Satellite Updates: Landsat, Sentinel, and NPP

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Current Status – Operations

Landsat 5

- Launched in 1984 with 3-year design life
- **Imaging suspended November 17, 2011,** due to degraded traveling wave tube amplifier on X-band transmitter
- Currently in 90-day test and analysis period to investigate operational options--**likely outcome is partial or intermittent functionality** at best
  - Priority is to capture 2012 North American growing season, if at all possible
- Latest estimate for end of mission (fuel projection only) is December 2013

Landsat 7

- Launched in 1999 with 5-year design life
- Imaging anomaly in May 2003 causes each scene to be **missing 22% of pixels**
  - Images still acceptable for most science and operational users
- Acquiring over 350 new images/day
- Latest estimate for end of mission (fuel projection only) is January 2017

The Landsat Data Continuity Mission and its Satellite Observatory

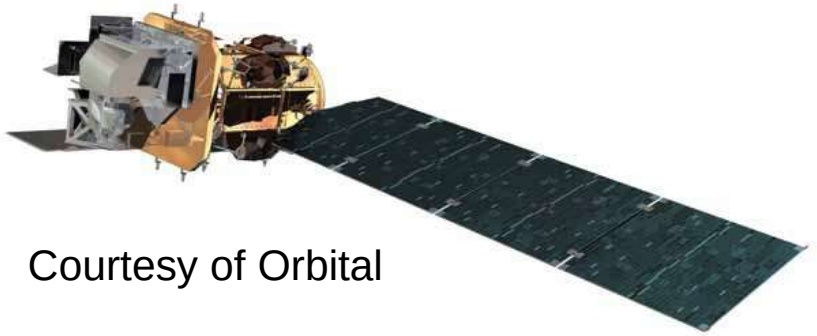
PECORA18
Herndon, Virginia
November 16, 2011

Jim Irons
LDCM Project Scientist
Bill Anselm
LDCM Observatory Manager
NASA Goddard Space Flight Center
Greenbelt, Maryland

Landsat Data Continuity Mission

LDCM

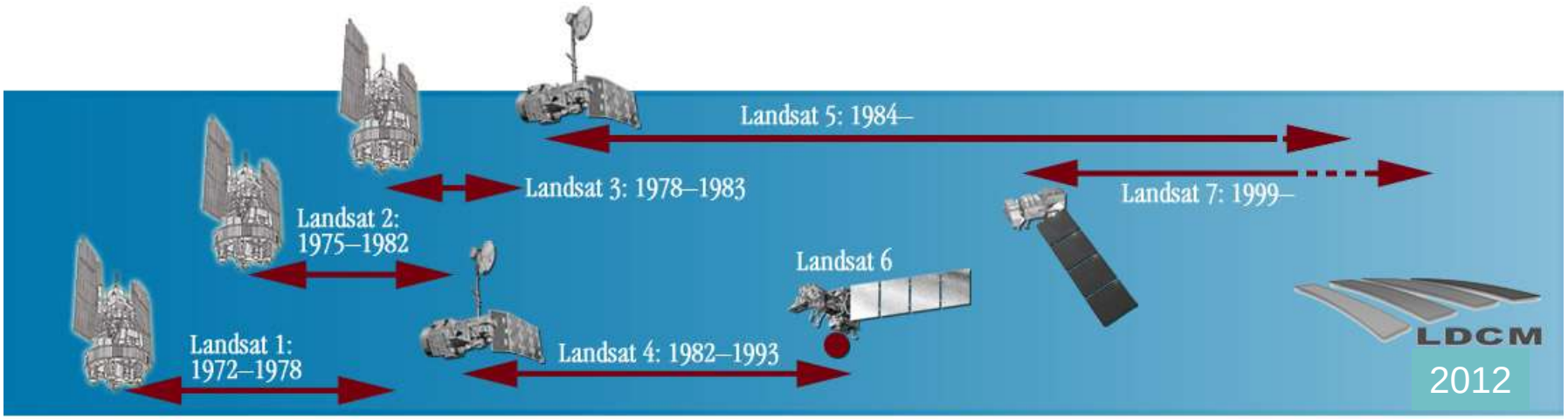
- The Landsat Data Continuity Mission (LDCM) is the follow-on mission to Landsat 7
  - The 8th satellite in the Landsat series
- NASA and the Department of Interior / U.S. Geological Survey (USGS) are building and will operate the LDCM in an interagency partnership
- The LDCM is on schedule for a December 01, 2012 launch



Courtesy of Orbital

The launch will likely be delayed to a January 15 to February 15, 2013 window to accommodate launch vehicle manifest conflicts with other satellites

History of the Landsat Program



1970 1975 1980 1985 1990 1995 2000 2005 2010 2015

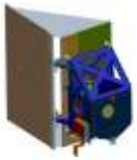
Gov't Operations | Commercial Operations | Gov't Operations

NASA / USGS Mission Responsibilities

Space Segment – NASA Lead

Operational Land Imager
- Multi-Spectral Imaging Instrument
- Pushbroom VIS/SWIR sensor
- Four mirror telescope
- FPA consisting of 14 SCAs

Thermal Infrared Sensor
- 2 thermal channels
- Pushbroom design
- QWIP detectors
- Actively cooled FPA



Spacecraft
- 3-axis stabilized
- Accommodated OLI & TIRS

Launch Segment – NASA Lead

Atlas V 401

Ground System & In-Orbit Operations – USGS Lead

Ground Network Element (GNE)
- Antenna & associated equipment for X-Band image & S-Band telemetry data downlink reception and generation of S-Band command uplink

Collection Activity Planning Element (CAPE)
- Generates high level imaging mission schedules

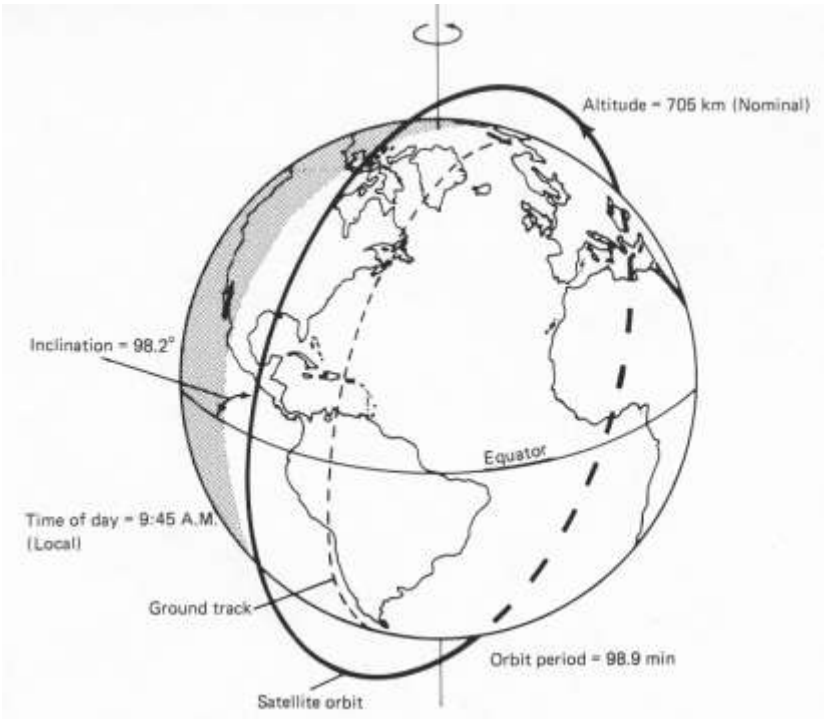
Mission Operations Element (MOE)
- Mission planning & scheduling, command & control, monitoring and analysis, flight dynamics & onboard memory management

Data Processing and Archive System (DPAS)
- Ingests and generates L0Ra data from GNE-provided Mission data
- Stores and archives LDCM data (Mission, L0Ra, and product)
- Provides inventory and metrics database services
- Provides Product Generation, Image Assessment, & Subsetter
- Provides web interface to facilitate: data discovery, product selection & ordering (for Cal/Val), & product distribution

