

Landsat Data Continuity Mission

presented at

The 15th Annual LCLUC Science Team Meeting

March 29, 2011

UMUC Marriott, Adelphi, Maryland

by

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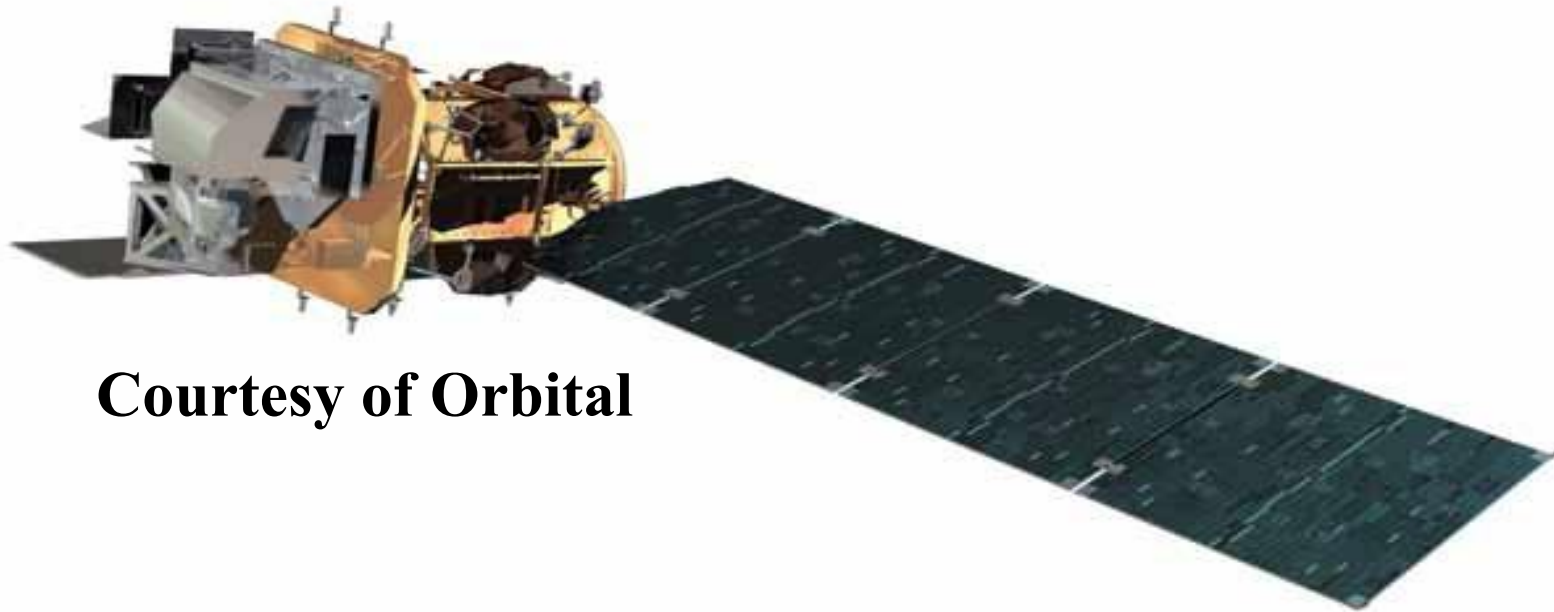
NASA Goddard Space Flight Center

Greenbelt, MD

Future Landsat Data

LDCM

- **The Landsat Data Continuity Mission (LDCM) is under development for a December, 2012 launch**
 - **Developed as a NASA / USGS partnership**
 - **LDCM conducted a successful critical design review (CDR) May 25 – 27, 2010**



Courtesy of Orbital

Mission Life Cycle Status

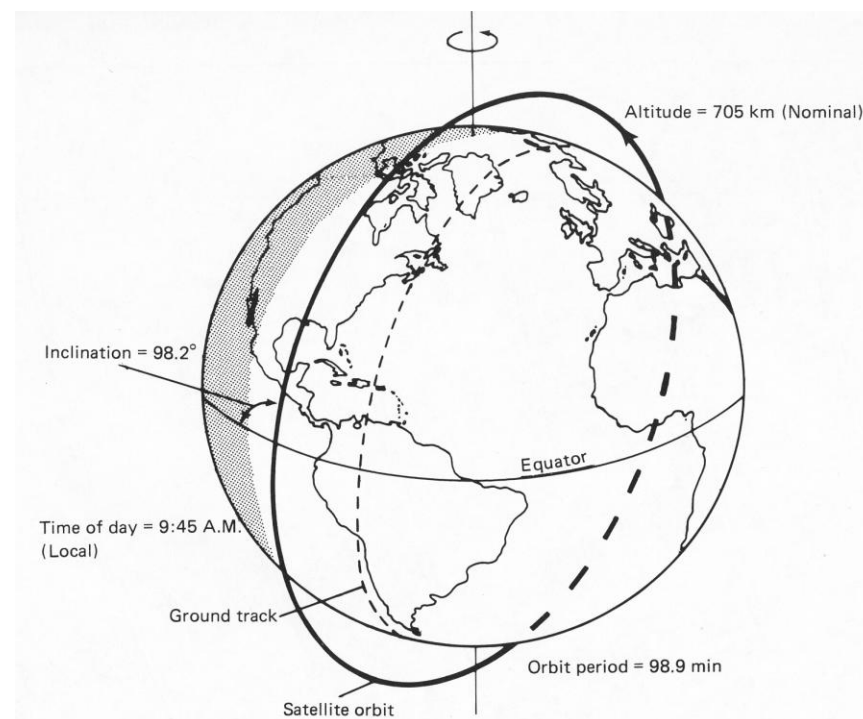
LDCM

- **LDCM is a NASA Category 1 Mission**
 - **LDCM receives the highest level of visibility in NASA**
 - Same as Hubble Space Telescope, Space Shuttle, Space Station, etc.
 - **LDCM requires approval of the Agency Program Management Council to initiate each phase of the project lifecycle**
 - **An independent Standing Review Board evaluates the mission periodically (all mission level reviews) and makes recommendations to the Agency Program Management Council (both technical and programmatic)**

Top Level Mission Ops Concept - Continuity

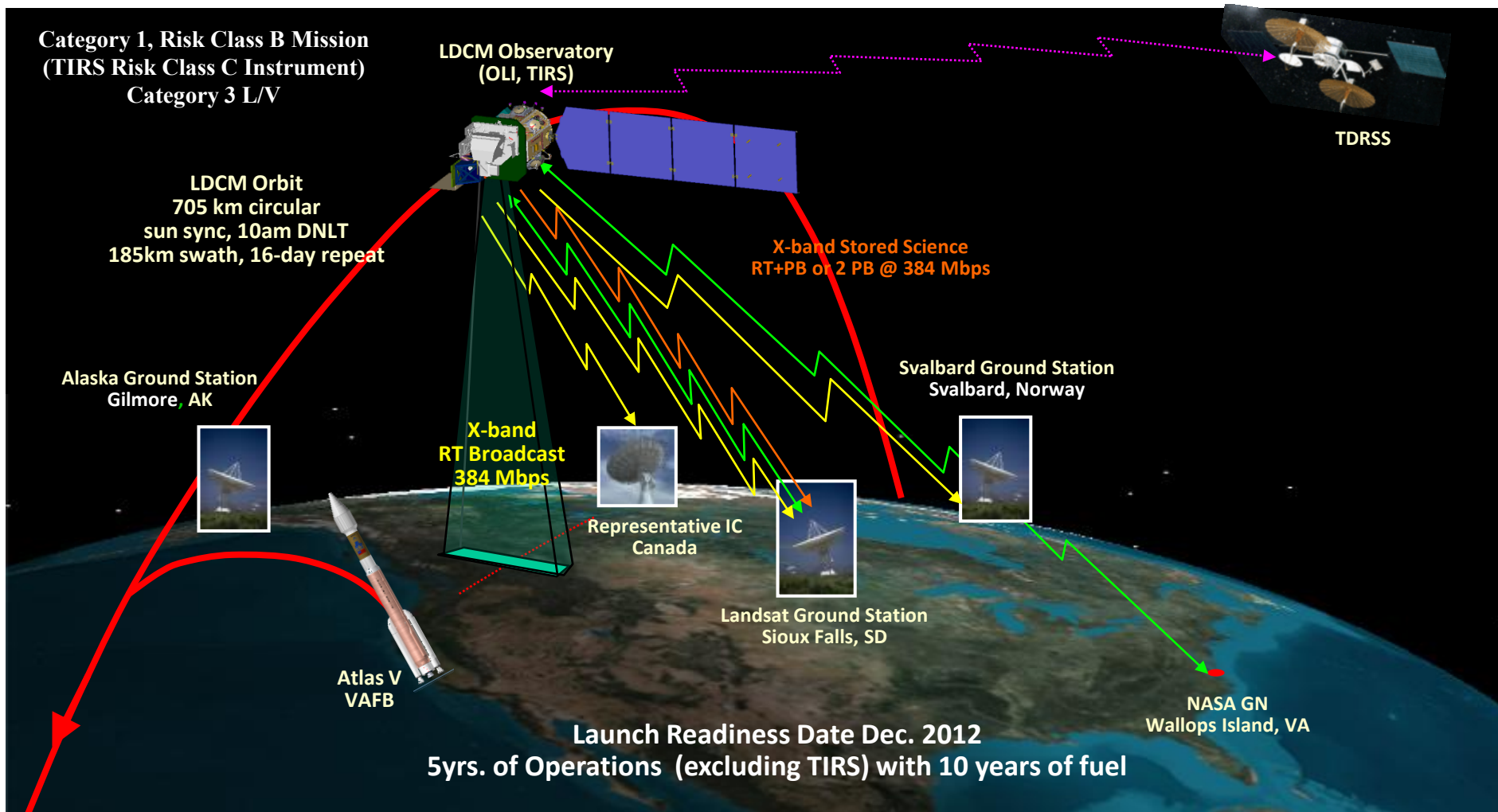
LDCM

- **Fly LDCM observatory in legacy orbit (716 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**



