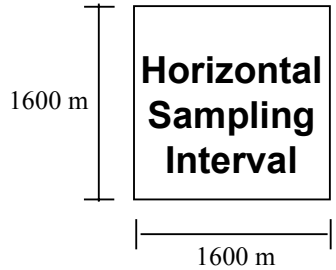
To ~1700 km

- aggregate 2 samples
- SNR increases by sqrt(2)



To 3000 km

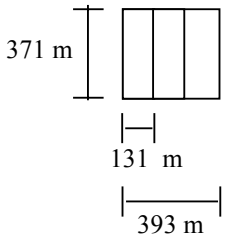
- no aggregation



Imaging ("High-Resolution") Bands

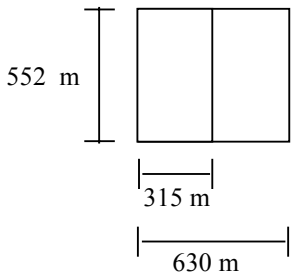
Nadir to 1060km

- aggregate 3 samples
- SNR increases by sqrt(3)



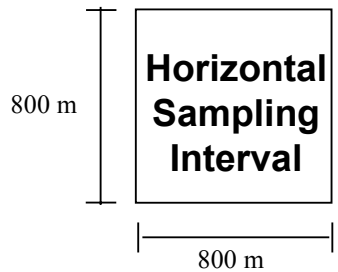
To ~1700 km

- aggregate 2 samples
- SNR increases by sqrt(2)



To 3000 km

- no aggregation



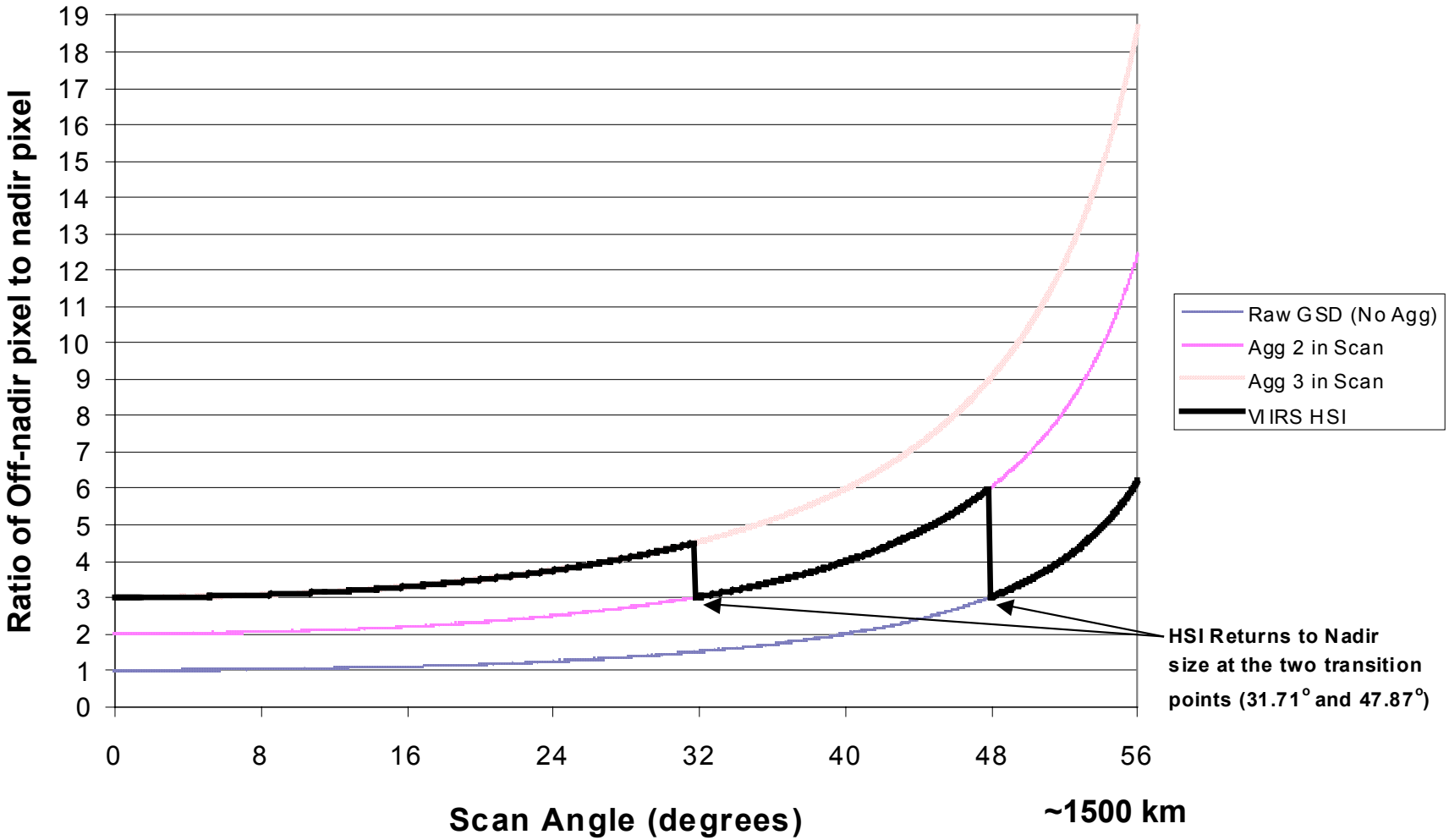
AVHRR & MODIS "1 km" Bands: ~2x6km At Edge

