The NPOESS Preparatory Project
NPP

Presentation to
NASA Ocean Science Meeting
April 16, 2004

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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)

- Separately Mounted Electronics Module
- Solar Diffuser
- Blackbody
- Half-angle Mirror
- Cryoradiator
- Cold FPA Dewar Assembly
- 4-Mirror Anastigmat All Reflective Aft Optics Imager
- 3-Mirror Anastigmat All reflective Rotating telescope

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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’ Optimized Bandset Provides Rich Data for All EDRs**

<table>
<thead>
<tr>
<th>nm/µm</th>
<th>Band Name</th>
<th>DNB</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>M6</th>
<th>M7</th>
<th>M8</th>
<th>M9</th>
<th>M10</th>
<th>M11</th>
<th>M12</th>
<th>M13</th>
<th>M14</th>
<th>M15</th>
<th>I5</th>
<th>I6</th>
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<tbody>
<tr>
<td></td>
<td>Band Position</td>
<td>700</td>
<td>412</td>
<td>445</td>
<td>488</td>
<td>555</td>
<td>645</td>
<td>672</td>
<td>751</td>
<td>865</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
<td>1.6</td>
<td>2.3</td>
<td>3.7</td>
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<td>8.6</td>
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<tr>
<td></td>
<td>Band Width</td>
<td>400</td>
<td>20</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>50</td>
<td>20</td>
<td>15</td>
<td>39</td>
<td>39</td>
<td>0.02</td>
<td>0.015</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
<td>0.18</td>
<td>0.38</td>
<td>0.16</td>
</tr>
</tbody>
</table>

- 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
VIIRS Ocean Bands in the Vis/NIR

VIIRS: R-1 R-2 R-3 R-4 R-5 R-6 R-7

MODIS: 12 13/14 15 16
Detector Aggregation Reduces Pixel Growth

**Radiometric (“Moderate-Resolution”) Bands**

<table>
<thead>
<tr>
<th>Nadir to 1060km</th>
<th>To ~ 1700 km</th>
<th>To 3000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>• aggregate 3 samples</td>
<td>• aggregate 2 samples</td>
<td>• no aggregation</td>
</tr>
<tr>
<td>• SNR increases by ( \sqrt{3} )</td>
<td>• SNR increases by ( \sqrt{2} )</td>
<td></td>
</tr>
</tbody>
</table>

**Imaging (“High-Resolution”) Bands**

<table>
<thead>
<tr>
<th>Nadir to 1060km</th>
<th>To ~ 1700 km</th>
<th>To 3000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>• aggregate 3 samples</td>
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<td>• no aggregation</td>
</tr>
<tr>
<td>• SNR increases by ( \sqrt{3} )</td>
<td>• SNR increases by ( \sqrt{2} )</td>
<td></td>
</tr>
</tbody>
</table>

**AVHRR & MODIS**

“1 km” Bands: ~2x6km At Edge

**VIIRS**

1.6x1.6 km At Edge

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**Moderate and Imaging bands nest 2x2**

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Reduced Pixel Growth Along Scan

Scan HSI as a Function of Scan Angle for Unit Raw GSD at Nadir

Ratio of Off-nadir pixel to nadir pixel

Scan Angle (degrees)

~1500 km

HSI Returns to Nadir size at the two transition points (31.71° and 47.87°)

Raw GSD (No Agg)  Agg 2 in Scan  Agg 3 in Scan  WIRS HSI
Dual Gain Bands Meet Ocean & Land Needs

412 nm Band

High Gain: $\alpha = 1.1628E-04$  Low Gain: $\alpha = 1.1628E-04$

$\beta = 3.4392E-03$  $\beta = 1.6177E-02$

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

<table>
<thead>
<tr>
<th>Band Name</th>
<th>Wavelength</th>
<th>Native Sensor</th>
<th>NADIR</th>
<th>EOS</th>
<th>GSD</th>
<th>Lttyp</th>
<th>SNR</th>
<th>Onboard Aggregation Factor</th>
<th>On ground Aggregation Factor</th>
<th>Effective Algorithm GSD</th>
<th>Effective Algorithm SNR</th>
<th>Product HCS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NADIR</td>
<td>Trk</td>
<td>Scn</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>0.412</td>
<td></td>
<td>742</td>
<td>262</td>
<td>1094</td>
<td>617</td>
<td>44.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>0.445</td>
<td></td>
<td>742</td>
<td>262</td>
<td>1094</td>
<td>617</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>M3</td>
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<tr>
<td>M4</td>
<td>0.555</td>
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<td>742</td>
<td>262</td>
<td>1094</td>
<td>617</td>
<td>21.0</td>
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<tr>
<td>M5</td>
<td>0.672</td>
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<td>262</td>
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<td>10.0</td>
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<tr>
<td>M6</td>
<td>0.751</td>
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<td>262</td>
<td>1094</td>
<td>617</td>
<td>9.6</td>
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<td>M7</td>
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<td>6.4</td>
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Performance Summary for Low-gain State of Dual-gain Bands

<table>
<thead>
<tr>
<th>Source File: F.VRPMO14.xls</th>
<th>Low gain for dual-gin bands</th>
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</thead>
<tbody>
<tr>
<td>Q= watt m⁻² sr⁻¹μm⁻¹</td>
<td>1 x 3 aggregation</td>
</tr>
<tr>
<td>Band</td>
<td>λ (μm)</td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>M1</td>
<td>0.4</td>
</tr>
<tr>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td>M3</td>
<td>0.5</td>
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<tr>
<td>4.0</td>
<td>0.6</td>
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<tr>
<td>M5</td>
<td>0.7</td>
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<tr>
<td>M7</td>
<td>0.9</td>
</tr>
<tr>
<td>M13</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Q=watt m⁻² sr⁻¹μm⁻¹
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 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

<table>
<thead>
<tr>
<th>CVWG Executive Board</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contractors</strong></td>
</tr>
<tr>
<td>Cal/Val Lead:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Cal/Val Scientist:</td>
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<tr>
<td></td>
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<tr>
<td>Payload Performance Lead:</td>
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<td></td>
</tr>
<tr>
<td>Algorithm Performance Lead:</td>
</tr>
<tr>
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</table>
# Multi-Faceted Approach to Cal/Val

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

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

01/17/03

W Esaias April 16, 2004
Milestones Sensor Character. and Calib.

Program Milestones

Program Phases

Prelaunch Phase

VIIRS Drivers

Joint Gov/SSPR NPP On-Orbit Cal/Val plan (Vol. 12)

NPOESS Sensor Specific Cal/Val plans

Critical Inputs

ST&E CVP DV7.0

Cal/Val Data Base
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 accessibility 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

Front of instrument

Solar Diffuser

Internal Baffle

Nominal SD angles (10-17°)

Sweet Spot center (12.5°)

Max. Earth glancing angle (27°)

Solar specular Refl. (29°)

Wolfe et al

To Sun

To Scan Mirror

18°

To Sun angle seen by SD (37°)

Lowest angle seen by SD (37°)

W Esaias April 16, 2004
ISS photo of sunrise over the Pacific

Frame 10805  Time: 10:17:01Z  Nadir Sun El: -05

Wolfe et al

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