NPP/VIIRS: Status and Expected Science Capability

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Contributions from:
Government VIIRS Data Analysis Working Group
NASA, NOAA/IPO, Aerospace, MIT/Lincoln, Wisconsin
NPP Status: What instruments are on NPP?

- VIIRS – Medium resolution Visible& Infra-red Imager
- CrIS – Fourier Transform Spectrometer for IR Temperature and Moisture sounding
- ATMS – Microwave sounding radiometer
- OMPS – Total Ozone Mapping and Ozone Profile measurements

CERES Earth Radiation Budget measurements
- Initial concept 2/07
- Confirmed 2/08
- On spacecraft 11/08
CERES Flight Model 5

CERES scanning radiometer measuring three spectral bands at TOA
- Total (0.3 to >50 µm)
- Shortwave (0.3 to 5.0 µm)
- Longwave Bandpass (8 to 12 µm)

Operations, Data Processing, Products, and Science are a continuation of experience developed on
- TRMM (1), EOS Terra (2), EOS Aqua (2)

Current Status: On NPP

Margins

<table>
<thead>
<tr>
<th>CERES</th>
<th>Spec</th>
<th>CBE</th>
</tr>
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<tbody>
<tr>
<td>Mass - kg</td>
<td>50</td>
<td>50</td>
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<tr>
<td>Power (Avg.) - W</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Power (Max) - W</td>
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<td>Data Rate (Avg,) - Kbps</td>
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<td>10</td>
</tr>
<tr>
<td>Data Rate (Max) - Kbps</td>
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</tr>
</tbody>
</table>

Primary CERES Climate Data Records
- Reflected Solar Energy
- Emitted Thermal Energy
Temperature & Water Vapor Profiles

Advanced Technology Microwave Sounder

- Scanning passive microwave radiometer
- Combines 3 instruments
  - AMSU A1 / A2, MHS
- (22 channels (23GHz - 183GHz)

Status
- Flight Model on Spacecraft

Cross-Track Infrared Sounder

- Michelson Interferometer
  3 bands (3.5 µm - 16 µm)

Status
- Flight Unit #1 has finished calibration.
- Electronics Boards Re-built
- Re-Qualifying T/V: Complete
- Ship to NPP: June 2010
Ozone Mapping Profiler Suite

Description

- **Purpose:** Monitors the total column and vertical profile of ozone
- **Predecessor Instruments:** TOMS, SBUV, GOME, OSIRIS, SCIAMACHY
- **Approach:** Nadir and limb push broom CCD spectrometers
- **Swath width:** 2600 km

Status

- Limb re-manifested
- Nadir and Limb has completed TV testing and calibration
- Integrated Instrument on spacecraft

Products: Total ozone maps and SBUV2-like ozone profiles
Higher resolution ozone profiles from Limb instrument
Visible Infrared Imaging Radiometer Suite

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

• Flight Unit #1 Completed Ambient, Vibration, EMI/EMC and Thermal Vacuum characterization, calibration and on spacecraft
• VIIRS on NPP
• VIIRS Testing on Spacecraft: Gain, Relative Spectral Response, End-to-End (NIST) complete
VIIRS F1 Reflective Bands: Radiometric Performance

Meets all Requirements for:
Signal to Noise Ratio, Dynamic Range, Linearity, Uncertainty, Stability and Polarization

Minor Variances for:
**Gain Transition**: Gain transition points are well characterized (VIIRS has dual gain bands)

**Uniformity**: Potential for striping, Plan for post-launch fix if needed
VIIRS F1 Emissive Bands:
Radiometric Performance

Meets all Requirements for:
NEdT, Dynamic Range, Gain Transition,
Linearity, Uniformity,
Absolute Radiometric Difference, and Stability
VIIRS F1 Spatial Performance

Meets Requirements for or only minor non-compliances:

**Line Spread Function:**
- Scan and Track DFOV
- Scan and Track MTF
- Scan and Track HSR
- Band-to-Band Registration

Pixel growth to “1.5 km x 1.5 km” at to the edge of scan
VIIRS F1 Spectral Performance

Significant Non-Compliance for: Band-to-Band Crosstalk

Optical Crosstalk
The VIIRS Integrated Filter Assembly (IFA), as built, scatters light across the focal plane detector.
This optical scattering is caused by defects in the multi-layer deposition manufacturing process. It is expected that this will be fixed for FM2.