Vs.

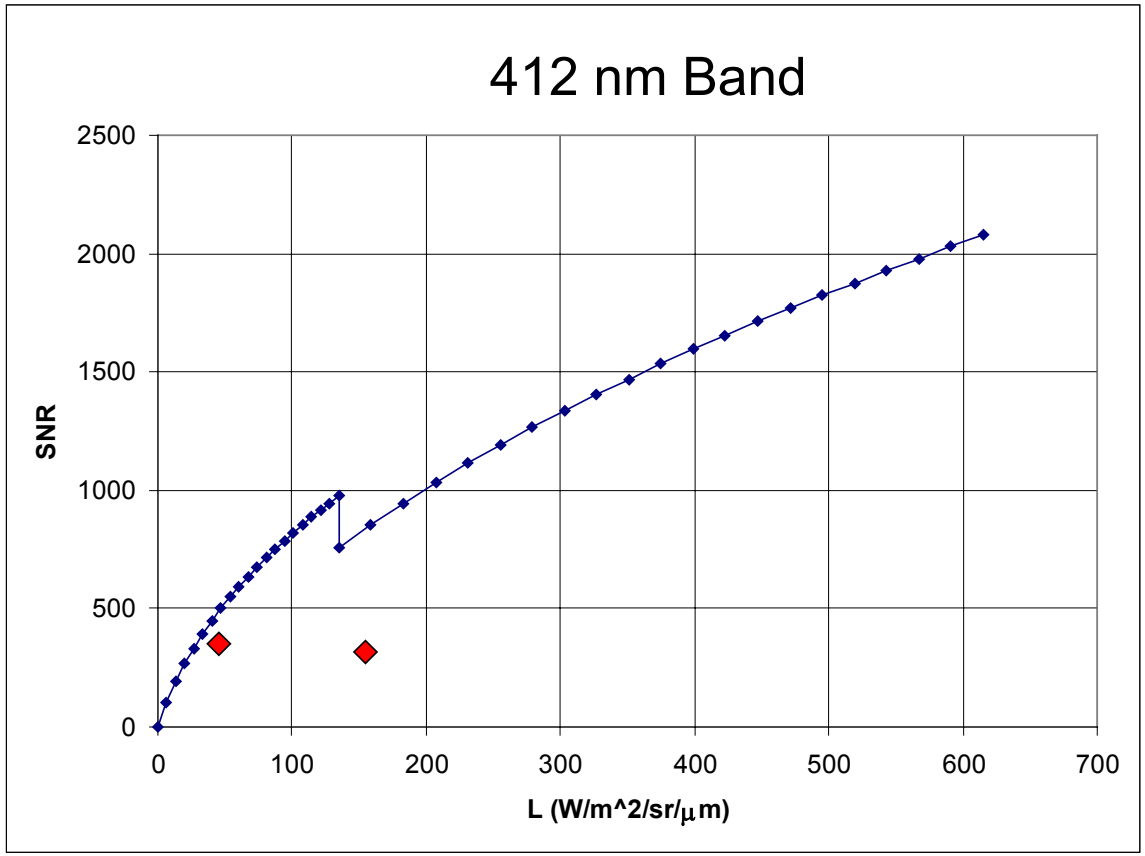
VIIRS 1.6x1.6 km At Edge

Moderate and Imaging bands nest 2x2

Reduced Pixel Growth Along Scan



Dual Gain Bands Meet Ocean & Land Needs



High Gain:	α =	1.1628E-04	Low Gain:	α =	1.1628E-04
	β =	3.4392E-03		β =	1.6177E-02

