USGS Report to the CEOS WGCV 30

May 26 – 29, 2009

Ilhabela, Brazil

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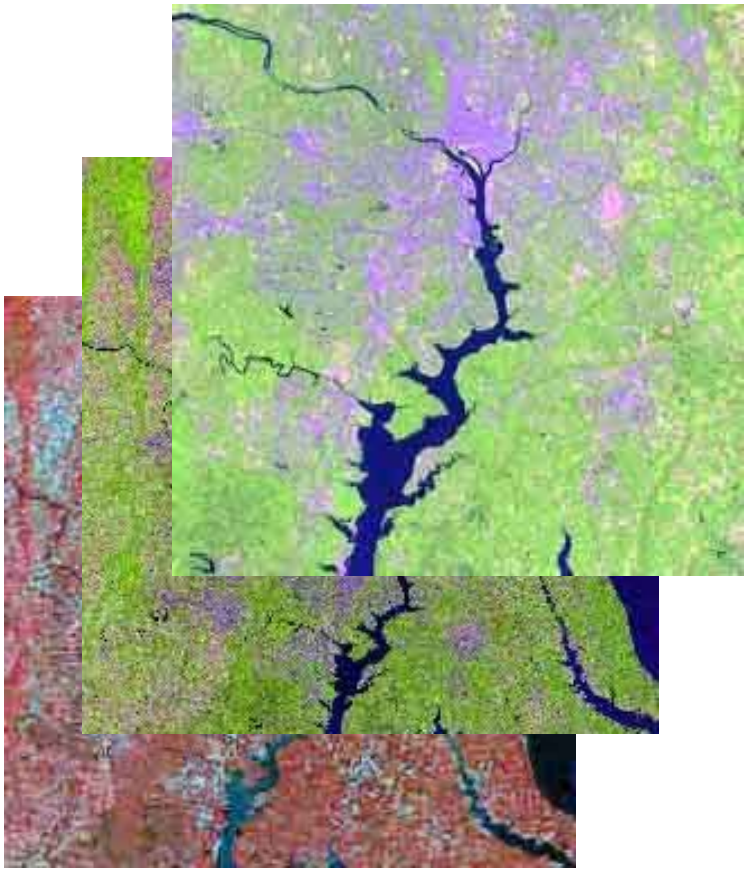
U.S. Department of the Interior

U.S. Geological Survey

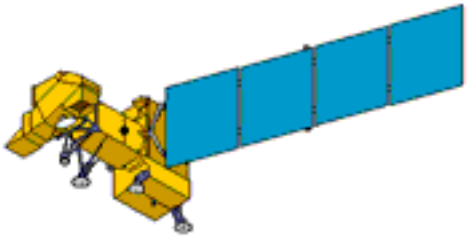
U.S. Landsat Archive Overview
(Marketable Scenes through May 11, 2009)

- **ETM+: Landsat 7**
  - 922,274 scenes
  - 856 TB RCC and L0Ra Data
  - Archive grows by 260 GB Daily
- **TM: Landsat 4 & Landsat 5**
  - 792,407 scenes
  - 198 TB of L0Ra Data
  - Archive Grows by 40 GB Daily
- **MSS: Landsat 1 through 5**
  - 652,163 scenes
  - 20 TB of Data



Landsat 7 Mission Status

- **Landsat 7 – 15 April 1999 (~10+ Years)**
  - 53,360 orbits
  - Spacecraft
    - Gyro 3 Failure (Shut down May 5, 2004)
    - Other Spacecraft Issues (non-critical)
      - Solid State Recorder (SSR) – PWA#22 Failure (Mar 28, 2008)
      - SSR Recovery (Sep 3, 2008) – Recovered 1 of 5 failed board
      - Delta-Inclination maneuver completed (Oct 7, 2008)
      - Additional Inclination maneuvers planned to extend mission life
  - ETM+
    - Scan Line Corrector Failure (May 31, 2003)
    - Bumper Mode Operations (April 1, 2007)



Landsat 5 Mission Status

- **Landsat 5 – 1 March 1984 (~25 years)**
  - L5 has exceeded 130,000 orbits!
  - Spacecraft
    - Battery 2 Anomaly – Oct 2007
    - Star Tracker Issue – June 2007
    - Solar Array Drive (Fixed array operations) – Aug 2006
    - Delta-Inclination maneuver completed (Nov 5, 2008)
  - TM
    - Functioning normally in bumper-mode
    - Outgassing of TM completed Jan 27-29, 2009