This effect is referred to as optical crosstalk; light from one band in one pixel is measured in another pixel. Test data was taken to quantify the amount of optical crosstalk.

The data product that is most affected is Ocean Color.

NGAS has proposed a correction method. Their methodology is still undergoing government peer-review.
VIIRS F1 Spectral Performance

Meets all Requirements for:
Spectral Band Center, Spectral Bandwidth, Extended Bandwidth
Significant Non-Compliance for: Integrated Out-of-Band Response

<table>
<thead>
<tr>
<th>Band</th>
<th>Center Wavelength (nm)</th>
<th>Bandwidth (nm)</th>
<th>Requirement Maximum Integrated OOB Response (%)</th>
<th>Measured Maximum Integrated OOB Response (%)</th>
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<tbody>
<tr>
<td>M1</td>
<td>412</td>
<td>20</td>
<td>1.0</td>
<td>3.7</td>
</tr>
<tr>
<td>M3</td>
<td>488</td>
<td>20</td>
<td>0.7</td>
<td>1.1</td>
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<tr>
<td>M4</td>
<td>555</td>
<td>20</td>
<td>0.7</td>
<td>4.3</td>
</tr>
<tr>
<td>M5</td>
<td>672</td>
<td>20</td>
<td>0.7</td>
<td>3.2</td>
</tr>
<tr>
<td>M6</td>
<td>746</td>
<td>15</td>
<td>0.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Notes: Smaller non-compliances for emissive bands
Well characterized
More accurate measurements from spacecraft testing
(Bruce Guenther presentation tomorrow)
Gov’t EDR analysis ongoing
“The VIIRS on-orbit performance, due to the OOB calibration biases alone, should be no worse than SeaWiFS. If the VIIRS OOB calibration biases are not adversely complicated by the crosstalk, the heritage OOB mitigation approaches that were developed for SeaWiFS and Aqua MODIS should work for VIIRS. These approaches use vicarious calibration as the primary correction for the OOB bias in the calibrated TOA radiances, then use direct OOB corrections of the water-leaving radiances to remove residual OOB biases.”
VIIRS EDR Performance:
IPO Requirements

• For most of the EDRs which are not dependent on precise multi-wavelength radiometric calibration (all the EDRs except Ocean Color), the VIIRS instrument performance is expected to be pretty good.

• The VIIRS EDRs will meet their operational performance requirements, with the exception of Ocean Color.
VIIRS EDR Performance: NASA Science Requirements

Given satisfactory VIIRS performance;

- EOS data continuity requires algorithm continuity
- Similar physics is needed to reduce systematic errors
- Not all current VIIR EDRS use current MODIS algorithms

Need to adapt where instruments differ,
- MODIS and VIIRS do not have all the same bands
- Band Aggregation is a challenge
VIIRS EDR Performance: NASA Science Requirements

Land:
IDPS products should meet operational needs
Minimal effects from cross-talk

Land Surface Reflectance, Surface Albedo, and Vegetation Index have significant algorithmic differences with current EOS products
Active Fires products are a special case due to instrumental differences. Research product being developed for MODIS continuity
Atmospheres; Aerosols:

Current IDPS uses MODIS Collection 5
Current version does not have Deep Blue AOT retrieval over bright land surfaces
High priority candidate for IDPS update

Largest effect seen from IOOB features
Can compensated for using measured RSRs in LUT
Cross-talk effects on ocean AOT are minimal
Cross-talk effects on land AOT are small.
still need to understand polarization effects
VIIRS EDR Performance: NASA Science Requirements

Atmospheres: Cloud Properties see White Paper, Bryan Baum editor

Significant Instrumental differences;
MODIS has CO$_2$ and H$_2$O bands

Cloud Mask; Good collaboration

Other Cloud Properties: cloud top height/temperature/pressure, optical thickness, and effective particle size

Major algorithmic differences; no CO$_2$ slicing bands for cloud height

Minor differences in assumptions for phase function, spectral albedo, ice cloud scattering, max cloud optical thickness

Significant Work needed for EOS Continuity

Minimal Cross talk and IOOB effects
Joint Polar Satellite System

As Briefed by NOAA/NASA
Feb 4, 2010
NPOESS Background

• NPOESS is a national priority -- essential to meeting both civil and military weather-forecasting, storm-tracking, and climate-monitoring requirements.