Science Team

Top Level Mission Ops Concept - Continuity

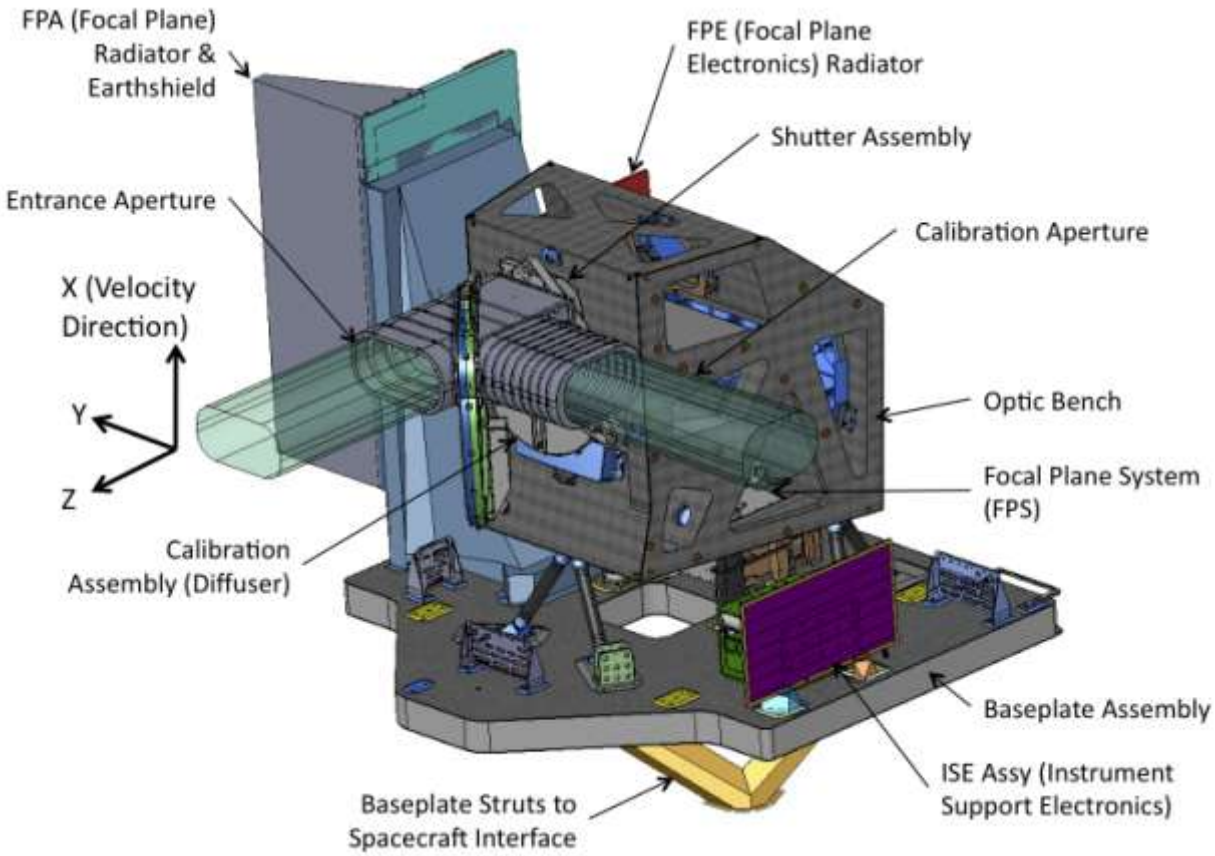
- **Fly LDCM observatory in legacy orbit** (705 km, near-polar, sun-synchronous)
  - Ground tracks maintained along heritage WRS-2 paths with 10:00 a.m. equatorial crossing time
- **Collect image data for multiple spectral bands (Vis/NIR/SWIR/TIR) across 185 km swath along each path**
  - Provide coverage of global land mass each season by scheduling the collection of 400 WRS-2 scenes per day
  - Maintain rigorous calibration



- **Archive data and distribute data products**
  - Provide nondiscriminatory access to general public, generate Level 1 data products, distribute data products at no cost upon request
- **Direct broadcast of data to network of international ground stations having memoranda-of-understanding with USGS**

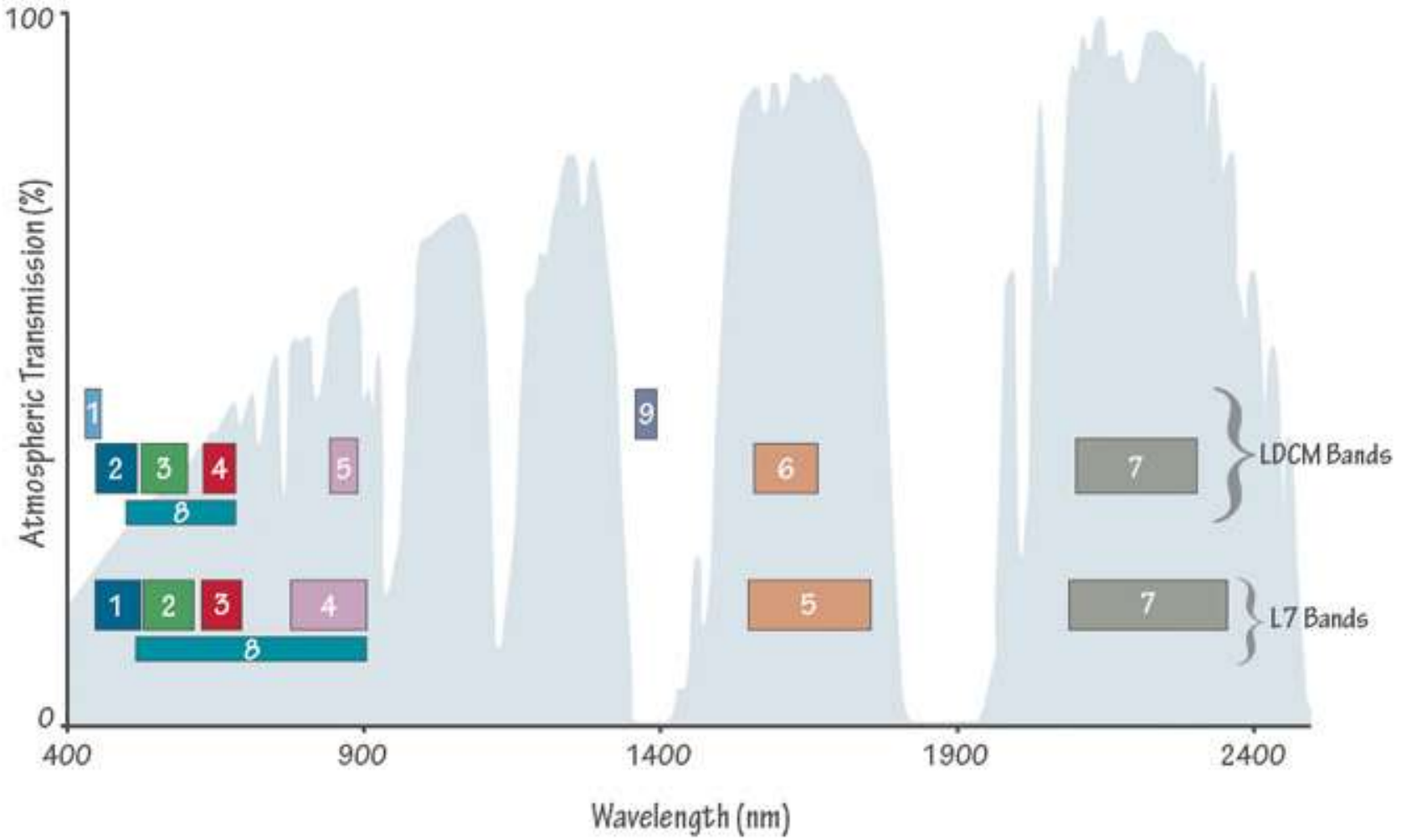
Operational Land Imager (OLI)