LDCM Overview

LDCM



NASA/USGS Partnership

LDCM

- **NASA Responsibilities**

- Space Segment, Launch Segment, and Mission Operations Element (MOE)
- Lead mission development as system integrator and lead missions systems engineering for all mission segments throughout development, on-orbit check-out, and acceptance
- Lead Mission Operations through completion of on-orbit checkout period
- Accountable for mission success through on-orbit check-out and acceptance across all mission segments

- **USGS Responsibilities**

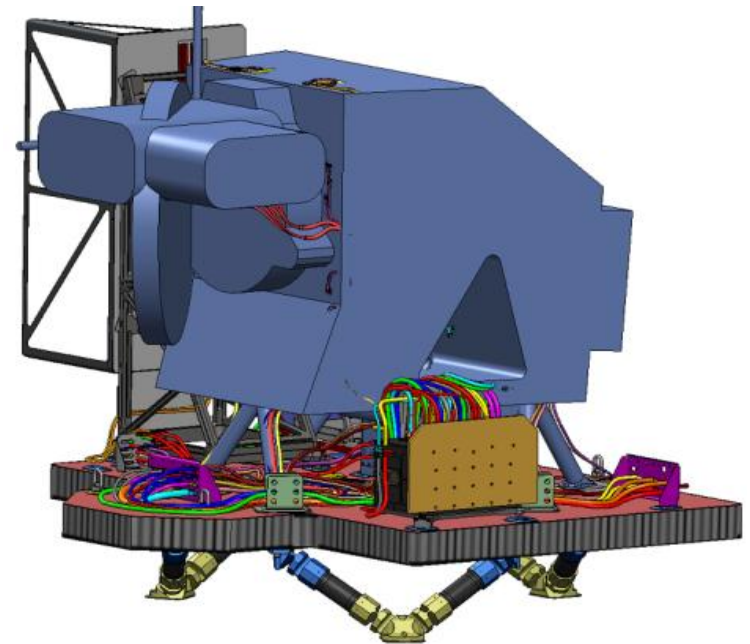
- Development of Ground System
 - Excluding the MOE
- Lead, fund, and manage the Landsat Science Team
- Lead LDCM mission operations, after the completion of the on-orbit checkout period
- Accept and execute all responsibilities associated with the transfer of the LDCM Operational Land Imager (OLI) instrument, spacecraft bus, Mission Operations Element, and NSC/KSAT contracts from NASA following on-orbit acceptance of the LDCM system including assuming contract management

Operational Land Imager (OLI)

LDCM

- OLI Provides
 - Accurate spectral and spatial information
 - Precise calibrated, geo-referenced data

- OLI Contains
 - Pushbroom VIS/NIR/SWIR detectors
 - Focal plane consisting of 14 Sensor Chip Assemblies (SCA) – 6,000 detectors per SCA for a total of 84,000 detectors
 - Visible and Short Wave Infrared Sensors
 - Four-mirror telescope
 - On-board calibration with both diffusers and lamps



- OLI is being built by Ball Aerospace and Technology Corp. of Boulder, CO
 - Contract awarded in July 2007
 - Critical design review held October, 2008

OLI Spectral Bands

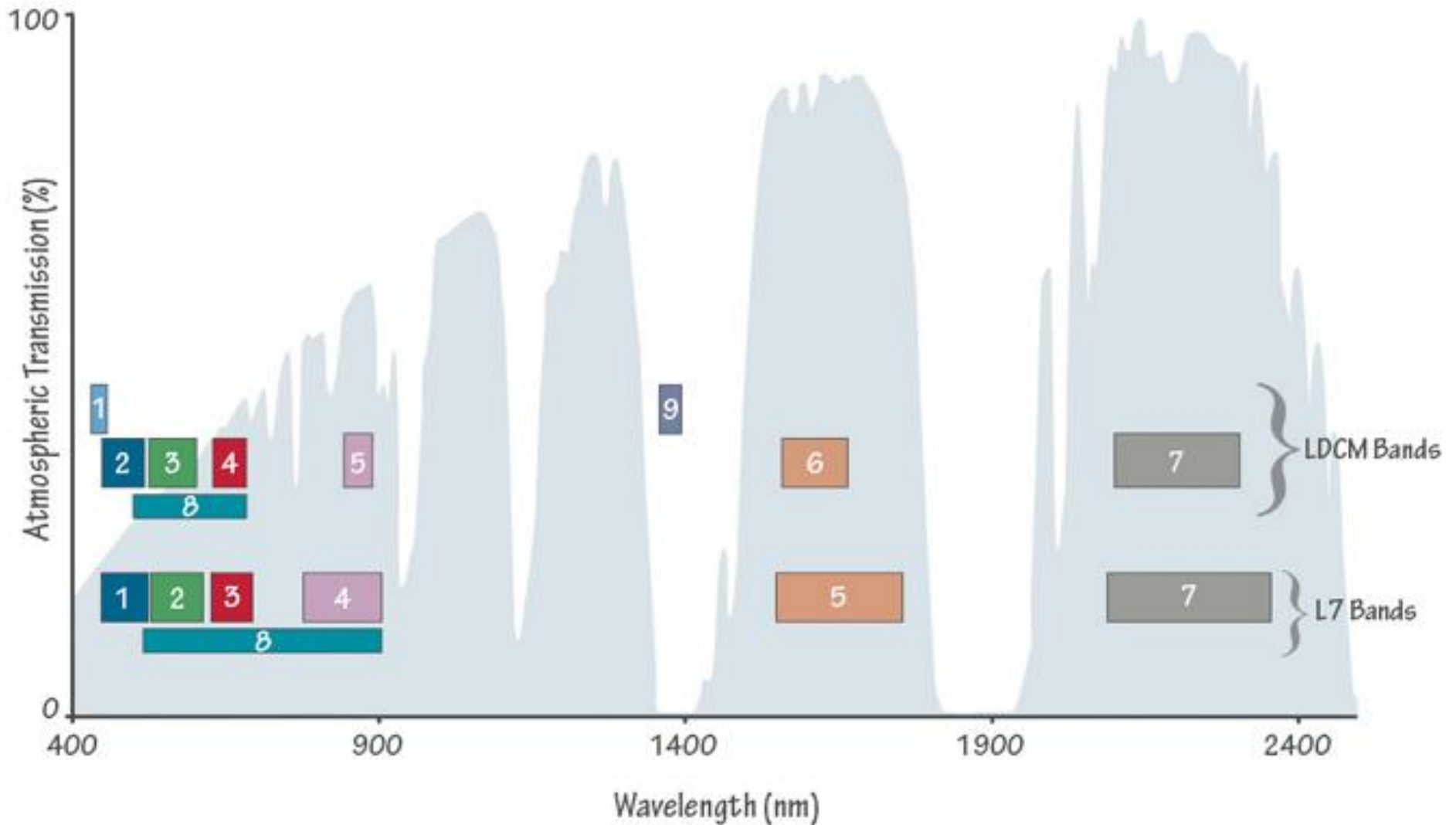
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L7 ETM+ Bands			LDCM OLI Band Requirements		
			30 m Coastal/Aerosol	0.433 - 0.453 (2)	Band 1
Band 1	30 m Blue	0.450 - 0.515	30 m Blue	0.450 - 0.515	Band 2
Band 2	30 m Green	0.525 - 0.605	30 m Green	0.525 - 0.600	Band 3
Band 3	30 m Red	0.630 - 0.690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

- Explanation of Differences**

- 1) **Cirrus Band added in 2001 to detect cirrus contamination in other channels**
- 2) **Coastal Band added in 2001 at request of ocean color investigators requiring higher resolution of coastal waters relative to MODIS and SEAWifs**
- 3) **LWIR data to be collected by Thermal InfraRed Sensor (TIRS)**
- 4) **Bandwidth refinements made in all bands to avoid atmospheric absorption features**
 - 1) Enabled by higher SNR which is, in turn, enabled by push-broom instrument architecture