• An Administration task force and independent reviews have concluded that the current program cannot be successfully executed with the current management structure, and with the current budget structure.

• These challenges originate in large part because of a combination of management deficiencies that result from conflicting perspectives and priorities among the three agencies who manage the program.

• Absent a major restructuring, the Agencies would have continued to face major risks in executing the current program, threatening our ability to ensure weather and climate observations.
Administration Decision on Restructuring

• Acquisition responsibilities will be shared
  – NOAA/NASA responsible for the PM orbit – to be called Joint Polar Satellite System (JPSS)
  – DoD (AF/SMC) responsible for the early AM orbit
  – Agencies will share a common ground system to be managed by NOAA/NASA
  – Agencies will share data from each orbit to meet the national need for weather and climate information
• Mid and early-AM orbits covered by EUMETSAT and remaining DOD/DMSP platforms
• Acquire 2 lower risk JPSS satellites
• Observations planned in the PM orbit for NPOESS are maintained
  – VIIRS, CrIS, ATMS, OMPS, and CERES/ERBS remain
  – AMSR sensor data from Japanese GCOM satellite to replace MIS for microwave imaging/sounding
• Continue plan for operational use of NPP data (PM orbit) with a
  – Fall 2011 launch readiness date
DoD option to move to AM orbit

LEGEND
DMSP: Defense Meteorological Satellite Program
MetOp: Meteorological Operational satellite for EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites)
PEPS: Post EUMETSAT Polar System
Terra & Aqua: NASA's Earth Observing Satellites
NOAA-19: NOAA's Polar-orbiting Operational Satellite
NPP: NPOESS Preparatory Project
JPSS: Joint Polar Satellite System
* Details to be defined during the transition period
Transition Approach

- NOAA/DoD leadership agree to cooperate to ensure a smooth and transparent transition.
- Government Transition Team will immediately develop and execute Transition Plan.
- IPO team maintained and continue current efforts in parallel with Transition Team:
  - Careful and controlled transition of IPO team from NPOESS to JPSS and other programs.
- NOAA/NASA management of JPSS program (PM Orbit) and shared Ground System:
  - Maintain work on instruments, ground system, and algorithms that support PM orbit while transitioning those contracts to NASA/GSFC.
  - Acquire 2 lower risk JPSS satellites.
  - Climate sensor acquisitions (CERES/ERBS, TSIS, OMPS Limb) continue via the NOAA climate program.
  - International agreements for SARSAT and ADCS user services payloads remain in place.
- Work with DoD/Northrop Grumman Aerospace Systems Procurement organizations to transfer work on Instruments/Ground System to NASA-led acquisition vehicles.
- DoD maintains acquisition authority of NGAS contract:
  - DoD and NOAA to share any termination costs.
- NOAA JPSS Program will be subject to independent review of mission concepts, organizational structure, acquisition strategies, and budget prior to program baseline.
NOAA JPSS Budget

- Supports JPSS mission through FY 2026, including shared ground system, and NOAA portion of shared NPOESS termination costs
- Climate instruments TSIS, CERES/ERBS, OMPS Limb are developed under the existing NOAA Climate Program (outside JPSS budget)
- SARSAT, ADCS, and AMSR (data) will be provided by international partners
- Reflects high confidence level cost estimate
- Increased funding in near-years to mitigate risk and support transition

<table>
<thead>
<tr>
<th>OUTYEAR FUNDING ESTIMATES</th>
<th>FY10 &amp; Prior</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>Cost to Complete</th>
<th>Total</th>
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<tbody>
<tr>
<td>Joint Polar Satellite System</td>
<td>2,908,494</td>
<td>1,060,800</td>
<td>1,160,000</td>
<td>960,000</td>
<td>740,000</td>
<td>610,000</td>
<td>4,489,506</td>
<td>11,928,800</td>
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Sensitive – For Official Use Only
JPSS Transition Summary

• NOAA/NASA committed to working with DOD to ensure an efficient and effective transition
• NOAA/NASA stand ready to lead transition team
• NOAA/NASA Acquisition and legal teams have already initiated procurement transition strategies
• The afternoon orbit is NOAA’s top priority – it is critical for work to continue seamlessly through this transition
Questions?