- OLI built by Ball Aerospace and Technology Corp. (BATC) of Boulder, CO
  - Contract awarded in July 2007
  - Critical design review held October, 2008
  - Fully assembled & tested OLI shipped to spacecraft vendor on October 02, 2011



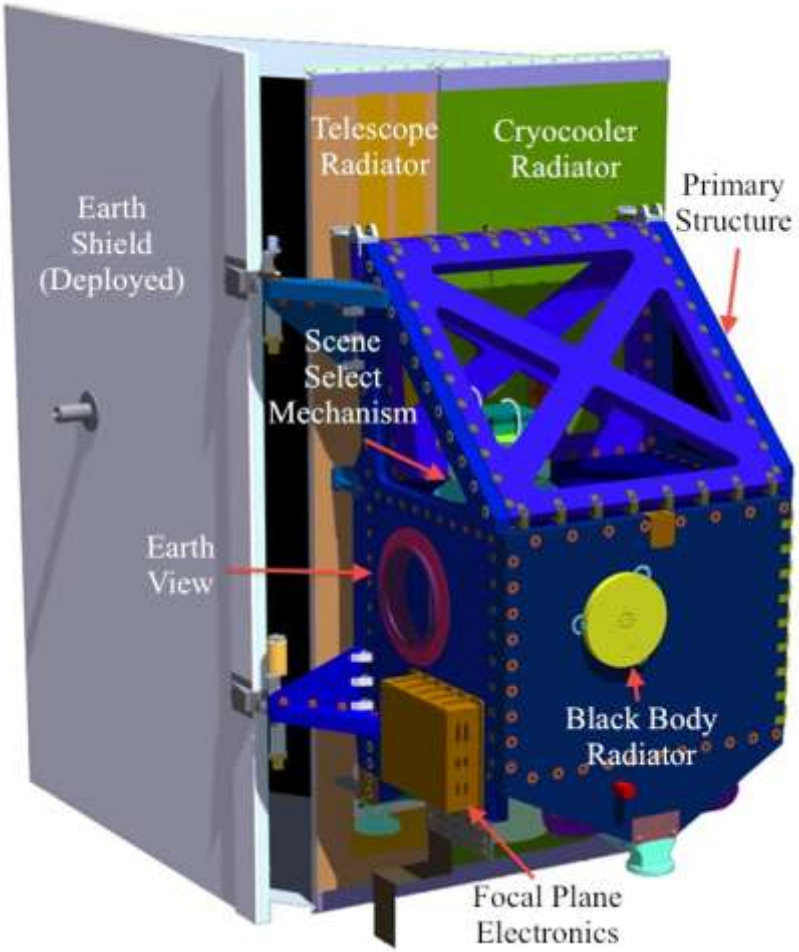
Fully Assembled OLI

OLI Spectral Bands



Thermal Infrared Sensor (TIRS)

- **TIRS is being built in-house at NASA/GSFC**
  - TIRS was officially added to the scope of the mission in December 2009
  - TIRS is fully assembled and currently in environmental testing
  - TIRS is scheduled to be shipped to the spacecraft vendor in January, 2012



Fully Assembled TIRS

TIRS and ETM+ Spectral Bands

L7 ETM+ Thermal Band		LDCM TIRS Band Requirements		
Band 6	**60 m LWIR** 10.00 - 12.50	**100 m LWIR**	10.30 – 11.30	**Band 10**
		100 m LWIR	11.50 – 12.50	**Band 11**

ETM+ and OLI/TIRS Spectral Bands

L7 ETM+ Bands		LDCM OLI/TIRS Band Requirements	
		30 m, Coastal/Aerosol, 0.433–0.453 µm (*A)	Band 1
Band 1	30 m, Blue, 0.450–0.515 µm	30 m, Blue, 0.450–0.515 µm	Band 2
Band 2	30 m, Green, 0.525–0.605 µm	30 m, Green, 0.525–0.600 µm	Band 3
Band 3	30 m, Red, 0.630–0.690 µm	30 m, Red, 0.630–0.680 µm (*B)	Band 4
Band 4	30 m, Near-IR, 0.775–0.900 µm	30 m, Near-IR, 0.845–0.885 µm (*B)	Band 5
Band 5	30 m, SWIR-1, 1.550–1.750 µm	30 m, SWIR-1, 1.560–1.660 µm (*B)	Band 6
Band 7	30 m, SWIR-2, 2.090–2.350 µm	30 m, SWIR-2, 2.100–2.300 µm (*B)	Band 7
Band 8	15 m, Pan, 0.520–0.900 µm	15 m, Pan 0.500–0.680 µm (*B)	Band 8
		30 m, Cirrus, 1.360–1.390 µm (*C)	Band 9
Band 6	60 m, LWIR, 10.00–12.50 µm	100 m, LWIR-1, 10.30–11.30 µm (*D)	Band 10
		100 m, LWIR-2, 11.50–12.50 µm (*D)	Band 11

*Explanation of Differences

A. Coastal Band added at request of ocean color investigators requiring higher resolution of coastal waters relative to MODIS and SeaWiFS.

B. Bandwidth refinements made to avoid atmospheric absorption features (enabled by the higher signal-to-noise ratio inherent in push-broom architecture).

C. Cirrus Band added to detect cirrus contamination in other channels.

D. TIRS will acquire the data for these two thermal bands.

Atlas V Launch Vehicle

- **Atlas V 401 selected by KSC**
  - Contract with United Launch Alliance (ULA)
  - Kickoff meeting held in October 2010
- **Launch will be from Vandenberg Air Force Base, California**

LDCM Spacecraft

- Spacecraft contract awarded to General Dynamics Advanced Information Systems (GDAIS) in April, 2008
  - GDAIS sold to Orbital Sciences Corporation in April 2010
- Space craft will accommodate two instruments (OLI, TIRS)
  - Provides pointing, power, data capacity, etc. to support LDCM operations
- Orbital Sciences Corporation will integrate OLI and TIRS onto the spacecraft at their Gilbert, AZ facility and ship the observatory to the launch site in September 2012

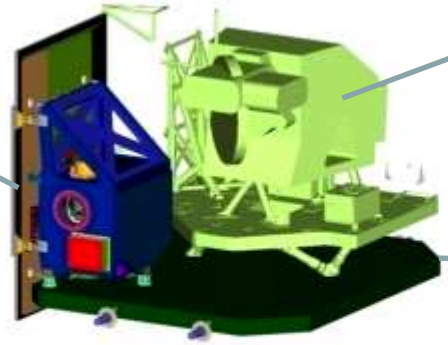
LDCM Space Craft

- **Orbital is building a three-axis stabilized vehicle built primarily of aluminum honeycomb structure with a hexagonal cross-section.**
  - spacecraft will supply power, orbit and attitude control, communications, and data storage for OLI and TIRS.
  - 5 year design life with 10 years of fuel

Spacecraft Subsytems

- **Mechanical subsystem (primary structure and deployable mechanisms)**
- **Command and data handling subsystem**
  - Includes a 3.14-terabit solid-state data recorder
- **Attitude control subsystem**
- **Electrical power subsystem**
- **Radio frequency (RF) communications subsystem**
  - Includes an omni X-band antenna will transmit OLI and TIRS data
- **Hydrazine propulsion subsystem**
- **Thermal control subsystem**