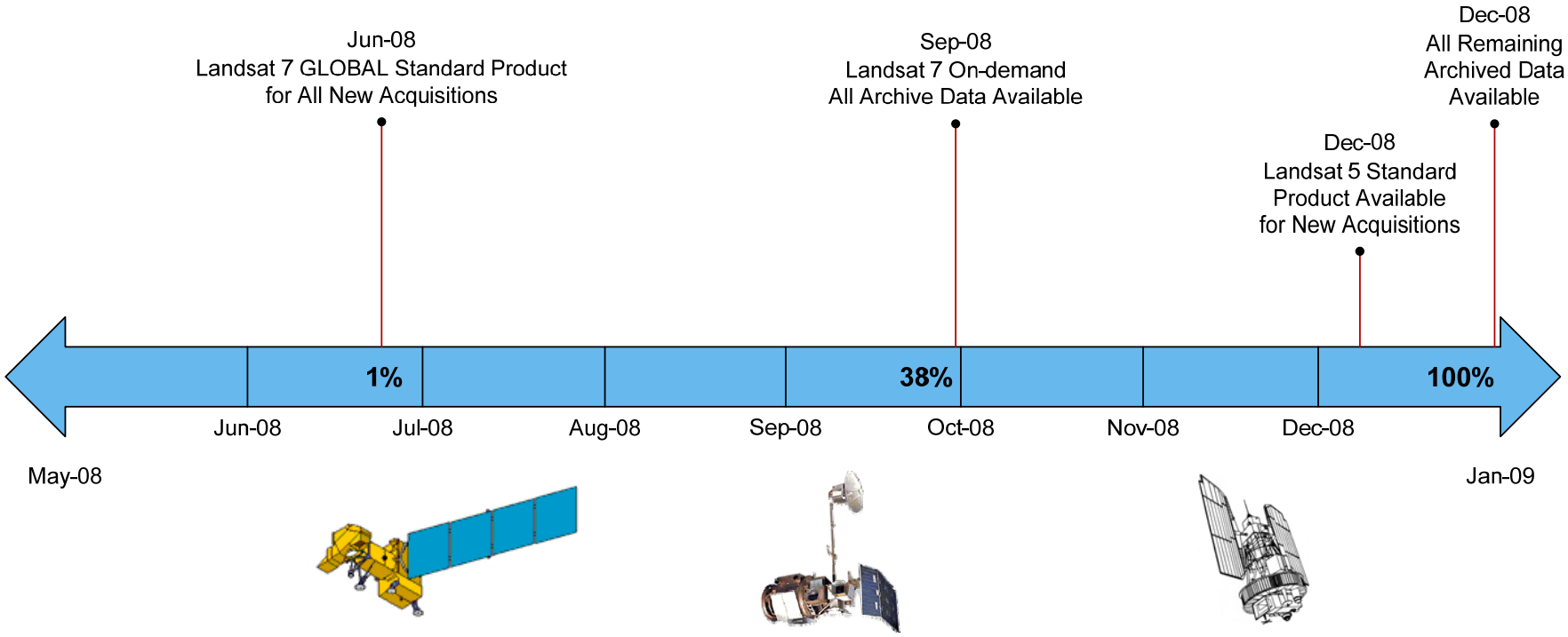
Landsat 7 ETM+ Calibration Update

- **Band-to-Band registration typically 0.05 pixels or better in line and scan direction (excluding band 6)**
- **Switch to bumper mode disrupted ETM+ sensor alignment calibration and degraded geodetic accuracy**
  - Pre-switch : 97% scenes better than 50 meters RMSE
  - Post-switch: 65% scenes better than 50 meters RMSE
- **Relative detector-to-detector normalization, i.e., striping less than ± 0.1%**
- **Absolute radiometric accuracy better than ± 5% (reflective) and 1 K (thermal)**
- **Noise stable over mission life**
- **SLC failure had no significant impact on L7 ETM+ reflective band radiometry- continues to be excellent**