Current Launch Readiness Date: September 23, 2011

LRD: No earlier than 15.5 months after delivery of last instrument: Launch NET Late Oct 2011

View of NPP from Back of Spacecraft

Photo Courtesy of Ball Aerospace
“However, we are optimistic that the VIIRS instrument may still be a viable ocean color instrument, provided that the calibration and validation infrastructure of heritage NASA EOS missions is in place. This infrastructure includes a plan and support for vicarious calibration site(s), a data/validation program, on-orbit calibration maneuvers, regular mission-level data reprocessing, and the use of NASA selected operational algorithms.”
## VIIRS Spectral, Spatial, & Radiometric Attributes

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Wavelength ((\mu)m)</th>
<th>Horiz Sample Interval (km Downtrack x Crosstrack)</th>
<th>Driving EDRs</th>
<th>Radiance Range</th>
<th>Ltyp or Typ</th>
<th>Signal to Noise Ratio (dimensionless) or NE(_A)T (Kelvins)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nadir</td>
<td>End of Scan</td>
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<td>Required</td>
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<tr>
<td>M1</td>
<td>0.412</td>
<td>0.742 x 0.259</td>
<td>1.60 x 1.58</td>
<td>Ocean Color Aerosols</td>
<td>Low</td>
<td>44.9</td>
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<tr>
<td>M2</td>
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<td>1.60 x 1.58</td>
<td>Ocean Color Aerosols</td>
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<td>40</td>
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<tr>
<td>M3</td>
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<td>1.60 x 1.58</td>
<td>Ocean Color Aerosols</td>
<td>Low</td>
<td>32</td>
</tr>
<tr>
<td>M4</td>
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<td>0.742 x 0.259</td>
<td>1.60 x 1.58</td>
<td>Ocean Color Aerosols</td>
<td>Low</td>
<td>21</td>
</tr>
<tr>
<td>I1</td>
<td>0.640</td>
<td>0.371 x 0.387</td>
<td>0.80 x 0.789</td>
<td>Imagery</td>
<td>Single</td>
<td>22</td>
</tr>
<tr>
<td>M5</td>
<td>0.672</td>
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<td>1.60 x 1.58</td>
<td>Ocean Color Aerosols</td>
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<tr>
<td>M6</td>
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<td>0.742 x 0.776</td>
<td>1.60 x 1.58</td>
<td>Atmospheric Corr'n</td>
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<td>0.371 x 0.387</td>
<td>0.80 x 0.789</td>
<td>NDVI</td>
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<td>1.60 x 1.58</td>
<td>Ocean Color Aerosols</td>
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<td>6.4</td>
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<td>CCD</td>
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<td>0.742 x 0.742</td>
<td>Imagery</td>
<td>Var.</td>
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<tr>
<td>M8</td>
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<td>0.742 x 0.776</td>
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<td>Cloud Particle Size</td>
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<td>Cirrus/Cloud Cover</td>
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<td>I3</td>
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<td>Binary Snow Map</td>
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<td>M11</td>
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<td>Clouds</td>
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<td>I4</td>
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<td>Imagery Clouds</td>
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<tr>
<td>M12</td>
<td>3.70</td>
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<td>1.60 x 1.58</td>
<td>SST</td>
<td>Single</td>
<td>270 K</td>
</tr>
<tr>
<td>M13</td>
<td>4.05</td>
<td>0.742 x 0.259</td>
<td>1.60 x 1.58</td>
<td>SST</td>
<td>Low</td>
<td>300 K</td>
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<td>LWIR</td>
<td>M14</td>
<td>8.55</td>
<td>0.742 x 0.776</td>
<td>Cloud Top Properties</td>
<td>Single</td>
<td>270 K</td>
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<tr>
<td>M15</td>
<td>10.763</td>
<td>0.742 x 0.776</td>
<td>1.60 x 1.58</td>
<td>SST</td>
<td>Single</td>
<td>300 K</td>
</tr>
<tr>
<td>I5</td>
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<td>M16</td>
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<td>1.60 x 1.58</td>
<td>SST</td>
<td>Single</td>
<td>300 K</td>
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</tbody>
</table>
# VIIRS Bands and Products