LDCM Observatory

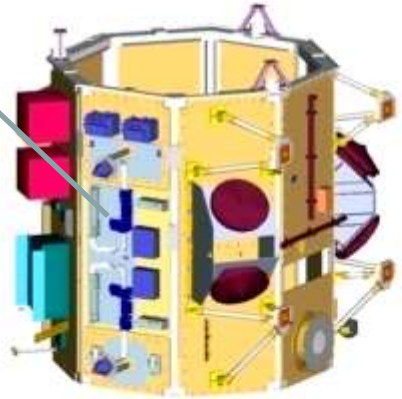


TIRS

OLI

INSTRUMENT DECK

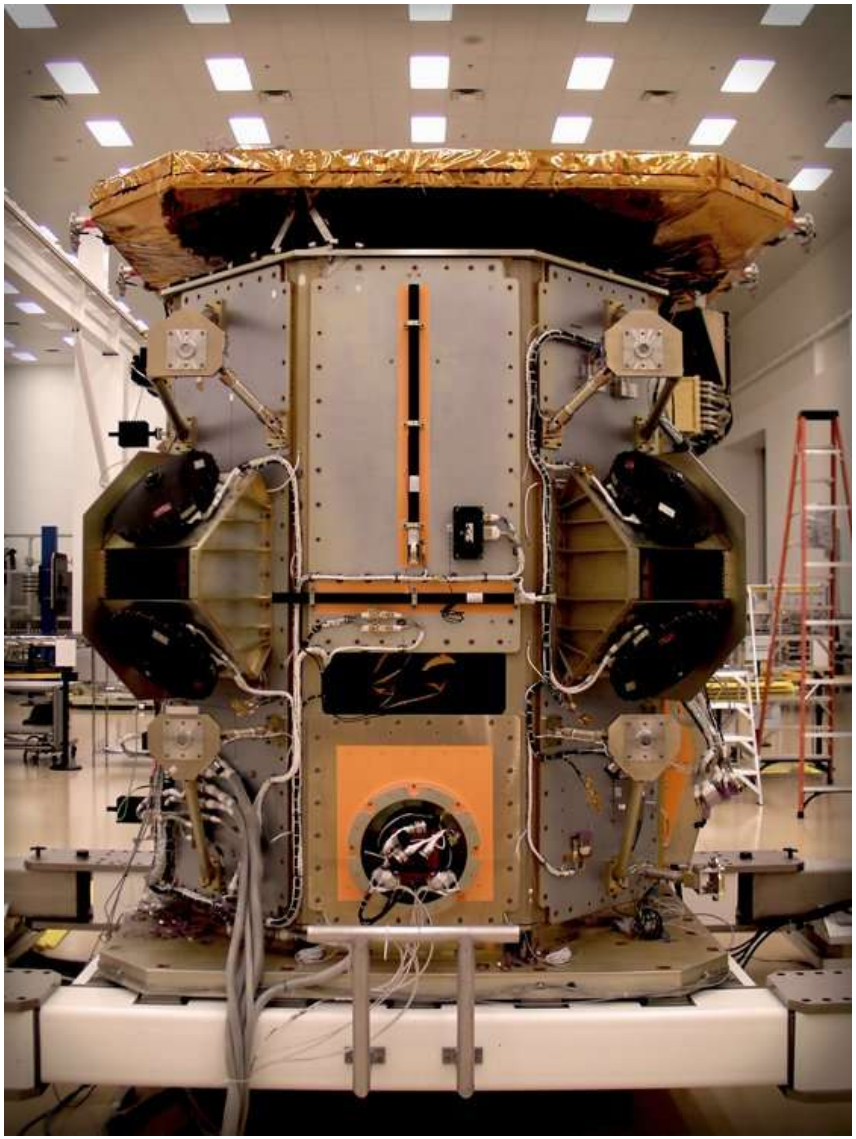
SPACECRAFT



SOLAR ARRAY

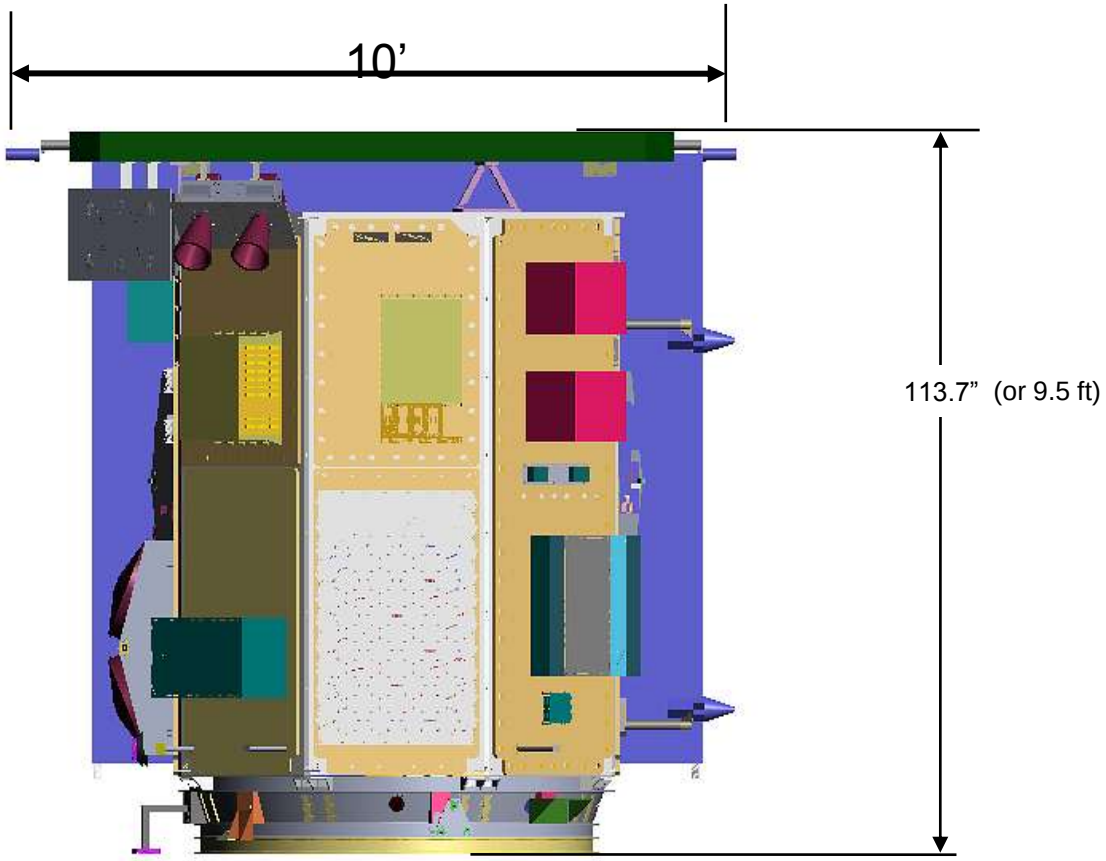
PROPULSION MODULE

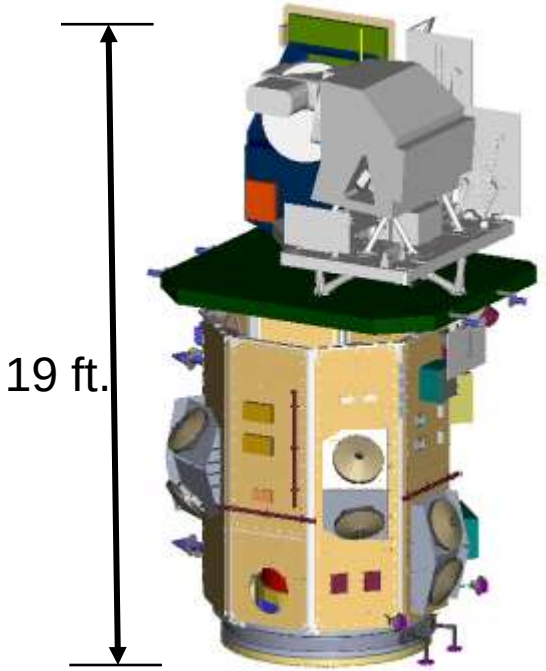
LDCM Spacecraft



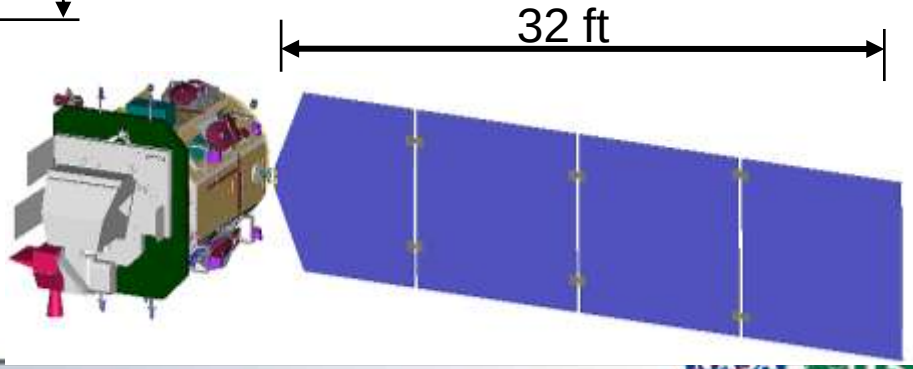
OLI to Spacecraft Integration / 18 October, 2011