Landsat 5 TM Calibration Update

- **Within-band within-scene internal stability**
  - Scan-Correlated Shift (SCS) of up to 0.7 DN
    - Correctable with scan line-by-scan line background subtraction
  - Memory effect of up to 4 DN
    - Currently corrected in NLAPS processing
  - Some banding and striping issues remain to be resolved
- **Between-date stability**
  - Interference cycling from icing on B5 and B7
    - Correctable with IC processing or LUT that includes interference cycling
- **Radiometric calibration processing**
  - Uses Gain Calibration History stored in Look-Up Table
  - Extracts and applies biases on a scan line by scan line basis
  - Rescaled to Fixed Radiance Range (LMIN, LMAX)
  - Look-up Table revised April 2, 2007 to reflect revised trends from Sahara desert site data obtained from ESA

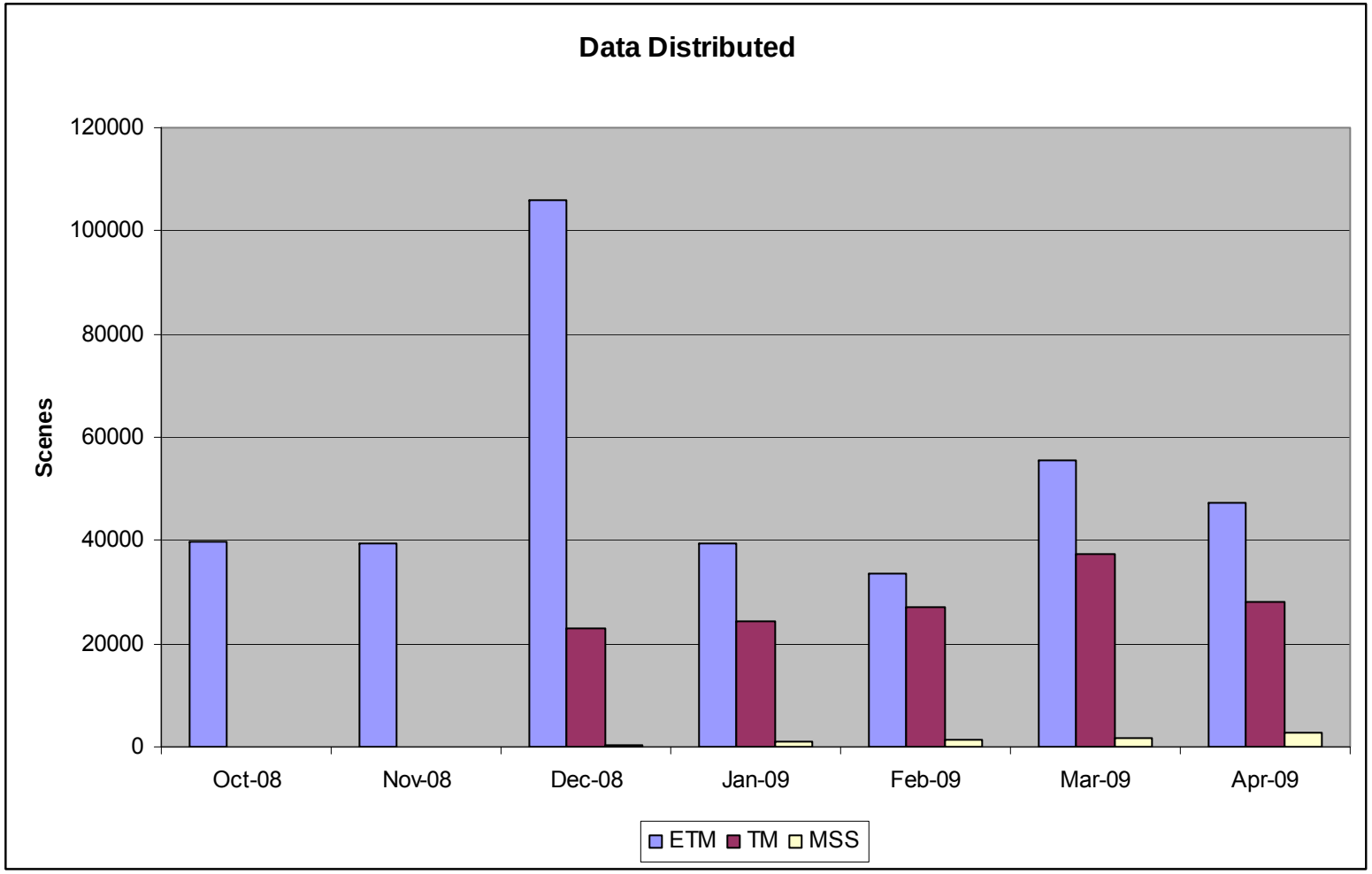
Web-enabled Schedule Complete!!