Spec. Values ◇

Unaggregated Pixels -

CDR Quality data from NPP VIIRS

NPP is a Risk-Reduction Mission for NPOESS, but a Data Continuity Mission for NASA and Climate. With sufficient interest and effort on the part of the ocean color stake holders, these may not be incompatible.

INSTRUMENT PERFORMANCE and CHARACTERIZATION

- **EDU DELIVERY SOON**
- **FLIGHT UNIT 1 (FU1, FOR NPP) DELIVERY FALL '05**

ALGORITHMS

DATA SEGMENT

CALIBRATION/VALIDATION

- **Vicarious Adjustments**
- **Data sources (MOBY)**

Ocean Color/Chlorophyll EDR - RDR Data Summary

Band Name	Wavelength	Native Sensor						NADIR								
								Fine coastal								
		GSD				Ltyp	SNR	Onboard		On ground		Effective		Effective		
		NADIR		EOS				Aggregation Factor		Aggregation Factor		Algorithm GSD		Algorithm SNR	Product HCS	
		Trk	Scn	Trk	Scn			Trk	Scn	Trk	Scn	Trk	Scn		Trk	Scn
M1	0.412	742	262	1094	617	44.9	352.0	1	3	1	1	742	786	609.7	1300	1300
M2	0.445	742	262	1094	617	40.0	337.8	1	3	1	1	742	786	585.2	1300	1300
M3	0.488	742	262	1094	617	32.0	310.6	1	3	1	1	742	786	538.0	1300	1300
M4	0.555	742	262	1094	617	21.0	257.1	1	3	1	1	742	786	445.3	1300	1300
M5	0.672	742	262	1094	617	10.0	242.1	1	3	3	3	2226	2358	1258.0	1300	1300
M6	0.751	742	262	1094	617	9.6	199.1	1	3	3	3	2226	2358	1034.6	1300	1300
M7	0.865	742	262	1094	617	6.4	#N/A	1	3	3	3	2226	2358	#N/A	1300	1300

Performance Summary for Low-gain State of Dual-gain Bands

Source File: F.VRPMO14.xls Q=watt m $^{-2}$ sr-1μm^{-1}					Low gain for dual-gin bands								
					1 x 3 aggregation		1 x 2 aggregation		1 x 1 aggregation				
Band	λ (μm)	# in TDI Gain	Ltyp or Ttyp Q or K	Lmax or Tmax Q or K	SNR @ Ltype (c-/c-)	NEdT @ Ttyp (K)	SNR@ Ltyp (c-/c-)	NEdT @ Ttyp (K)	SNR2 Lty (c-/c-)	NEdT @ Ttyp (K)	SNR Required (c-/c-)	NEdT Required (K)	SNR margin in Design
M1	0.4	1 Dual	200.0	465.0	1780.5	n/a	145.8	n/a	1028.0	n/a	841.0	n/a	22%
2.0	0.4	1 Dual	55.5	469.0	2456.0	n/a	2005.4	n/a	1418.0	n/a	866.0	n/a	60.0%
M3	0.5	1 Dual	51.8	541.0	3050.1	n/a	2490.4	n/a	1761.0	n/a	963.0	n/a	82.9%
4.0	0.6	1 Dual	29.0	590.0	3275.3	n/a	2674.3	n/a	1891.0	n/a	1018.0	n/a	85.8%
M5	0.7	1 Dual	22.0	468.0	3346.3	n/a	2732.3	n/a	1932.0	n/a	1379.0	n/a	40.1%
M7	0.9	1 Dual	25.0	278.0	3713.1	n/a	3032.1	n/a	2144.0	n/a	1059.0	n/a	102.5%
M13	4.1	1 Dual	380	500	844.7	0.039	844.7	0.048	597.3	0.068	386.5	0.105	54.5%

NPP Science Team Roles

To advise NASA on potentials of NPP for CDR data continuity, algorithm, instrument concerns

Provides input to VIIRS Operational Algorithm Team (VOAT), IPO Cal/Val Team

Interact with contractor and IPO teams as appropriate

Weekly PI level & NPP Project Steering Group meetings

BiWeekly VIIRS Telecons

NPP Cal/Val - Guenther; IPO lead Germain; NIST

VOAT Presentation on MODIS ocean lessons learned.