Spacecraft/Observatory Size





S/C Assembly Mass - 4565 lbs
Fully loaded with fuel



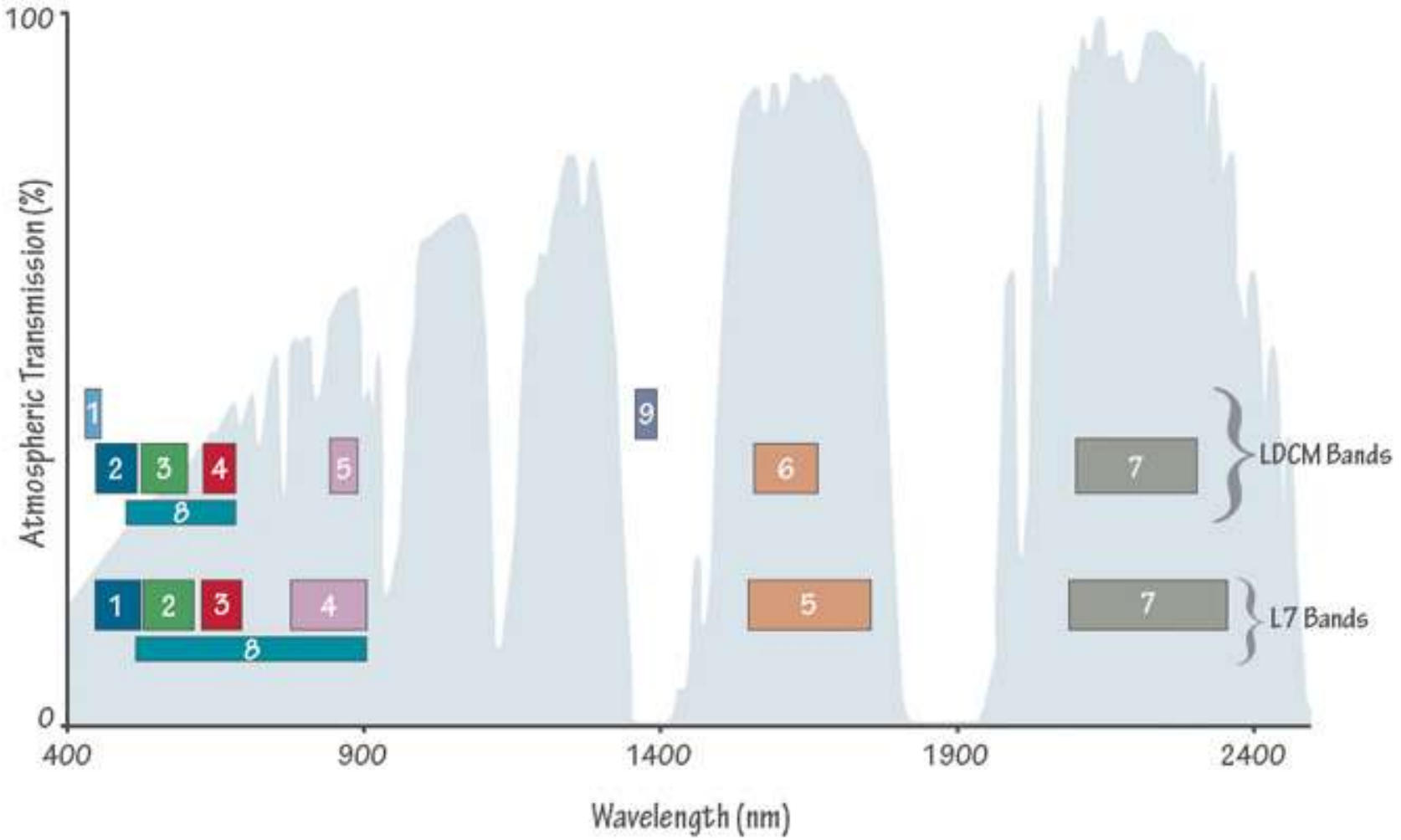
Project Summary

- Launch Readiness Date is December 1, 2012
  - Launch will likely slip to date between January 15 and February 15, 2013 due launch vehicle manifest conflicts with other satellite missions
- TIRS environmental testing underway at GSFC
  - Current delivery date to Orbital is 26 January, 2012
- Spacecraft ready for observatory integration at Orbital
  - OLI to spacecraft mechanical integration began Oct. 18
  - Observatory on schedule for September 2012 shipment to Vandenberg Air Force Base launch site
- Ground System development is going well