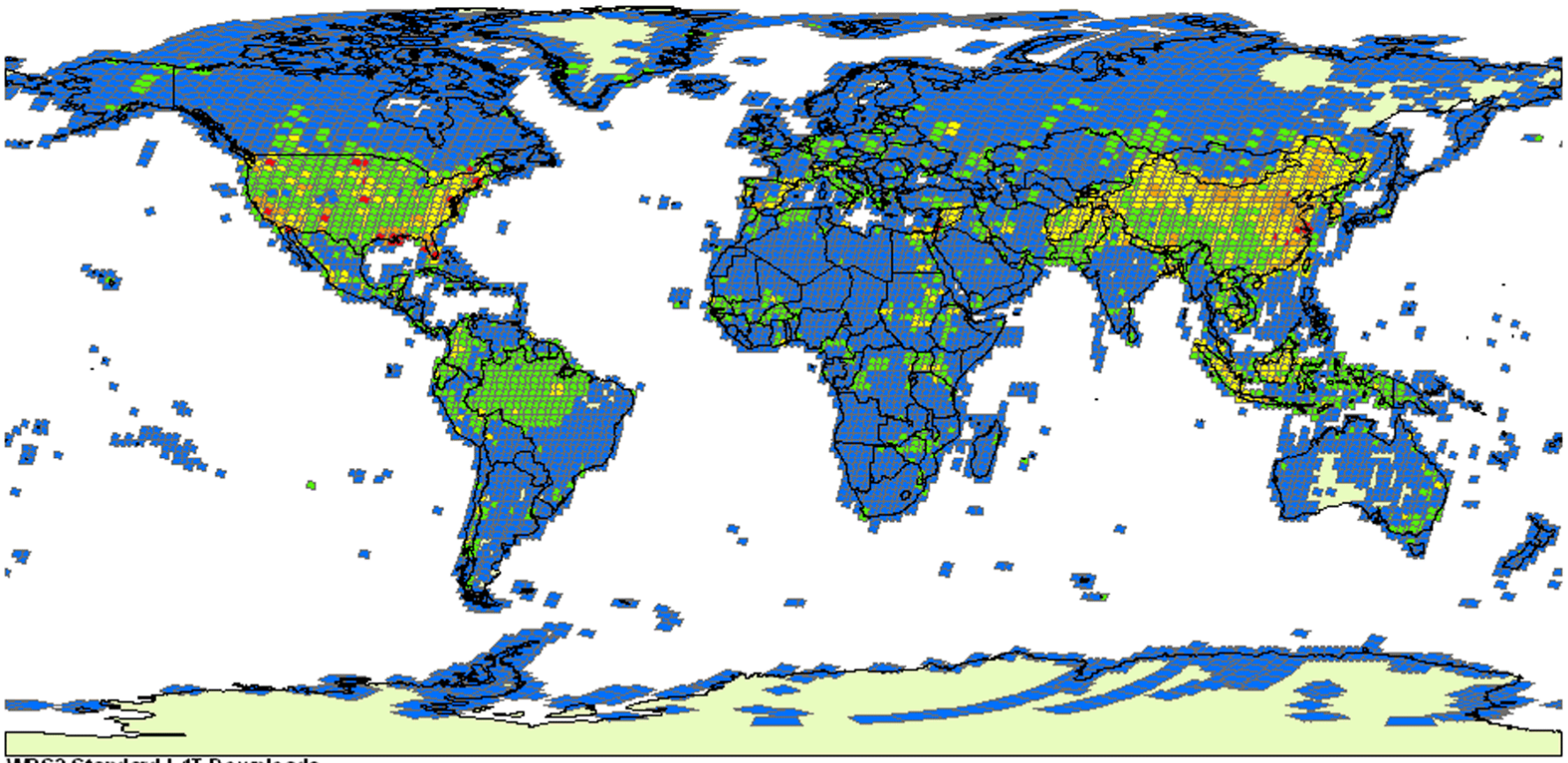
Landsat Data Distribution Concept

- **Process and Distribute data freely to users**
  - Process new data (currently <40% cloud cover) automatically for immediate download
  - Process requests on-demand for other data in archive
- **Single Processing Parameter Recipe**
  - Pixel size: 15m/30m/60m
  - Media type: Download only
  - Product type: L1T (terrain-corrected)
  - Output format: GeoTIFF
  - Map projection: UTM
  - Orientation: North up
  - Resampling: Cubic convolution