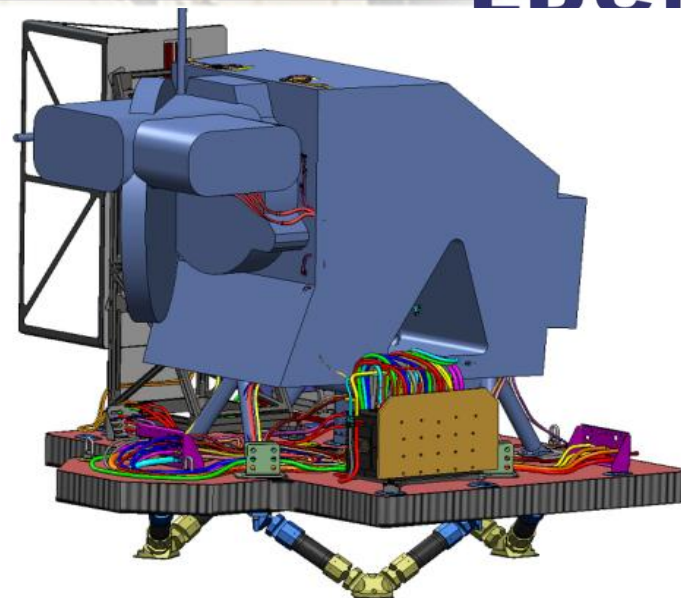
OLI Spectral Bands




OLI Status

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- **Flight instrument integration completed**
 - **Focal Plane System**
 - **Calibration Subsystem**
 - **Electronics Boxes**
 - **Baseplate**
- **Flight OLI completed performance testing**
 - **Spatial, spectral, and radiometric testing complete**
- **Sensor integrated to baseplate**



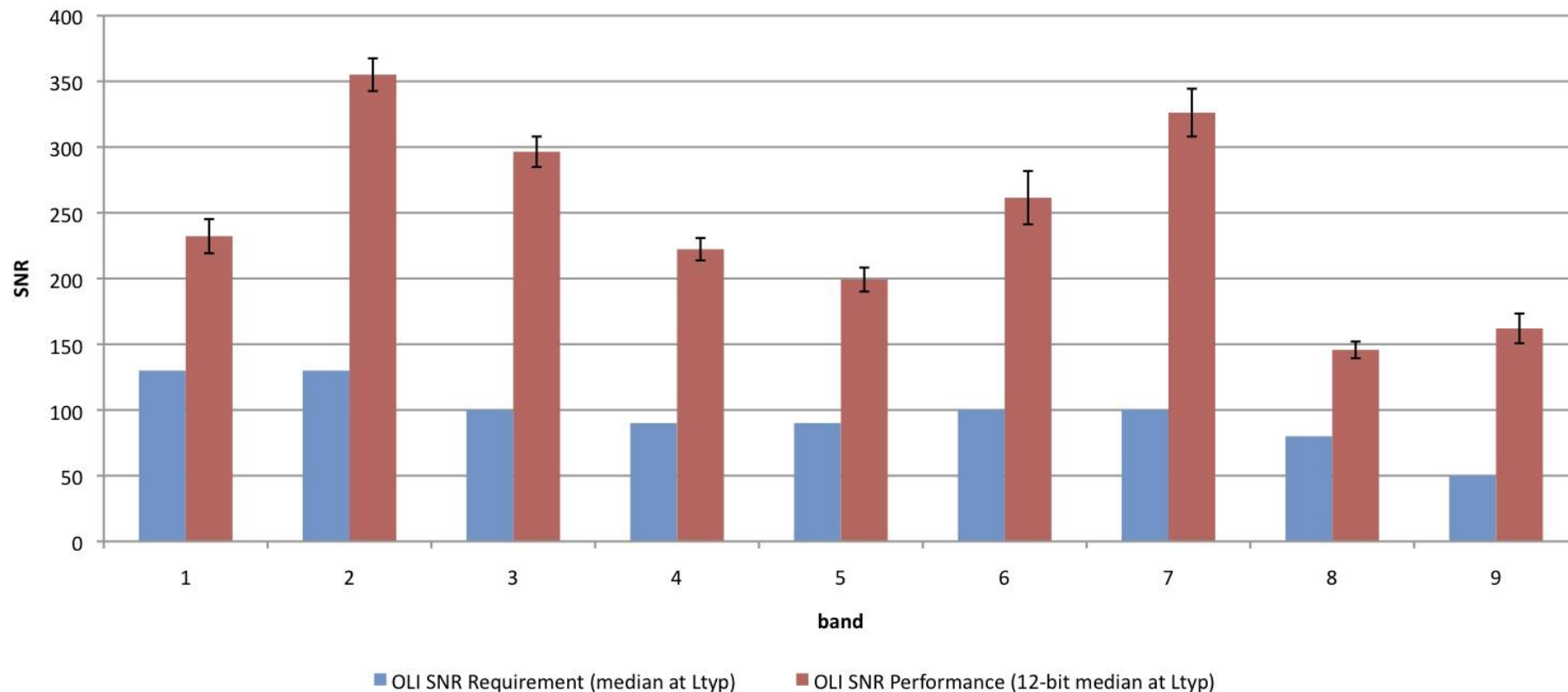


Near Term Milestones (Next 6 months)

- **Complete environmental testing**
 - **EMI/EMC**
 - **Vibration**
 - **Thermal vacuum/thermal balance**
- **OLI Pre-Ship Review will be held ~2 weeks prior to shipment**
- **Ship OLI to the spacecraft vendor – June 2011**
- **Integrate OLI to Spacecraft**

Pre-Launch OLI Signal-to-Noise Performance

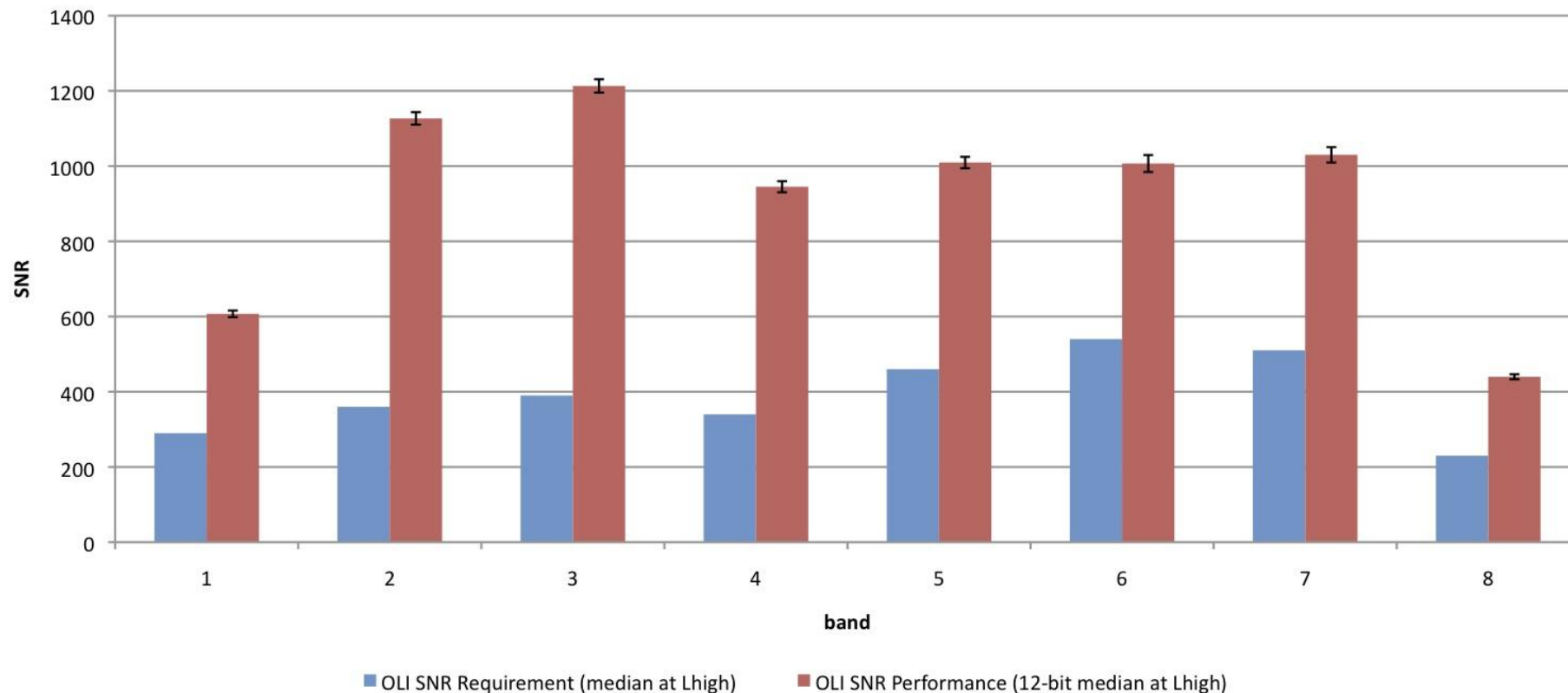
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OLI Signal-to-Noise Performance at L_{typ} 