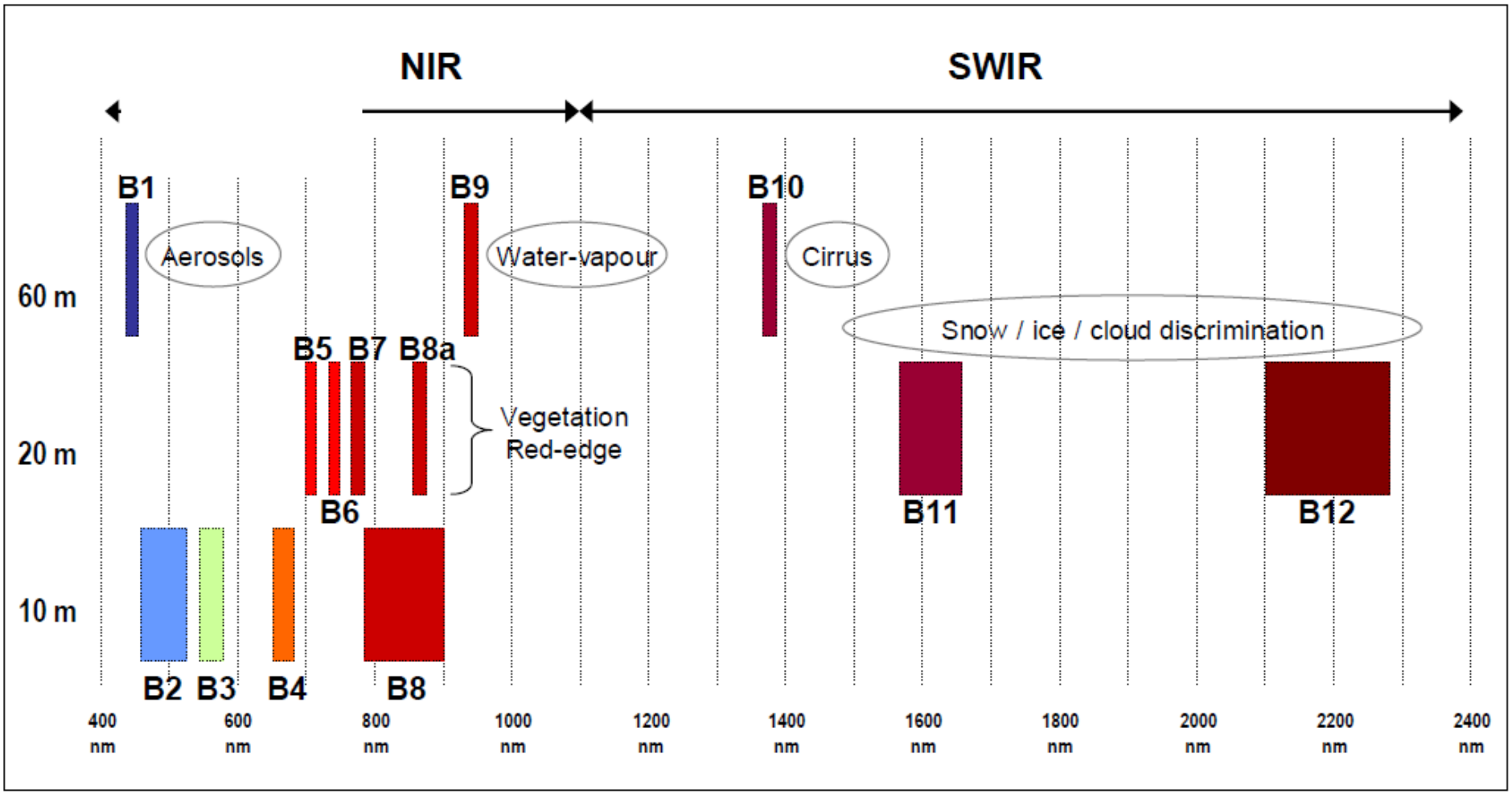
Web Sites

- http://landsat.nasa.gov
- http://landsat.gsfc.nasa.gov
- http://landsat.usgs.gov
- Facebook
  - http://www.facebook.com/NASA.Landsat
- Twitter
  - http://twitter.com/#!/NASA_Landsat
  - http://twitter.com/#!/USGSLandsat

OLI Spectral Bands

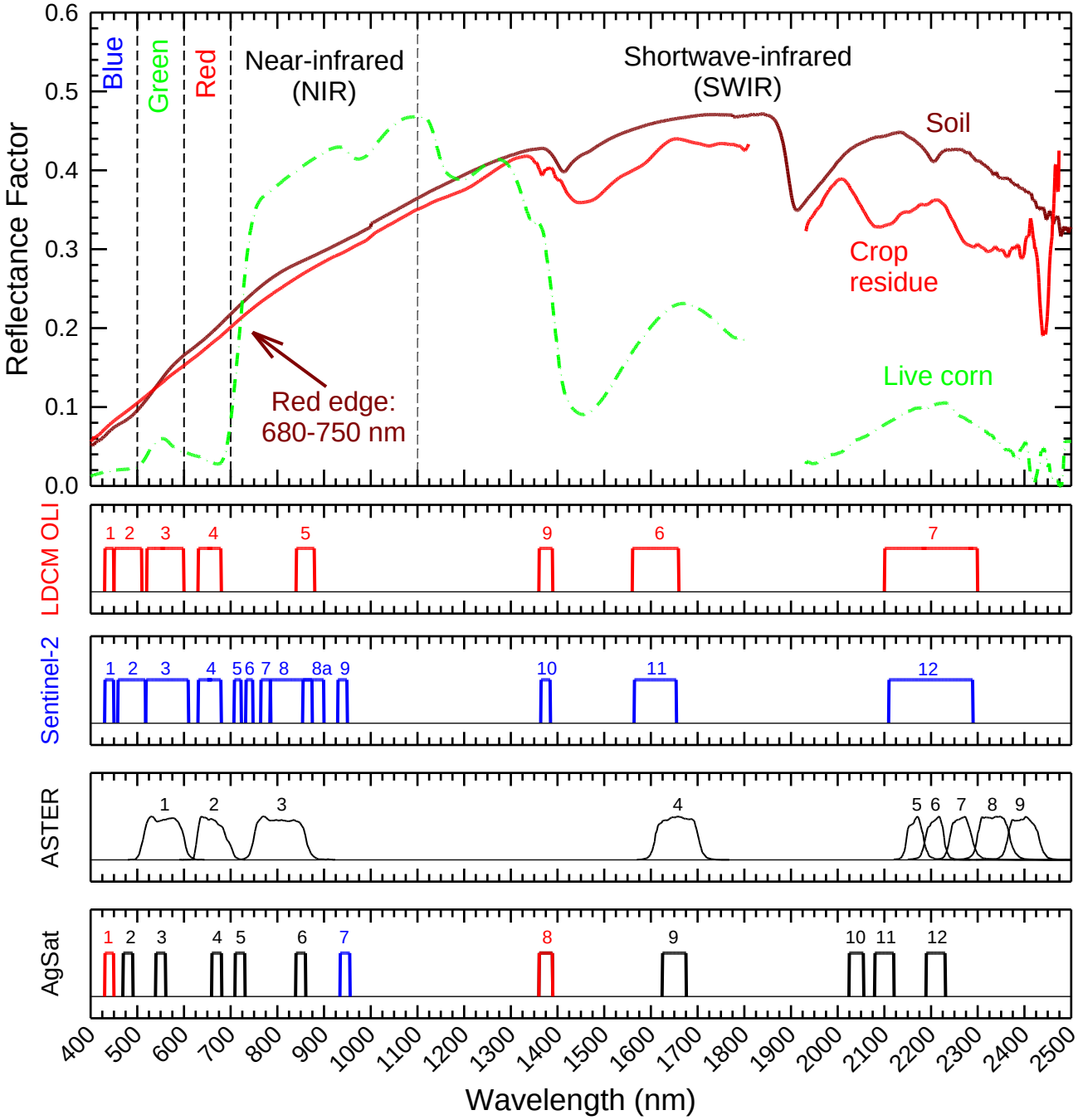


MSI Spectral Bands for Sentinal-2



Sentinel 2 – Multispectral imaging
Land applications: urban, forest, agriculture,..
Continuity of Landsat, SPOT