## VIIRS 22 Bands:
- 16 M_ Band, 5 I_Band and 1 DNB

## VIIRS 24 EDRs
- Land, Ocean, Atmosphere, Snow

### VIIRS Band

<table>
<thead>
<tr>
<th>VIIRS Band</th>
<th>Spectral Range (um)</th>
<th>Nadir HSR (m)</th>
<th>MODIS Band(s)</th>
<th>Range</th>
<th>HSR</th>
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<tbody>
<tr>
<td>DNB</td>
<td>0.500 - 0.900</td>
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<td></td>
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<tr>
<td>M1</td>
<td>0.402 - 0.422</td>
<td>750</td>
<td>8</td>
<td>0.405 - 0.420</td>
<td>1000</td>
</tr>
<tr>
<td>M2</td>
<td>0.436 - 0.454</td>
<td>750</td>
<td>9</td>
<td>0.438 - 0.448</td>
<td>1000</td>
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<tr>
<td>M3</td>
<td>0.478 - 0.498</td>
<td>750</td>
<td>3, 10</td>
<td>0.459 - 0.479, 0.483 - 0.493</td>
<td>500</td>
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<tr>
<td>M4</td>
<td>0.545 - 0.565</td>
<td>750</td>
<td>4 or 12</td>
<td>0.545 - 0.565</td>
<td>500</td>
</tr>
<tr>
<td>M5</td>
<td>0.662 - 0.682</td>
<td>750</td>
<td>13 or 14</td>
<td>0.662 - 0.672, 0.673 - 0.683</td>
<td>1000</td>
</tr>
<tr>
<td>M6</td>
<td>0.739 - 0.754</td>
<td>750</td>
<td>15</td>
<td>0.743 - 0.753</td>
<td>1000</td>
</tr>
<tr>
<td>M7</td>
<td>0.846 - 0.885</td>
<td>375</td>
<td>2</td>
<td>0.841 - 0.876</td>
<td>250</td>
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<tr>
<td>M8</td>
<td>1.230 - 1.250</td>
<td>750</td>
<td>5</td>
<td>SAME</td>
<td>500</td>
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<tr>
<td>M9</td>
<td>1.371 - 1.386</td>
<td>750</td>
<td>26</td>
<td>1.360 - 1.390</td>
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<tr>
<td>I2</td>
<td>1.580 - 1.640</td>
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<td>6</td>
<td>1.628 - 1.652</td>
<td>500</td>
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<tr>
<td>M10</td>
<td>1.580 - 1.640</td>
<td>750</td>
<td>6</td>
<td>1.628 - 1.652</td>
<td>500</td>
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<tr>
<td>M11</td>
<td>2.225 - 2.275</td>
<td>750</td>
<td>7</td>
<td>2.105 - 2.155</td>
<td>500</td>
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<tr>
<td>M12</td>
<td>3.660 - 3.840</td>
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<td>SAME</td>
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<tr>
<td>M13</td>
<td>3.973 - 4.128</td>
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<td>21 or 22</td>
<td>3.929 - 3.989, 3.929 - 3.989</td>
<td>1000</td>
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<td>M14</td>
<td>8.400 - 8.700</td>
<td>750</td>
<td>29</td>
<td>SAME</td>
<td>1000</td>
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<tr>
<td>M15</td>
<td>10.263 - 11.263</td>
<td>750</td>
<td>31</td>
<td>10.780 - 11.280</td>
<td>1000</td>
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<tr>
<td>I5</td>
<td>10.500 - 12.400</td>
<td>375</td>
<td>31 or 32</td>
<td>10.780 - 11.280, 11.770 - 12.270</td>
<td>1000</td>
</tr>
<tr>
<td>M16</td>
<td>11.538 - 12.488</td>
<td>750</td>
<td>32</td>
<td>11.770 - 12.270</td>
<td>1000</td>
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### Name of Product