CURRENT ACTIVITIES - OCEAN COLOR GROUP

Reviewing sensor specs and performance expectations

- Providing input to NPP, IPO, NGST

Reviewing sensor test plans - characterization

- Recommending additional tests, modifications

Reviewing Cal/Val plans

- Post-Launch performance verification/evaluation

Algorithm ATBD reviews - comments

VIIRS Summary Report to NPP Project

- T. Pagano editor, Land, Ocean, Atmos inputs

Beginning review of data segment, Ops/con.

- Products needed for cal/val, e.g. (P. Kealy)

Prototype climate analysis and research system

MODIS Ocean Color Lessons for VIIRS

Improve performance and characterization of the **Solar Diffuser and Stability Monitor**. Eliminate **Earthshine**.

Improve characterization of **Polarization**.

Improve characterization and analysis of **stray light**.

SIRCUS testing is needed to characterize the **out-of-band**.

Optical modeling is required to address long term stability of polarization sensitivity on orbit (add spectral response)

A greater level of effort, and greater coordination, will be needed **post-launch** to develop and implement the on-orbit corrections. They may not be successful without the recommended testing recommendations.

SSPR Cal/Val Working Group

CVWG Executive Board			
Contractors		**Government**	
Cal/Val Lead:	Brian Lottman	**IPO NPOESS/NPP Cal/Val Lead:**	Karen St. Germain
Cal/Val Scientist:	Mike Mussetto, Scott Shipley	**NASA NPP Cal/Val Lead:**	Bruce Guenther
Payload Performance Lead:	Jim McCarthy	**IPO Program Scientist:**	Steve Mango
Algorithm Performance Lead:	Pam Emch	**NASA NPP Project Scientist:**	Bob Murphy