Background – Landsat Downloads



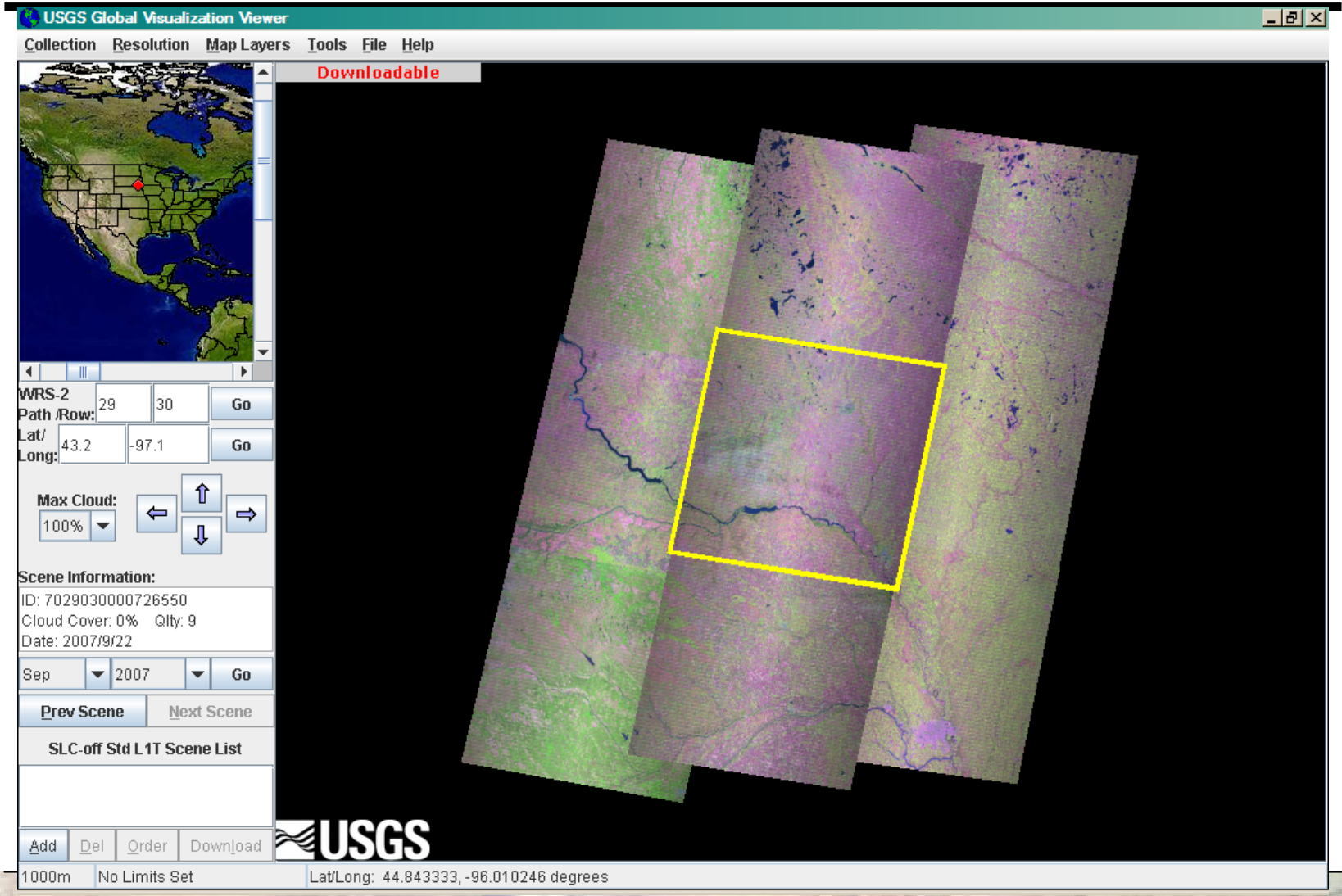
What are users downloading?