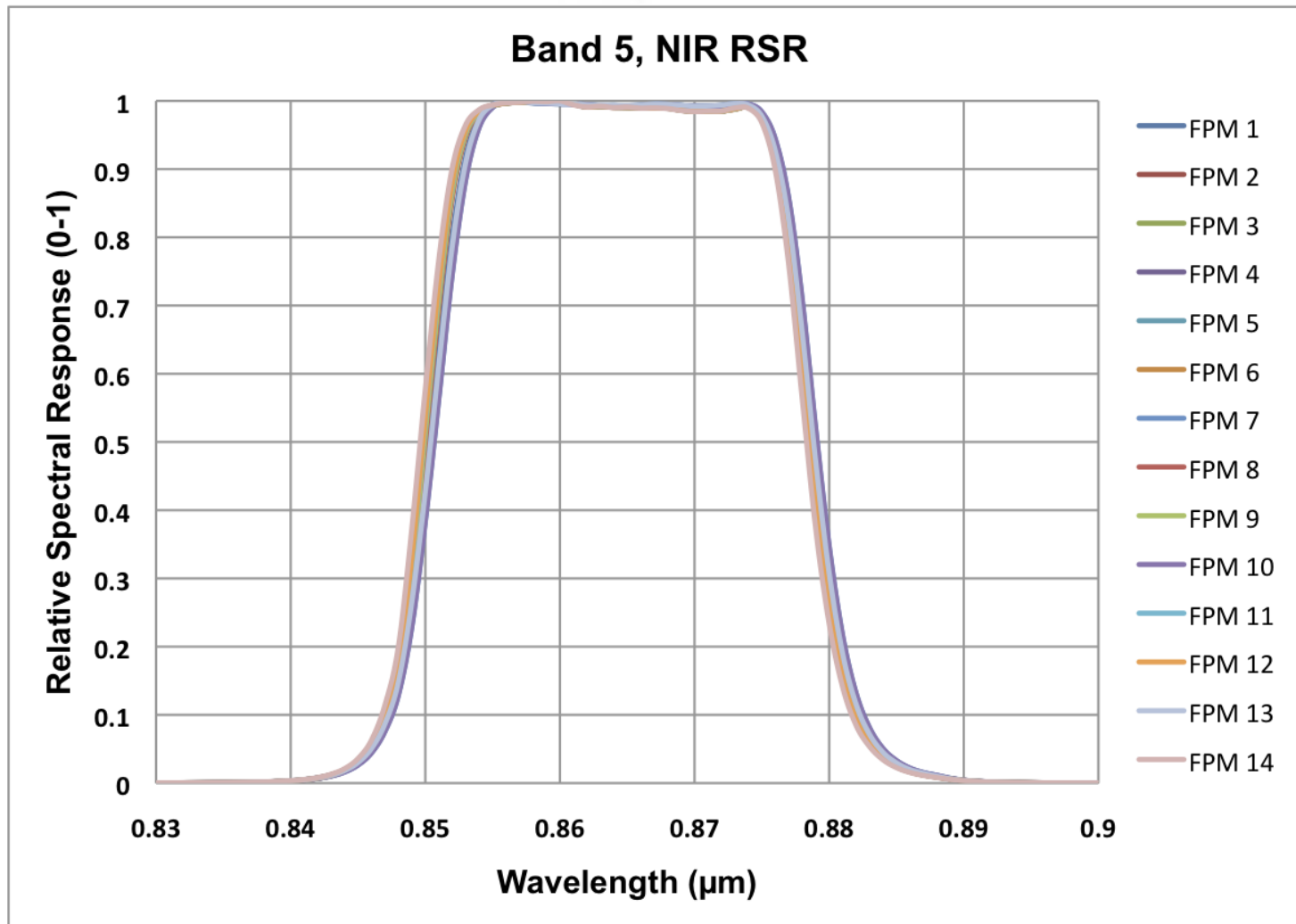
Pre-Launch OLI Signal-to-Noise Performance

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OLI Signal-to-Noise Performance at Lhigh



OLI Relative Spectral Response



Completed OLI Instrument

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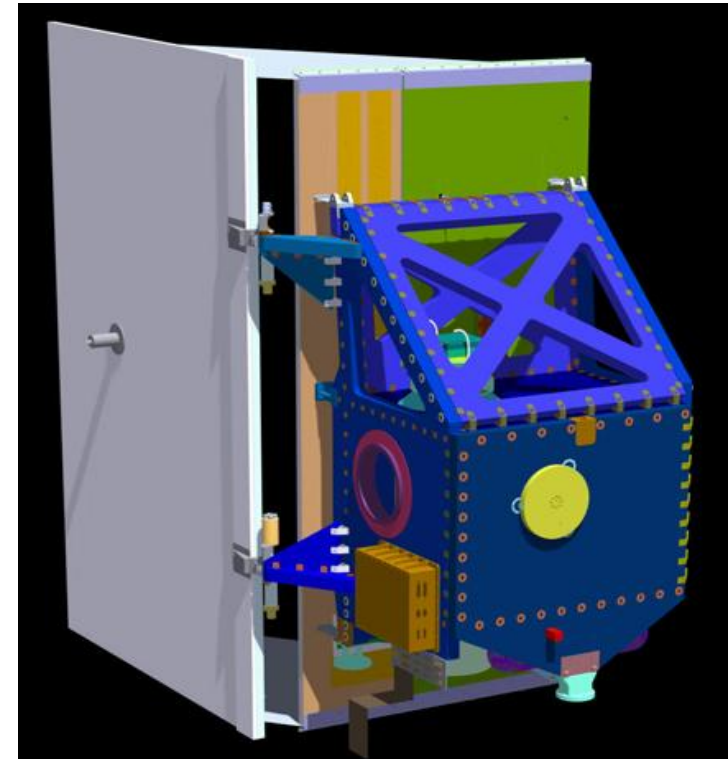


Courtesy of Ball
Aerospace &
Technologies
Corp.

TIRS Overview

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- **2 channel (10.8 and 12 um) thermal imaging instrument**
- **Quantum Well Infrared Photodiodes (QWIP) / FPA built in-house at Goddard**
- **100 m Ground Sample Distance**
- **185 km ground swath (15° field of view)**
- **Pushbroom design with a precision scene select mirror to select between calibration sources**
- **Two full aperture calibration sources: onboard variable temp black body and space view**
- **Passively cooled telescope assembly operating at 180K**
- **Actively cooled (cryocooler) FPA operating at 43K**
- **3 Year Design Life, Class C Instrument**
- **TIRS is being built in-house at NASA/GSFC**
 - **TIRS was officially added to the scope of the mission in December 2009**
- **Critical Design Review (CDR) completed - April 2010**



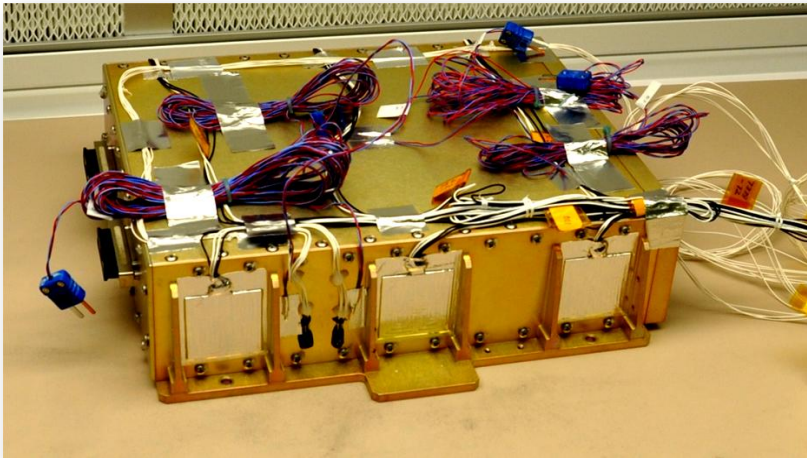
TIRS and ETM+ Spectral Bands



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

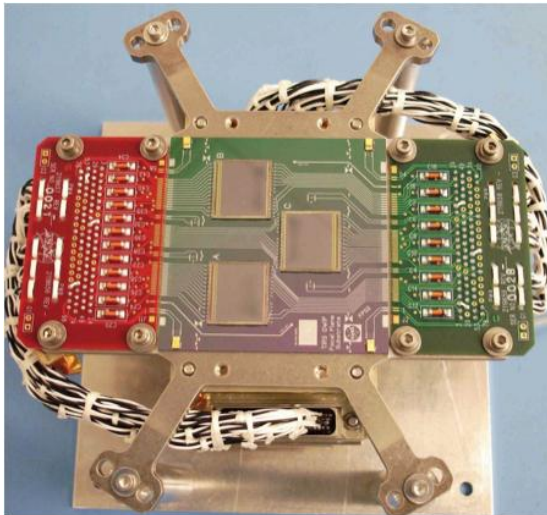
- 120 m resolution TIRS requirement deemed sufficient to resolve most center-pivot irrigation fields in U.S. West - typically 400 to 800 m in diameter – TIRS design provides for 100 m resolution
- Landsat 4 & 5 TM’s provided 120 m thermal images for a single thermal band
- Landsat 7 ETM+ provided 60 m thermal images for a single thermal band
- A two band instrument will enable atmospheric correction so that more accurate surface temperatures can be derived.