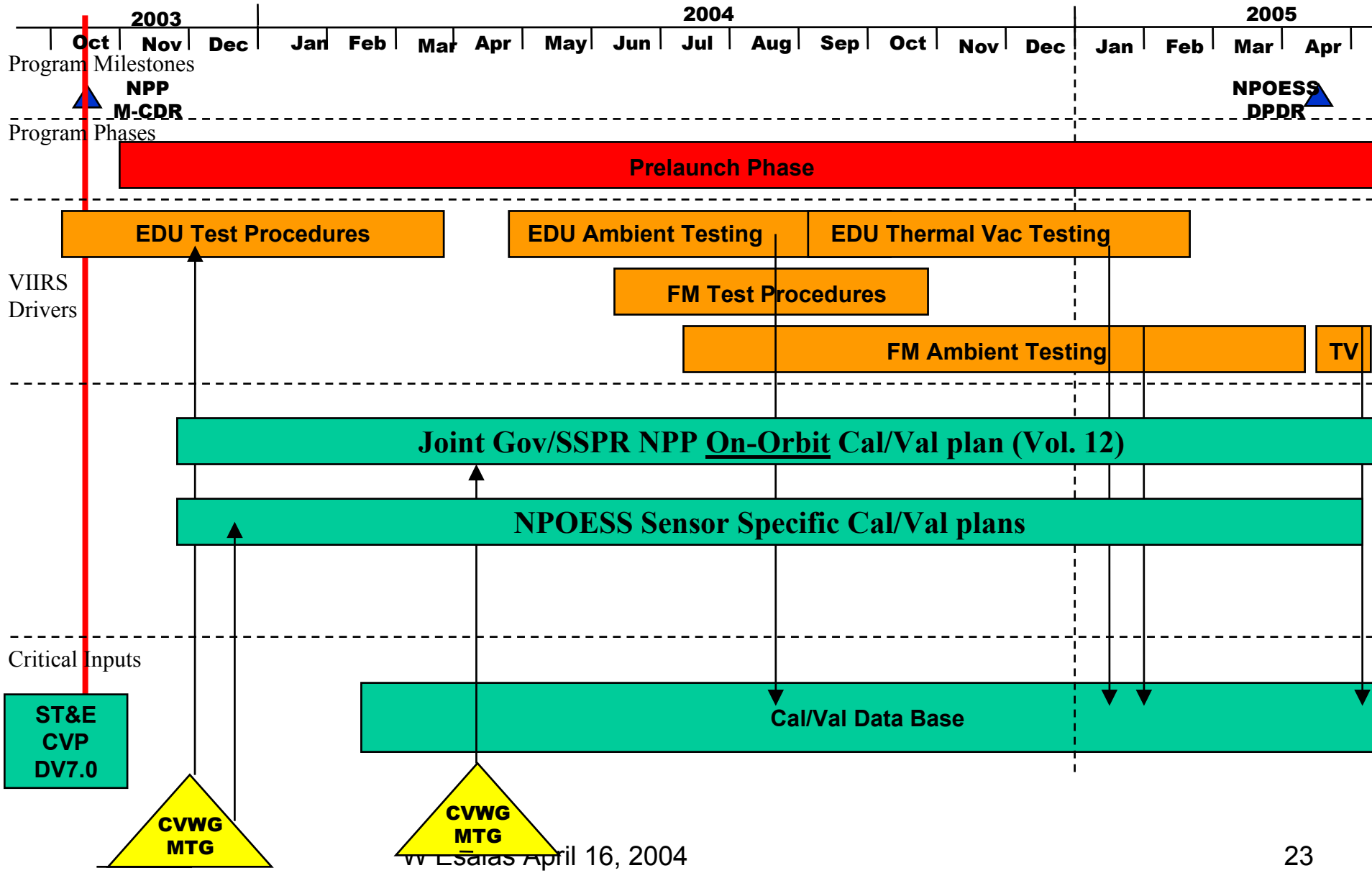
Multi-Faceted Approach to Cal/Val

SSPR (Northrop)	IPO (IORD Driven)	NASA (ESE Driven)	Other Government Participation	International Participation
Sensor Vendor Calibration Team	IGS NIST	**Science team (L1)** NCST		CEOS Calibration Protocols&Standards
Sensor Vendor Science Team	VOAT SOAT	**Science team (L2)**		CEOS Validation Protocols&Standards
Test Resources Instrument Tests TV Chambers	Centrals NOAA Air Force Navy	Test Resources Protocols Expertise		
IWPTB RT Modeling	NAST (aircraft sensor) RT Modeling Traceable Calibration	AERONET, MOBY MAS, AVIRIS, etc. Validation Sites Field Campaigns (e.g., SAFARI) EOS satellites	ARM Sites Buoy Network Balloon Network NOAA/DMSP satellites	CEOS Validation Sites
IDPS: Operational Data Production		SDS: Climate Data Processing	ADS: Long Term Archive	

Level 1 (L1B and SDR)
Level 2 (EDR and CDR)
Physical Resources
Programs and Networks
Data Processing and Archiving

In general, the government team will be responsible for provision of comparison data sets in post-launch validation

Milestones Sensor Charact. and Calib.



OBSERVATIONS

Managerial complexity increases by orders of magnitude SeaWiFS/MODIS/VIIRS.