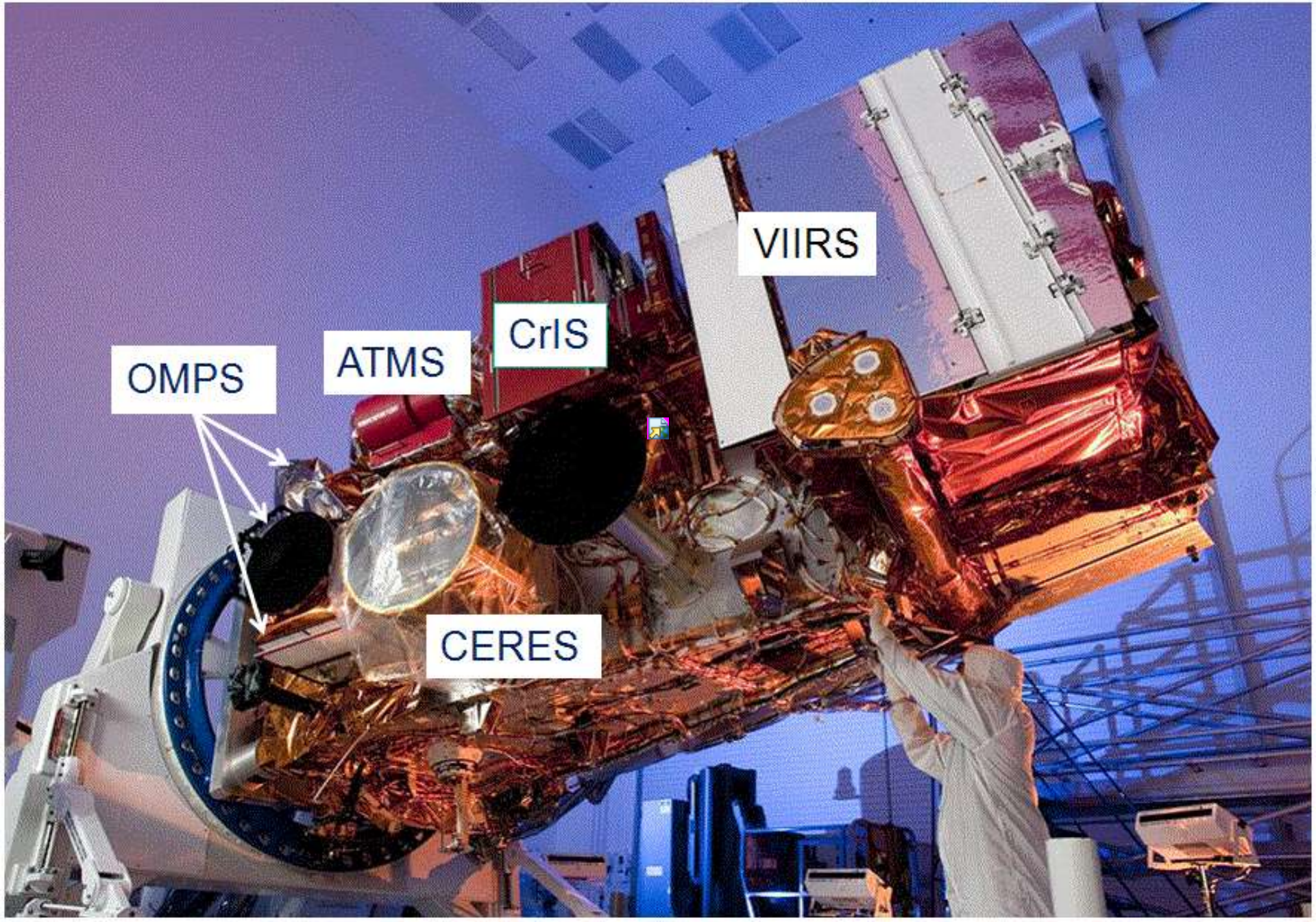
2013, 2014+


Reflectance Factor
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Blue
Green
Red
Near-infrared
(NIR)
Shortwave-infrared
(SWIR)
Soil
Crop
residue
Live corn
Red edge:
680-750 nm
LDCM OLI
1 2 3 4 5 9 6 7
Sentinel-2
1 2 3 4 5 6 7 8 8a 9 10 11 12
ASTER
1 2 3 4 5 6 7 8 9
AgSat
1 2 3 4 5 6 7 8 9 10 11 12
400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500
Wavelength (nm)

NPOESS Preparatory Project (NPP)

- NPP launched on October 28th at 5:48AM EDT.
- NPP is the bridge satellite between NASA's Earth Observing System (EOS) satellites (i.e., MODIS) and the forthcoming series of Joint Polar Satellite System (JPSS) satellites.
- Originally slated for as a research mission in the 10AM orbit, moved to operational mission in the 1:30PM orbit.
- VIIRS (**375**-meter) sensor on NPP will be the sensor replacement for MODIS (**250**-meter).
- VIIRS imagery will be supplied by NASA's LANCE (Land Atmosphere Near real-time Capability for EOS) system.
- Most likely posted here: http://lance.nasa.gov/imagery/rapid-response/

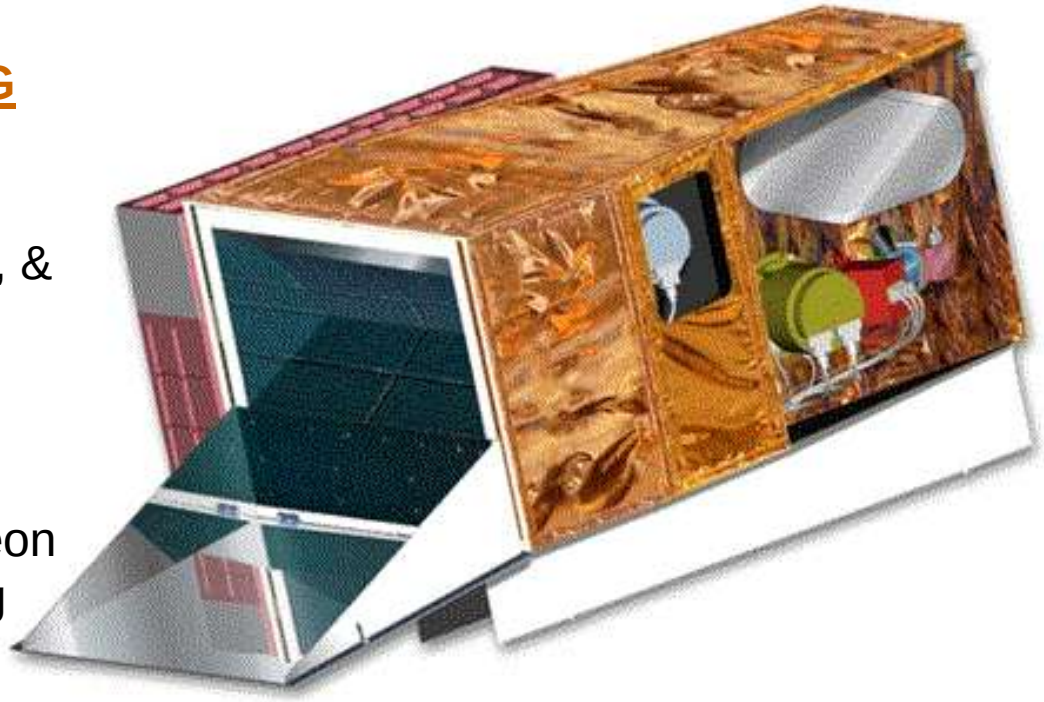
NPP Spacecraft Fully Integrated



VIIRS

VISIBLE INFRARED IMAGING SPECTROMETER

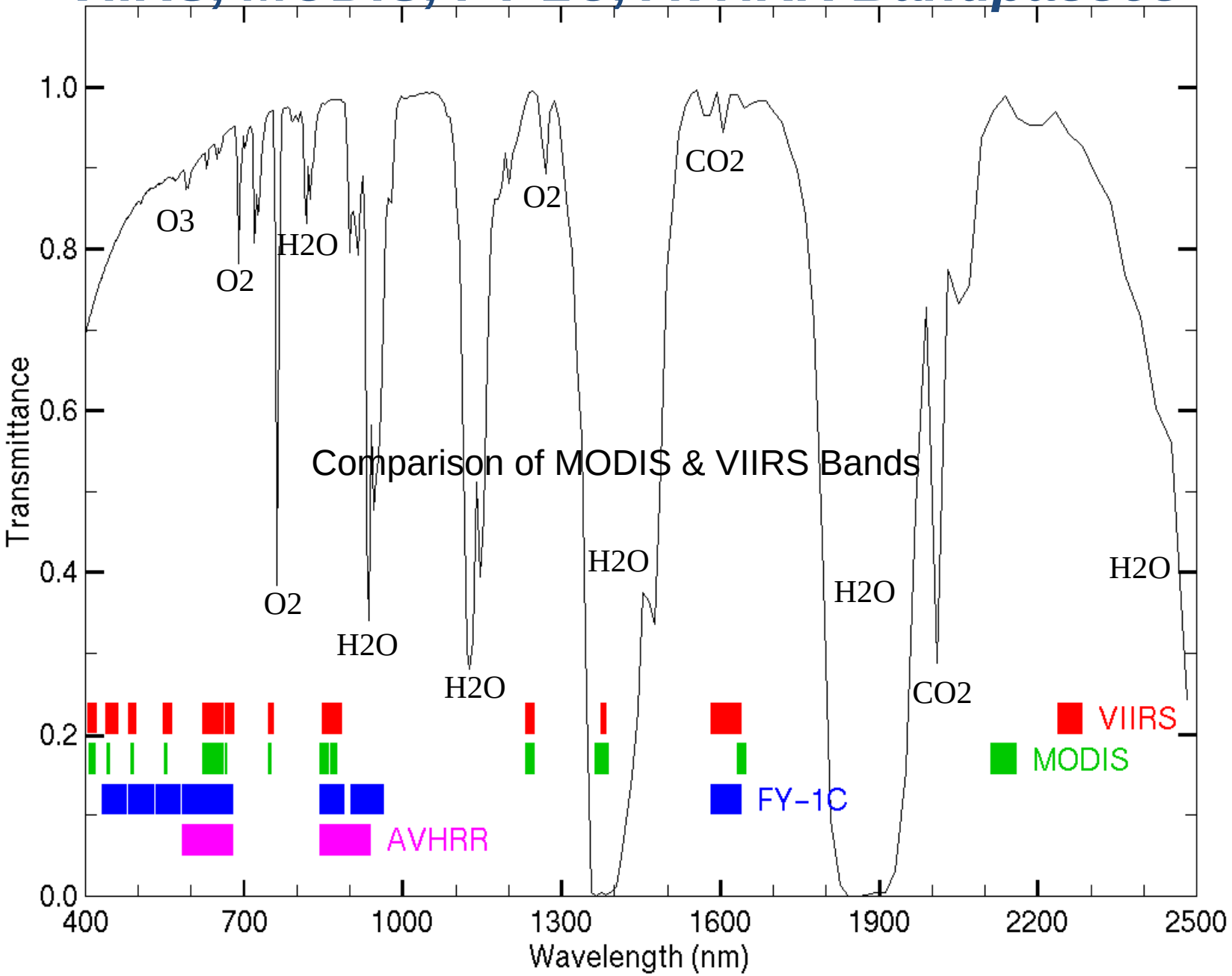
Global observations of land, ocean, & atmosphere parameters at high temporal resolution (~ daily).