TIRS Status

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Focal Plane Electronics

Focal Plane Array

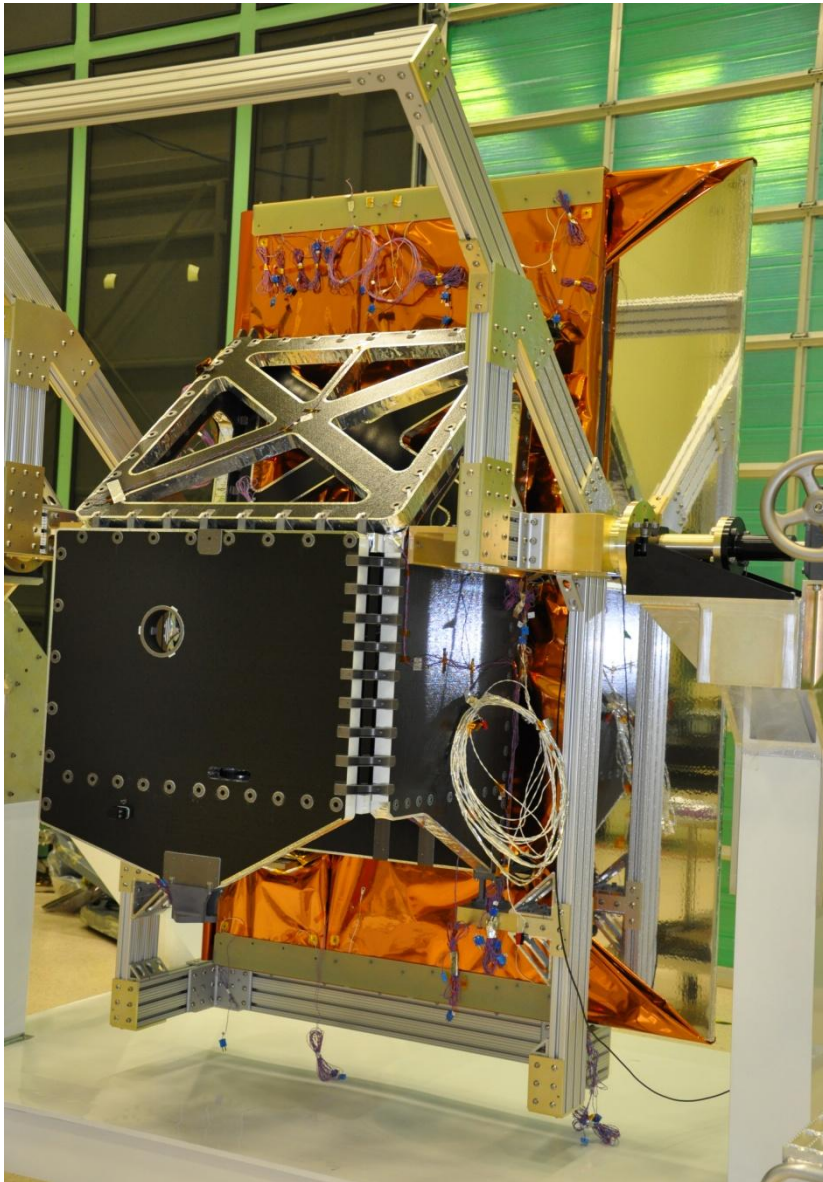


**Focal Plane Array,
Focal Plane Electronics,
and telescope assembled
and currently in flight
calibration testing.
Preliminary results are
within specification.**



TIRS Telescope

TIRS Status

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TIRS Primary Structure completed all qualification testing including thermal vacuum, vibration, acoustics, and cold Earthshield deployment.

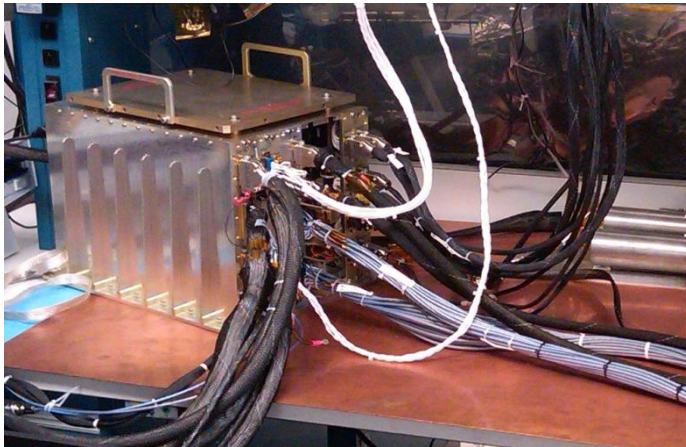
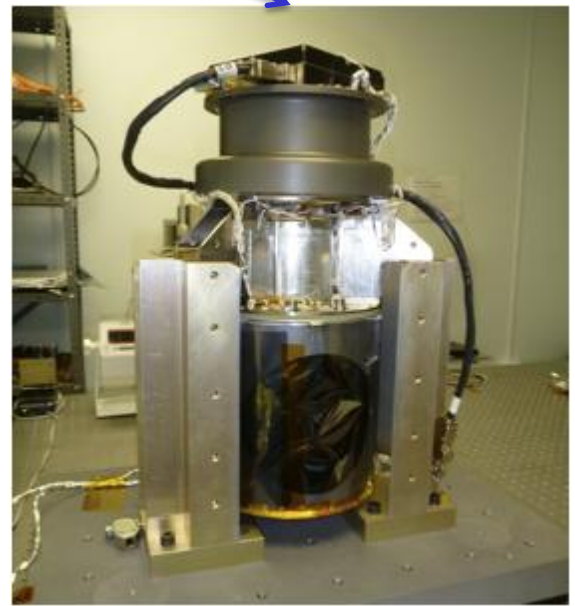
TIRS Status

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Flight Cryocooler with Electronics:
 All environmental testing has been completed Pre-Ship review scheduled for March 30th.

Flight Scene Select Mechanism:
 Completed vibration testing and is currently in Thermal Vacuum. T/V is the last of the qualification tests prior to delivery to I&T.



MEB Test Bed tested with no issues found. Flight boards have been assembled and are in testing. MEB delivery to I&T expected the end of May.

Near Term Milestones

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- **Pre-Environmental Review (PER), August 2011**
- **Deliver TIRS to spacecraft vendor in November 2011 for integration**

Spacecraft



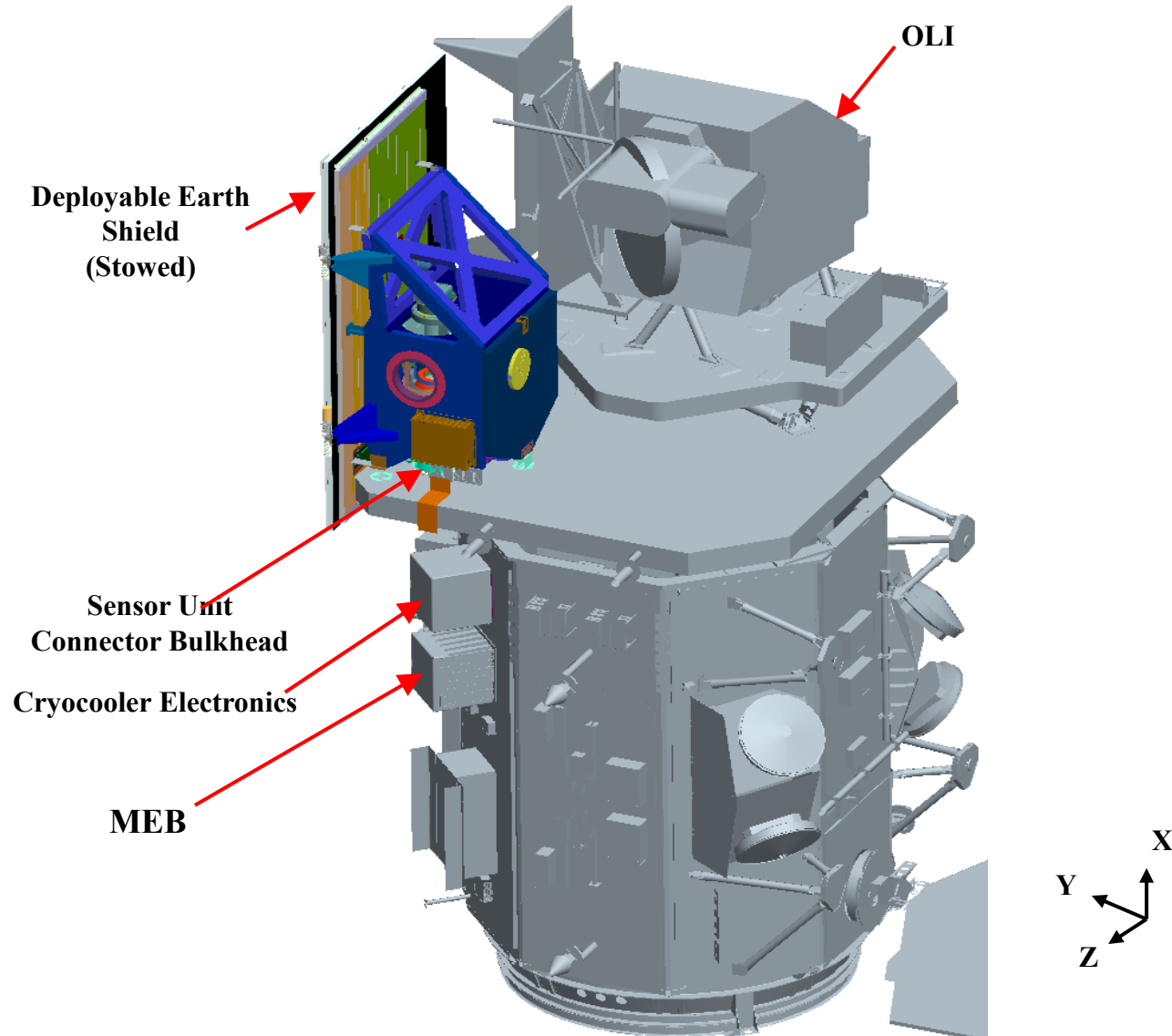
Spacecraft

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- **Spacecraft**
 - Accommodates two instruments (OLI, TIRS)
 - Provides pointing, power, data capacity, etc. to support LDCM operations
- **Contract awarded to General Dynamics Advanced Information Systems (GDAIS) in April 08**
 - GDAIS sold to Orbital Sciences Corporation in April 2010
- **Spacecraft Integration Readiness Review completed – August 2010**