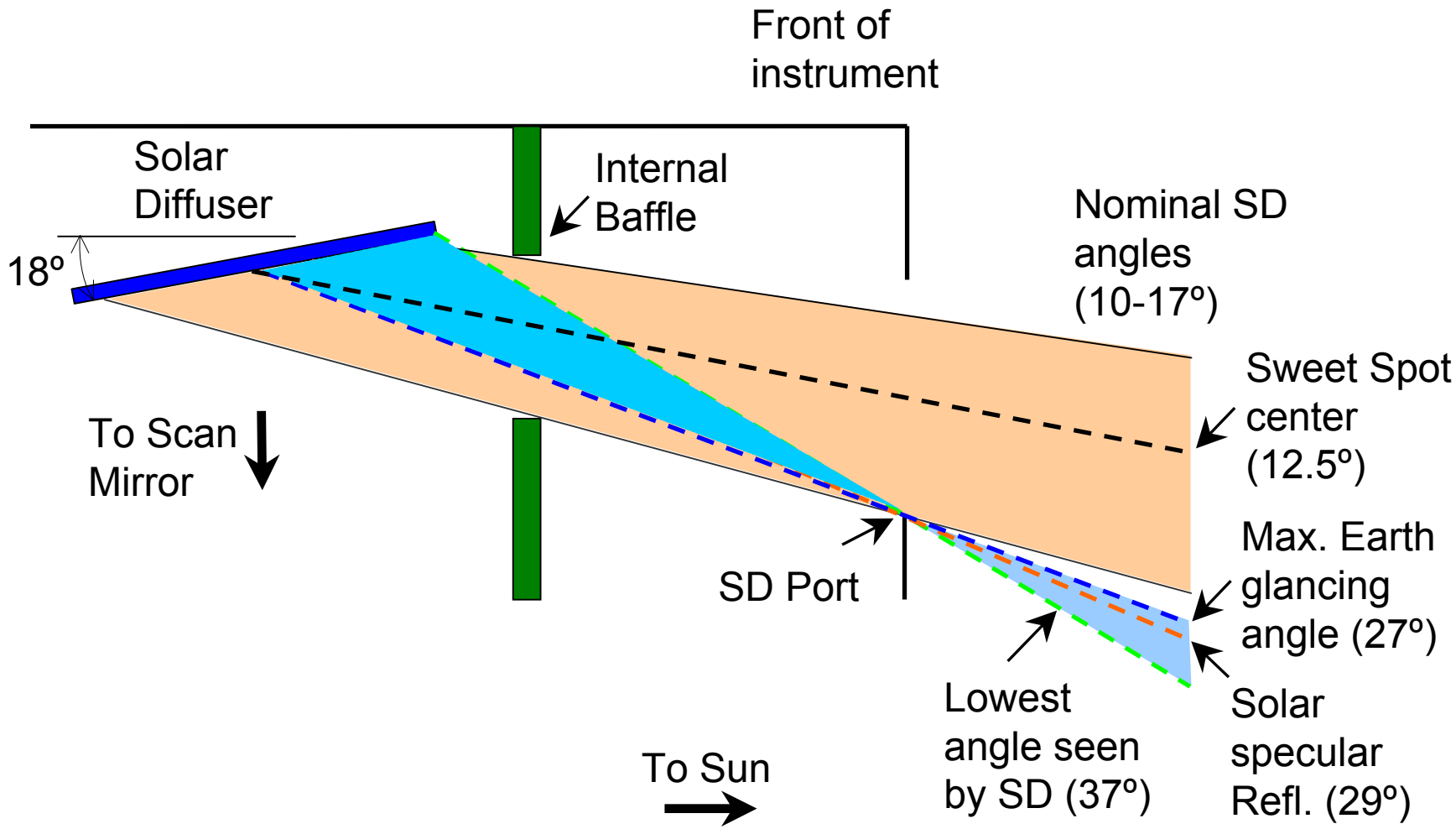
There is a tremendous amount of VIIRS documentation, not all is readily available to NPP Science Team, but accessability is improving.

The IPO, NGST, and SBRS have welcomed the expert input from the NPP teams, and have been very receptive to concerns.

Changes at this stage for improved performance are very constrained by cost and schedule, and will require solid justification and support from the community and HQ to implement.