- **Instrument Developer:** Raytheon Santa Barbara Remote Sensing
- **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:** 3,000 km

- Mass: **275 kg**
- Power: **240 w**
- Average Data Rate: **8 Mbps**

VIIRS, MODIS, FY-1C, AVHRR Bandpasses



Comparison of MODIS & VIIRS Bands

MODIS		VIIRS	
Band #	λ	λ	Band ID
1	620 - 670	600 - 680	I-1
2	841 - 876	845 - 885	I-2
3	459 - 479		
4	545 - 565		
5	1230 - 1250	1230 - 1250	M-8
6	1628 - 1652	1580 - 1670	M-10
		1580 - 1610	I-3
7	2105 - 2155	2225 - 2275	M-11
8	405 - 420	402-422	M-1
9	438 - 448	436-454	M-2
10	483 - 493	478-498	M-3
11	526 - 536		
12	546 - 556	545-565	M-4
13	662 - 672	662-682	M-5
14	673 - 683		
15	743 - 753	739-754	M-6
16	862 - 877	846-885	M-7
17	890 - 920		
18	931 - 941		
19	915 - 965		

MODIS		VIIRS	
Band #	λ	λ	Band ID
20	3.660 - 3.840	3.610 - 3.790	M-12
		3.550 - 3.930	I-4
21	3.929 - 3.989		
22	3.940 - 4.001		
23	4.020 - 4.080	3.973 - 4.128	M-13
24	4.433 - 4.498		
25	4.482 - 4.549		
26	1.360 - 1.390	1.371--1.386	M-9
27	6.535 - 6.895		
28	7.175 - 7.475		
29	8.400 - 8.700	8.400 - 8.700	M-14
30	9.580 - 9.880		
31	10.780 - 11.280	10.263 - 11.263	M-15
		10.050 - 12.400	I-5
32	11.770 - 12.270	11.538 - 12.488	M-16
33	13.185 - 13.485		
34	13.485 - 13.785		
35	13.785 - 14.085		
36	14.085 - 14.385		

MODIS Bands 1-2 are 250 m at Nadir
MODIS Bands 3-7 are 500 m at Nadir
MODIS Bands 8-36 are 1,000 m at Nadir

VIIRS Bands I1-I5 are 371 m at Nadir
VIIRS Bands M-1-M-16 are 742 m at Nadir

Increased Spatial Resolution

Decreased Spatial Resolution

VIIRS Active Fires

Algorithm Overview

- This deliverable Application Related Product (ARP) provides:
  - Geolocation of the pixels in which active fires are detected,
  - The sub-pixel average temperature of each active fire, and
  - The sub-pixel area of each active fire.
- Execution Conditions:
  - Both day and night
  - Confident Clear pixels
- HCS @ Nadir: 0.75 km

Issues

• Combination of higher resolution pixels and less dynamic range means earlier saturation of fire product compared to MODIS

• **Pixel aggregation scheme** means that a saturated pixel could be averaged with 1 or two unsaturated pixels resulting in erroneous data that is not flagged

Inputs Required

- VIIRS Moderate Resolution Reflectances and Brightness Temperatures
  - M5, M7, M11, M13, M15, M16
- VIIRS Quarterly Surface Types IP
- Ancillary Data
  - Land-Water Mask

Improvements to the Fire Product

• Dr Ivan Csizlar et al. have been contracted to provide an enhanced fire detection algorithm & evaluate the impact of undetected saturation.
• They will run this in the Land PEATE & evaluate its performance pr & post-launch
• Provides a test case for moving external (to NGST) algorithms into the operational stream &/or distribution by other means
• Expect to have improved dynamic range and better high range calibration for F2 & further improvements to the algorithm
• Looking for cost-effective ways to avoid the saturation problem

Detector Aggregation Reduces Pixel Growth

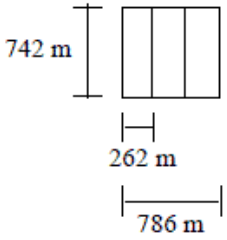
VIIRS Reduces Pixel Size Along Scan:

Much Better HSR, SNR Toward Nadir

Radiometric ("Moderate-Resolution") Bands

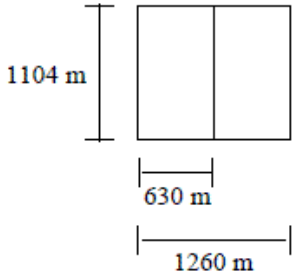
Nadir to 1060km

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



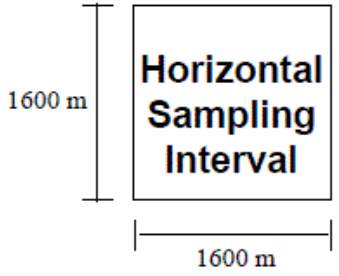
To ~1700 km

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



To 3000 km

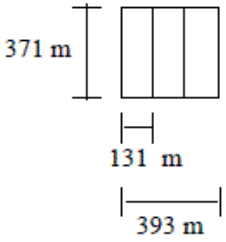
- no aggregation



Imaging ("High-Resolution") Bands

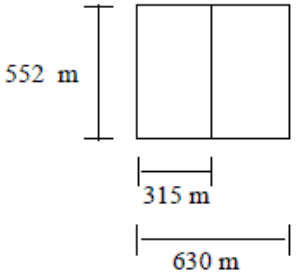
Nadir to 1060km

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



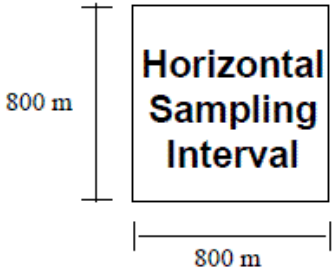
To ~1700 km

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



To 3000 km

- no aggregation



Moderate and Imaging bands nest 2x2

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

Vs.

VIIRS 1.6x1.6 km At Edge

VIIRS Pixel Aggregation Provides High SNR at Nadir, Reduced Pixel Growth

Parameter	AVHRR	MODIS-EOS	VIIRS-NPP	VIIRS-NPOESS
Spatial Resolution (m; nadir)	1000	250, 500, 1000	375, 750	375, 750
Constrained Pixel Growth Along Scan	No (Edge-of-scan ~6x nadir)	No (Edge-of-scan ~6x nadir)	Yes (Edge-of-scan ~2x nadir)	Yes (Edge-of-scan ~2x nadir)

- VIIRS provides aggregated pixels rather than allowing user to decide on usable area (degrees off nadir) and sampling to constant pixel size.

Reduced Pixel Growth Along Scan
== Reduced Spatial Resolution at Nadir

Costs: Stepwise decreased S/N Ratio;
Undetected detector saturation (single gain)