TIRS & OLI on LDCM Spacecraft

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Spacecraft Bus Making Progress

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Oven Controlled
Crystal Oscillators
(OCXO) Flight

Components in Italic Red are Engineering Models
S-Band
Transceivers 1 & 2

S-Band Antenna
Brackets

Instrument Deck

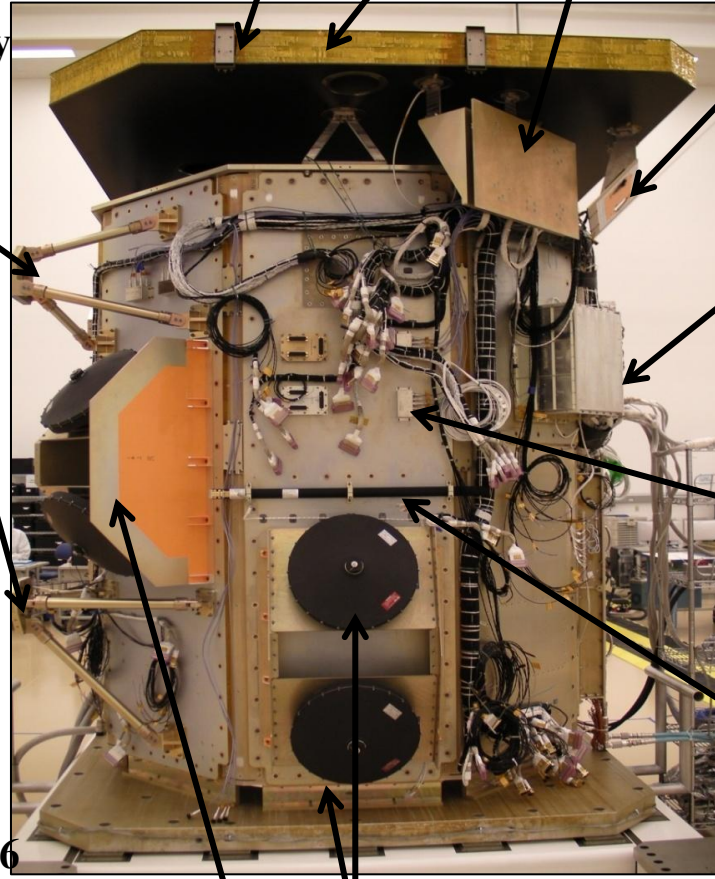
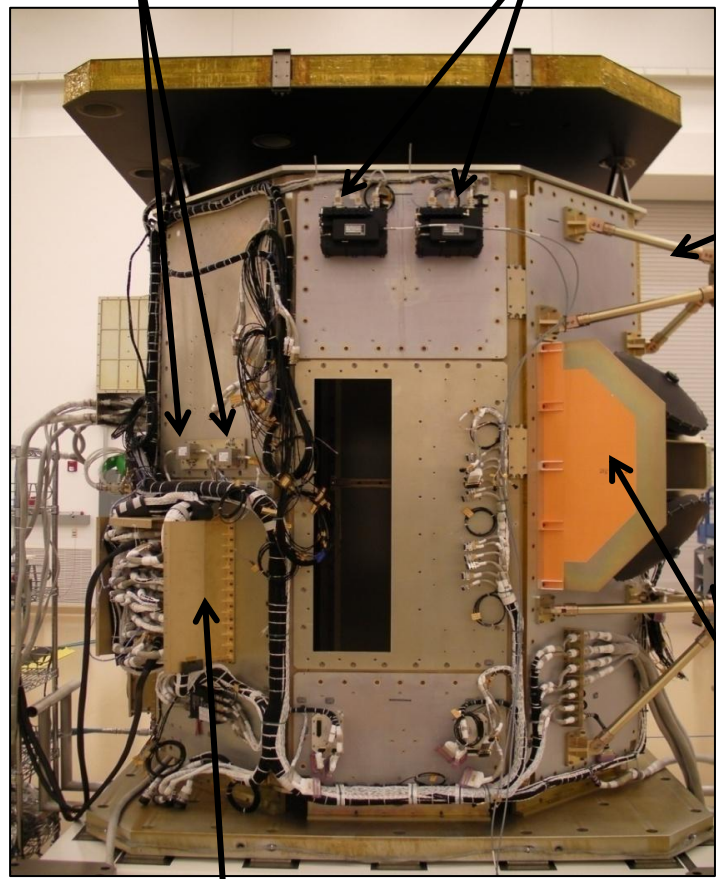
SIRU Bracket

Star
Tracker
Bracket

*Load
Control
Unit
(LCU)*

1553
Coupler

Electromagnetic
Torque Rods
(ETR)



Solar Array
Brackets
(Stowed)

Reaction
Wheels 5&6

Reaction
Wheels 3&4

Reaction
Wheels 1&2

*Integrated Electronics
Module (IEM)*

Spacecraft Bus Making Progress

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Components in Italic Red are Engineering Models

Electromagnetic
Torque Rods (ETR)
X & Z

Instrument Deck

Star
Tracker
Bracket

Three-Axis
Magnetometers
1&2 TAM

SIRU Bracket

Solar Array
Mounts
(Stowed)

Solar
Array
Mounts
(Stowed)

*Charge
Control
Unit (CCU)*

Reaction
Wheels 5&6

Reaction
Wheels
3&4

*Load
Control
Unit (LCU)*

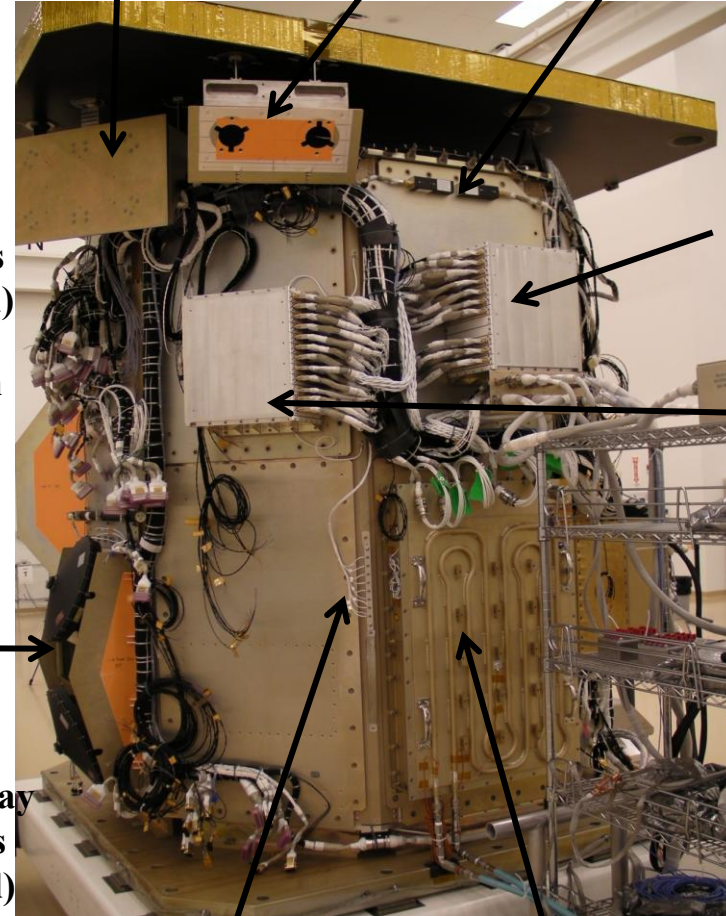
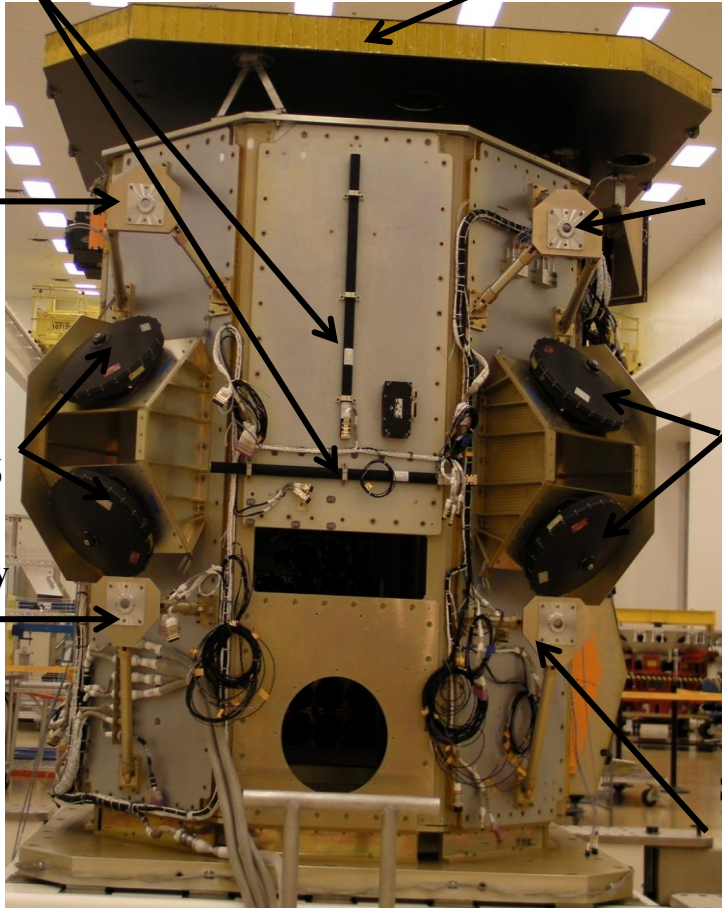
Solar Array
Mounts
(Stowed)