Backup

MODIS Solar Diffuser Geometry

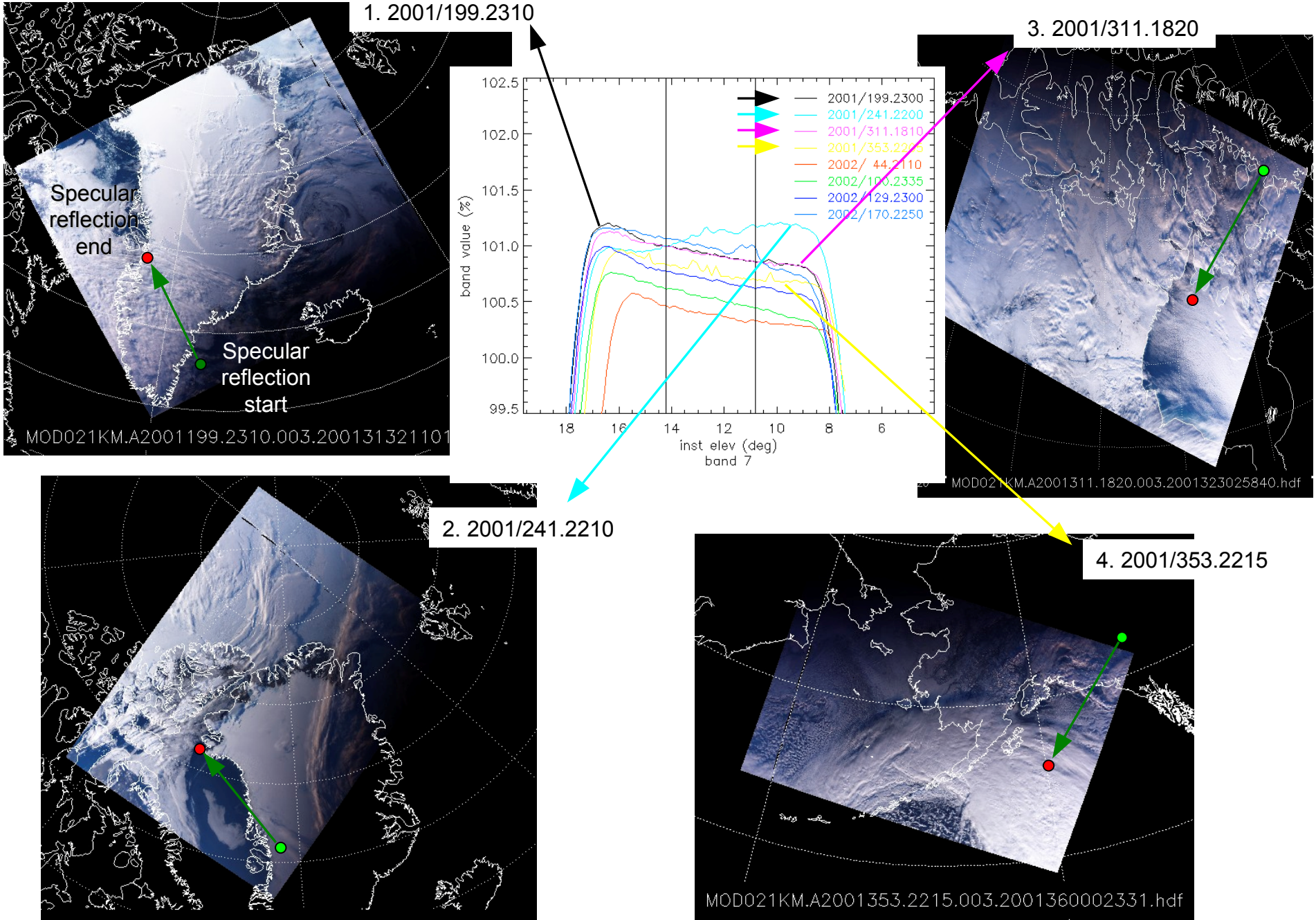


Wolfe et al

ISS photo of sunrise over the Pacific

Wolfe et al

Pacific Ocean 07/21/2003 ISS007E 377 km Alt.


1. 2001/199.2310
Specular reflection end
Specular reflection start
MOD021KM.A2001199.2310.003.200131321101
band value (%)
inst elev (deg)
band 7
2001/199.2300
2001/241.2200
2001/311.1810
2001/353.2215
2002/ 44.2110
2002/100.2335
2002/129.2300
2002/170.2250
3. 2001/311.1820
MOD021KM.A2001311.1820.003.2001323025840.hdf
2. 2001/241.2210
MOD021KM.A2001241.2210.003.2001340084515.hdf
4. 2001/353.2215
MOD021KM.A2001353.2215.003.2001360002331.hdf

Some Web Sites

- A description of the NPP mission may be found at:
  - **http://jointmission.gsfc.nasa.gov**
- The VIIRS instrument is described at:
  - **http://www.ipo.noaa.gov/viirs.html**
- The VIIRS ATBDs are at:
  - **http://npoess.lib.ipo.noaa.gov/atbd_viirs.htm**
- The complete list of NPOESS requirements may be obtained at:
  - **http://npoesslib.ipo.noaa.gov/Req_Docs.htm**

Summary

- **VIIRS instrument has potential to deliver quality measurements for NPP and the operational system (NPOESS)**
- **Similar radiometric quality to MODIS, SeaWiFS**
- **Improved geometric resolution**
- **Continued commitment to characterization and calibration is needed and is being worked**