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<thead>
<tr>
<th>Name of Product</th>
<th>Group</th>
<th>Type</th>
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<tbody>
<tr>
<td>Imagery *</td>
<td>Imagery</td>
<td>EDR</td>
</tr>
<tr>
<td>Precipitable Water</td>
<td>Atmosphere</td>
<td>EDR</td>
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<td>Suspended Matter</td>
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<td>Aerosol Optical Thickness</td>
<td>Aerosol</td>
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<td>Aerosol Particle Size</td>
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<td>Cloud Base Height</td>
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<td>EDR</td>
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<tr>
<td>Cloud Cover/Layers</td>
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<td>EDR</td>
</tr>
<tr>
<td>Cloud Effective Particle Size</td>
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<td>EDR</td>
</tr>
<tr>
<td>Cloud Optical Thickness/Transmittance</td>
<td>Cloud</td>
<td>EDR</td>
</tr>
<tr>
<td>Cloud Top Height</td>
<td>Cloud</td>
<td>EDR</td>
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<tr>
<td>Cloud Top Pressure</td>
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<td>Cloud Top Temperature</td>
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<td>Active Fires</td>
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<td>Application</td>
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<tr>
<td>Albedo (Surface)</td>
<td>Land</td>
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</tr>
<tr>
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<td>EDR</td>
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<td>Surface Type</td>
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<tr>
<td>Vegetation Index</td>
<td>Land</td>
<td>EDR</td>
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<tr>
<td>Sea Surface Temperature *</td>
<td>Ocean</td>
<td>EDR</td>
</tr>
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<td>Ocean Color and Chlorophyll</td>
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<td>EDR</td>
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<td>Net Heat Flux</td>
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<tr>
<td>Sea Ice Characterization</td>
<td>Snow and Ice</td>
<td>EDR</td>
</tr>
<tr>
<td>Ice Surface Temperature</td>
<td>Snow and Ice</td>
<td>EDR</td>
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<tr>
<td>Snow Cover and Depth</td>
<td>Snow and Ice</td>
<td>EDR</td>
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</table>

* Product has a Key Performance attribute
NASA’s NPP Science Role

• Climate data record (CDR): “a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change.” (NRC: CDRs from Env. Sat. 2004)
  – “CDR“ Definition of Consistent:
    > all temporal sensor artifacts removed
    > no obvious interannual discontinuities unattributable to natural variability
    > all known mission-dependent biases removed or quantified
    > similar data quality and structure

• The NPP Science Charter is to: *Continue the scientific data record started in the “EOS era.”*

• NICST/E Group to remove “all temporal sensor artifacts”

• NPP Science Team to “quantify and remove all known mission-dependent biases” removed or quantified and to provide similar data quality and structure”

• Reprocessing will be required to produce Consistent, Integrated EOS/NPP/ NPOESS Satellite data records.
Mission Success

- The NPP Mission Success is determined by its capabilities
  - to provide continuation of a group of earth system observations initiated by the Earth Observing System (EOS) Terra, Aqua and Aura missions and
  - by its ability to reduce the risks associated with its advance observational capabilities as they are being transitioned from the NASA research program into the NPOESS operational program in support of both the Department of Defense (DoD) and NOAA

> These include pre-operational risk reduction demonstration and validation for selected NPOESS instruments, and algorithms, as well as ground data processing, archive and distribution.
NPP Status: What instruments are on NPP?

**VIIRS – Medium resolution Visible & Infra-red Imager**

**CrIS – Fourier Transform Spectrometer for IR Temperature and Moisture sounding**

**ATMS – Microwave sounding radiometer**

**OMPS – Total Ozone Mapping and Ozone Profile measurements**

**CERES – Earth Radiation Budget measurements**

- Initial concept: 2/07
- Confirmed: 2/08
- On spacecraft: 11/08