Reaction
Wheels
1&2

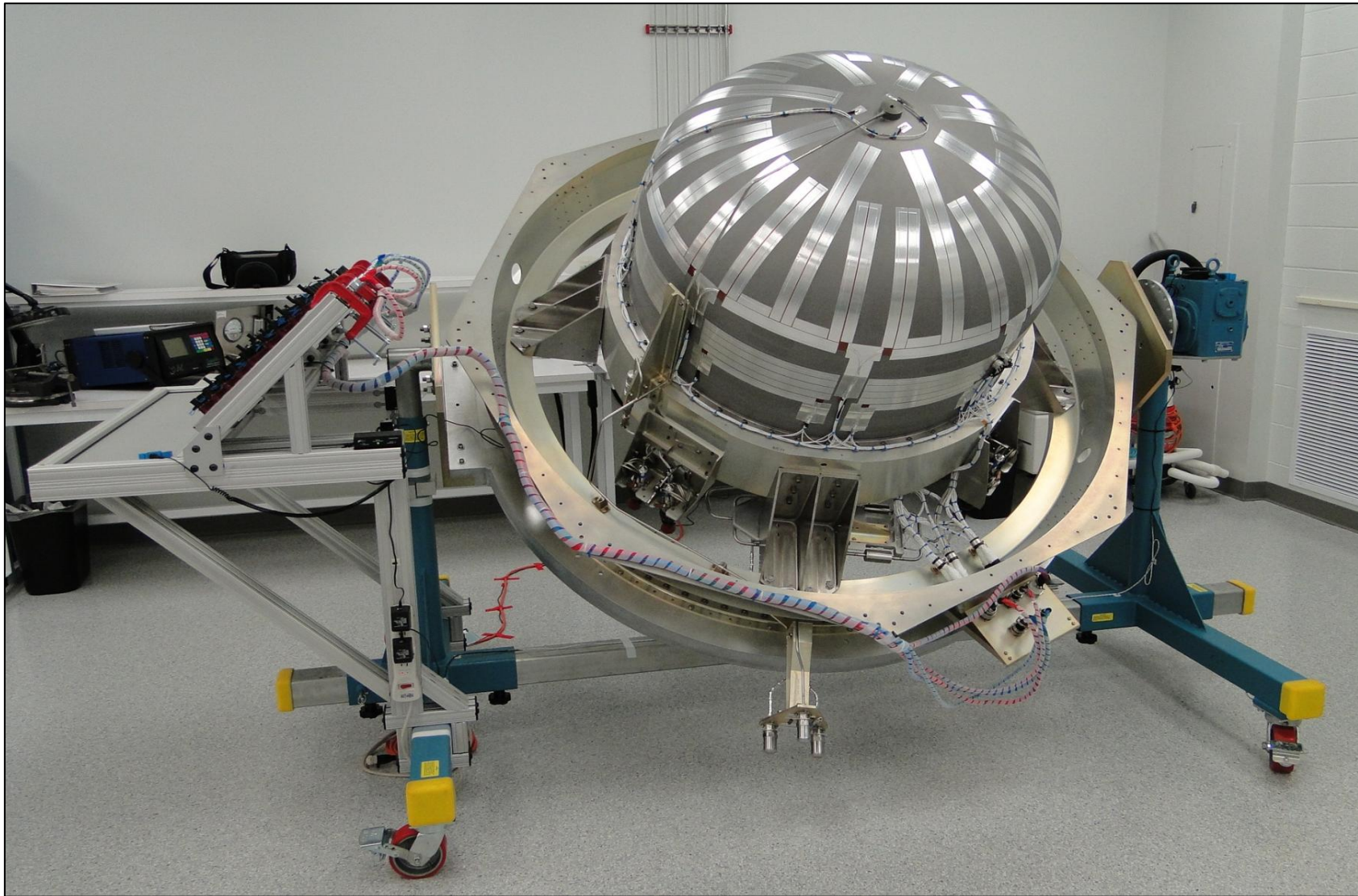
Solar Array
Mounts
(Stowed)

Spacecraft Single
Point Ground

*I&T Battery
With Cooling Plate*

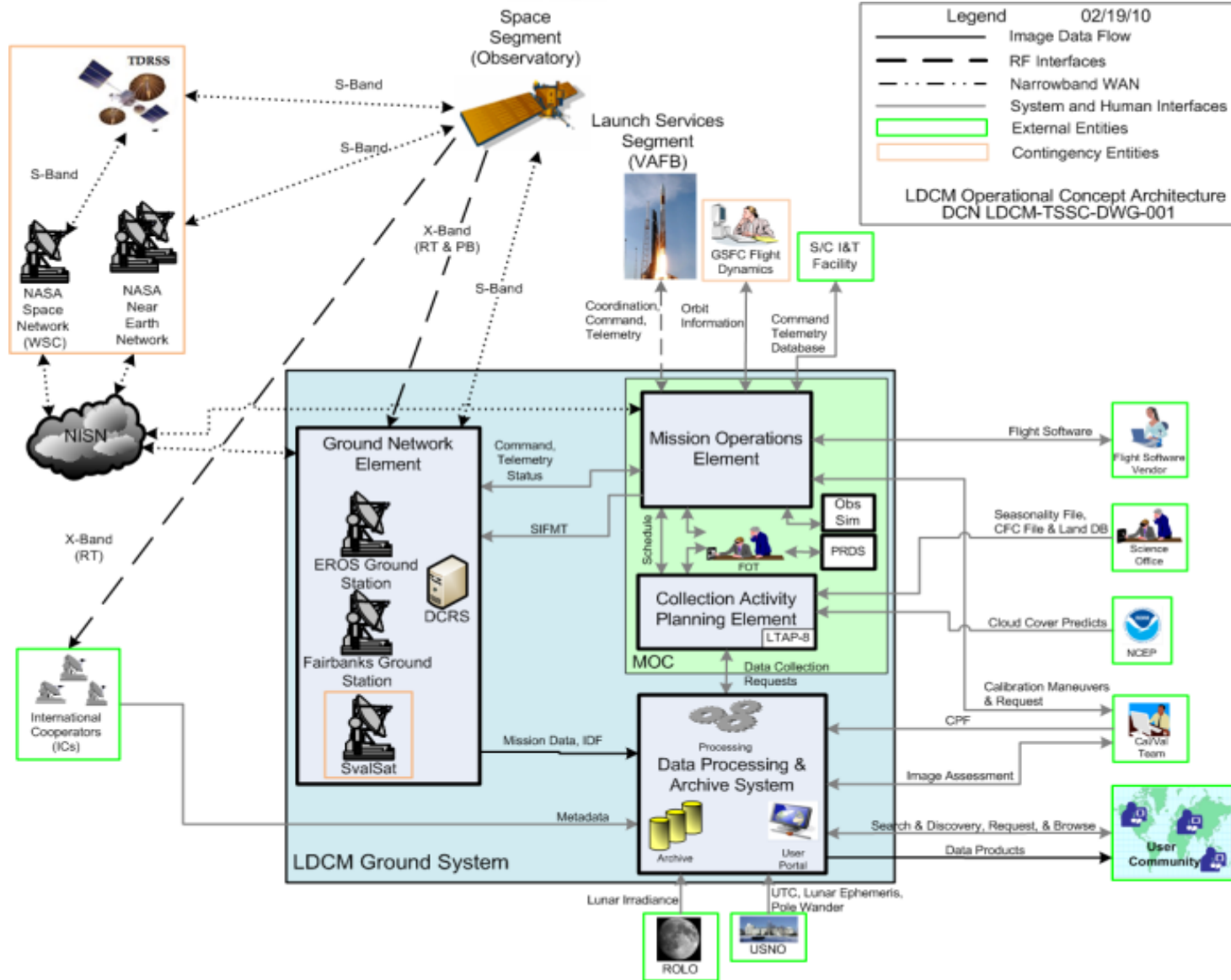


Completed Propulsion Subsystem

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Ground System Architecture

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Ground System Development Approach

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Element	Capability	Agency / Developer	Approach
Mission Ops Center and Backup Mission Ops Center	<ul style="list-style-type: none"> •Serves as control center for mission operations performed by the FOT •Hosts the MOE, CAPE, and other operations tools 	NASA / MOMS	Minor mods to HSM MOC, GSFC B3/14 and B32 (bMOC)
Mission Ops Element	<ul style="list-style-type: none"> •Performs command encryption and commanding, RT telemetry monitoring, mission planning and scheduling, monitoring and analysis, flight dynamics, and onboard memory management and mission data accounting 	NASA / The Hammers Co., Inc.	COTS customization
Collection Activity Planning Element	<ul style="list-style-type: none"> •Generates instrument image collection schedules based on science priorities 	USGS / TSSC	GOTS customization
Ground Network Element	<ul style="list-style-type: none"> •Performs S-band communication for S/C commanding and HK telemetry receipt •Receives S/C mission data via X-band •Routes HK telemetry to MOC and mission data to the DPAS 	USGS / TSSC, NOAA, KSAT	Modification of existing stations
Data Processing and Archive System	<ul style="list-style-type: none"> •Performs mission data ingest, product generation, and image assessment •Provides storage and archive services •Provides web interface for data discovery, product selection and ordering, and product distribution 	USGS / TSSC	Customization of heritage systems
NASA institutional services (SN, NEN, NISN, FDF)	<ul style="list-style-type: none"> •Performs S-band communication for S/C commanding and HK telemetry receipt •Provides network connectivity across GS •Supports post-launch FD 	NASA	Existing systems and services acquired through PSLA

GS Technical Performance Measures

LDCM

- **Ground System performance is monitored through a set of technical performance metrics (TPMs)**
 - **To support management of the development process between milestone reviews**
 - **Design is not static**

- **TPMs are monitored on a regular basis**

TPM	Requirement	Performance	Margin
LGN Contact Time (with SvalSat)	98 min/day	133 min/day 248 min/day	+36% +153%
Ingest and Processing Throughput	400 scenes/day	890 scenes/day	+123%
Distribution Capacity Years 1-2	1250 scenes/day	4,700 scenes/day	+276%
Distribution Capacity Years 3-5	3500 scenes/day	4,725 scenes/day	+35%
End to End Latency	85% in 48 hrs	85% in 12 hrs	+75%
Receiver Implementation Loss	3 dB	2.3 dB	+23%

LDCM Mission Ops Center

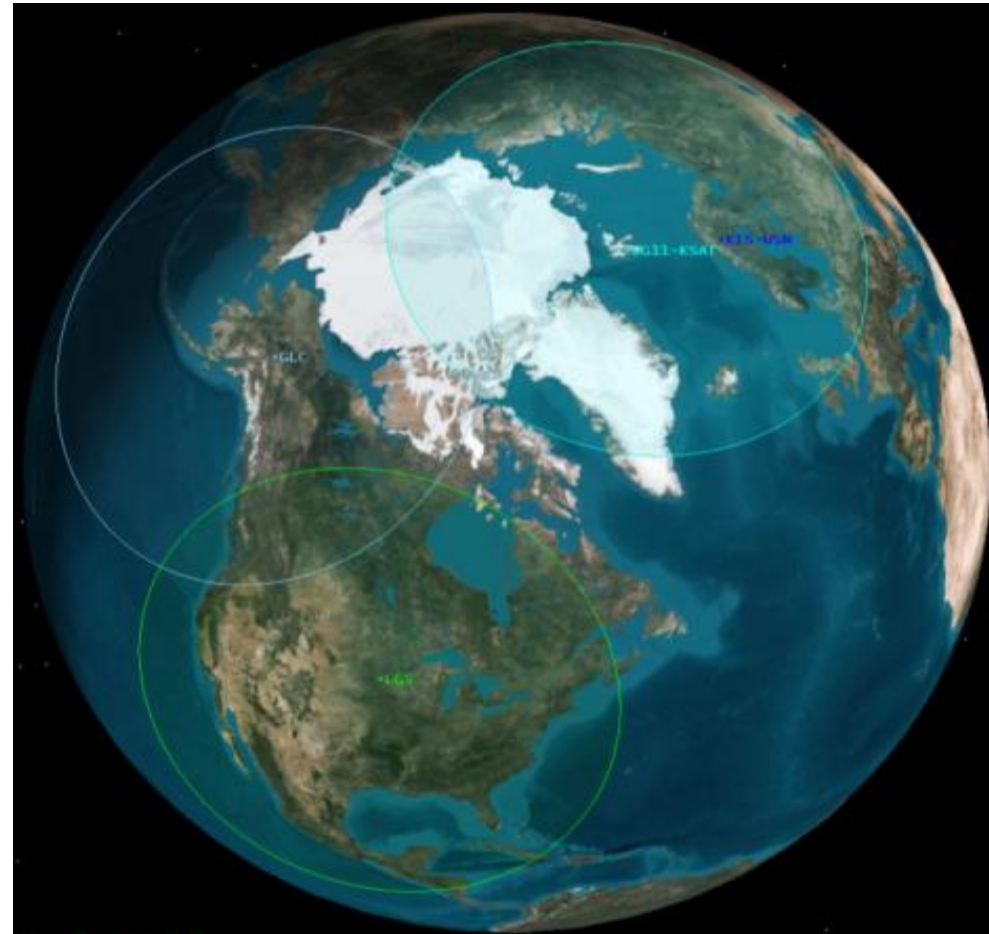
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LGN Design Approach

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- **LDCM Ground Network (LGN)**
 - Partnerships to use existing stations currently supporting Landsat
 - NOAA Interagency Agreement (IA) to use Gilmore Creek Station (GLC) near Fairbanks, AK
 - Landsat Ground Station (LGS) at USGS/EROS near Sioux Falls, SD
 - NASA contract with KSAT for Svalbard; options for operational use by USGS
 - Provides ≥ 200 minutes of Contact Time
- **Common Avtec Programmable Demods**
 - LDPC Forward Error Correction and CCSDS/CFDP Processing and Data Capture
- **Landsat Scalable Integrated Multi-mission Simulator System (LSIMSS)**
 - Used for T&C Processing at LGN Stations
 - Transfer of Station Status to MOE
 - Used for MOE and S/C testing





Standard LDCM Data Products

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- **LDCM standard Level-1T data products will be consistent with heritage Landsat product specifications – backward compatibility**
 - **OLI and TIRS data will be distributed as a combined product. Pixel size: 15m/30m/30m**
 - **Quality Assurance (QA) “band” will be included**
 - **Media type: Electronic**
 - **Product type: Level-1T (precision, terrain correction)**
 - **Output format: GeoTIFF**
 - **Map projection: UTM (Polar Stereographic for Antarctica)**
 - **Orientation: North up**
 - **Resampling: Cubic convolution**

First L1T Out of DPAS

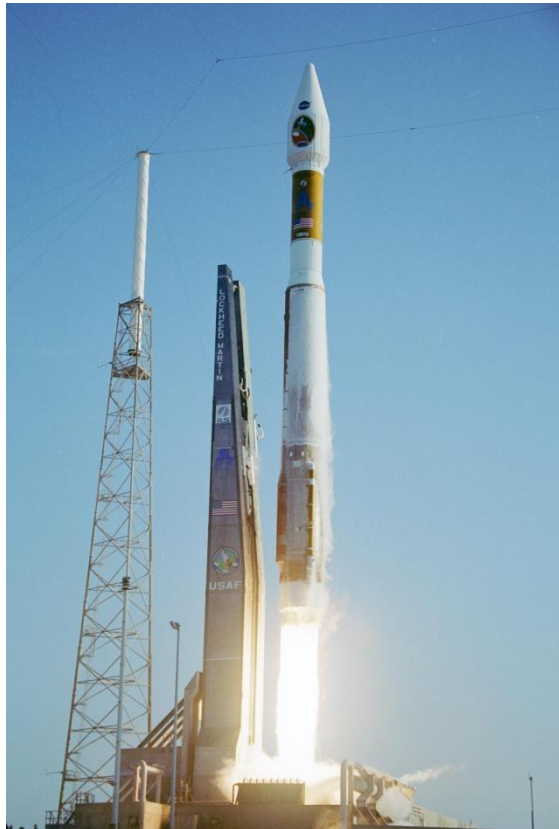
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Launch Vehicle

LDCM

- **Launch from Vandenberg Air Force Base on an Atlas V**
- **Interactions between Project, KSC, United Launch Alliance (ULA), and Orbital have begun**



Conclusion

LDCM

- **Continuity with previous Landsat missions is fulfilled by LDCM**
 - LDCM data will be comparable to data from previous Landsat satellites
 - Data collection along heritage orbital paths with identical 185 km swath width
 - Ensure global coverage of land mass on seasonal basis
 - LDCM data will be backward compatible with data from previous Landsat sensors
 - Supports long term retrospective studies to trend change over time
- **Capabilities are advanced**
 - Two new reflective bands, refined band widths avoid atmospheric absorption features, two thermal bands facilitate atmospheric correction
 - Improved performance
 - More data – 400 scenes per day lead to improved global coverage
- **USGS will distribute LDCM data free to the general public**
 - Capabilities to process and analyze large volumes of Landsat data are advancing rapidly for long term and broad area studies
- **On Schedule for a December 2012 launch**

The logo features several overlapping, curved bands in shades of orange, yellow, and green, set against a background of a grid pattern.

Landsat Science Team

LDCM

- **Ninth Science Team meeting held March 01 – 03 in Mesa, AZ**
 - **Included visits to Orbital to view spacecraft**
- **Final Science Team meeting scheduled for April 16 – 18 in Sioux Falls, SD**
 - **2011 is the fifth and final year of the initial Science Team contracts**
- **USGS plans to re-compete Science Team membership with a solicitation for proposals expected this summer**
 - **Five year contracts will be awarded**

Landsat Science Team

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