WRS2 Standard L1T Downloads
via User Interface and Bulk Users
October 1, 2008 through May 05, 2009
629,994 Total Scenes
9,054 Unique Locations

1 - 69 | 70 - 208 | 209 - 443 | 444 - 878 | 879 - 2094

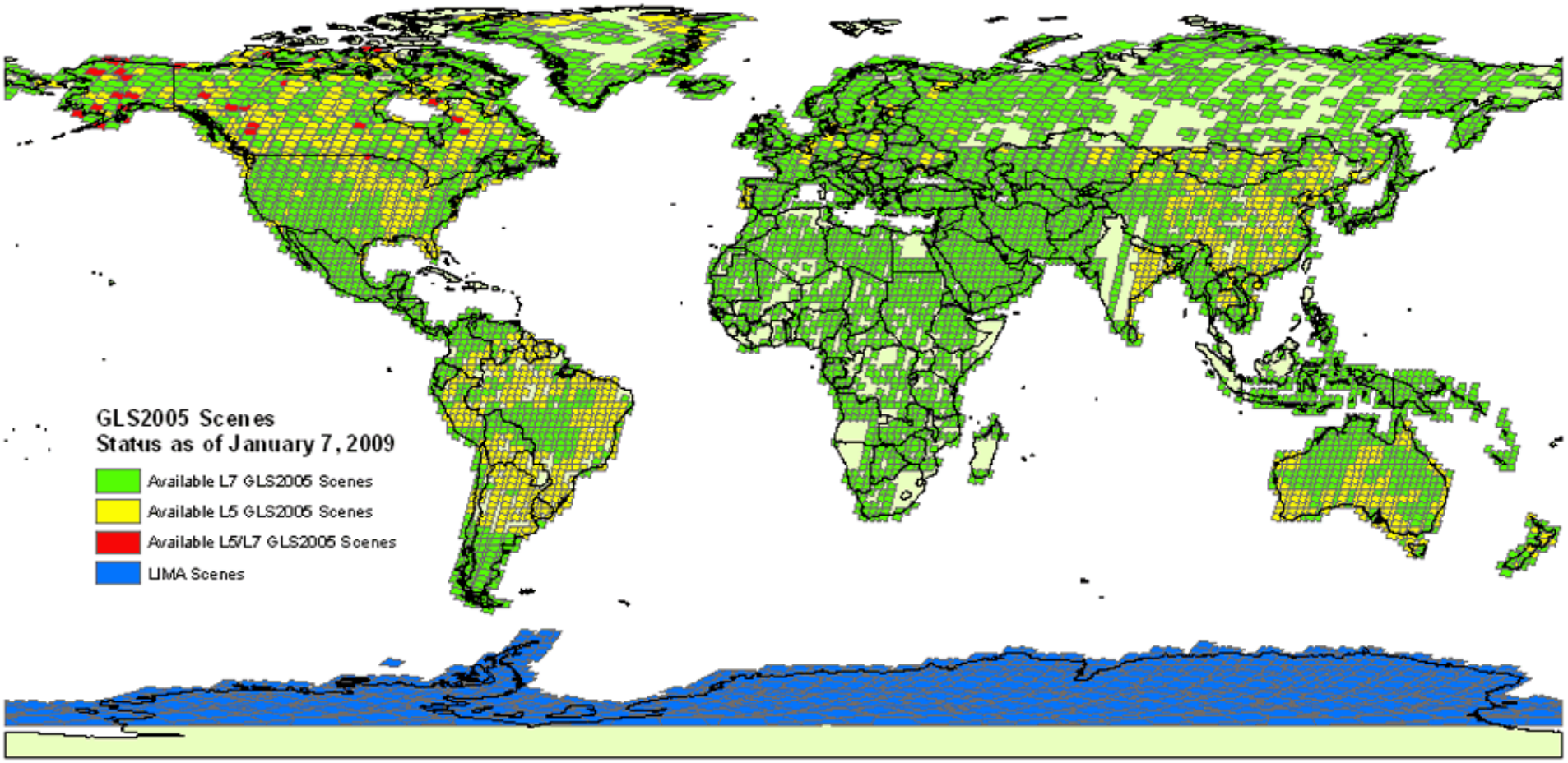
Glovis Interface



Global Land Survey

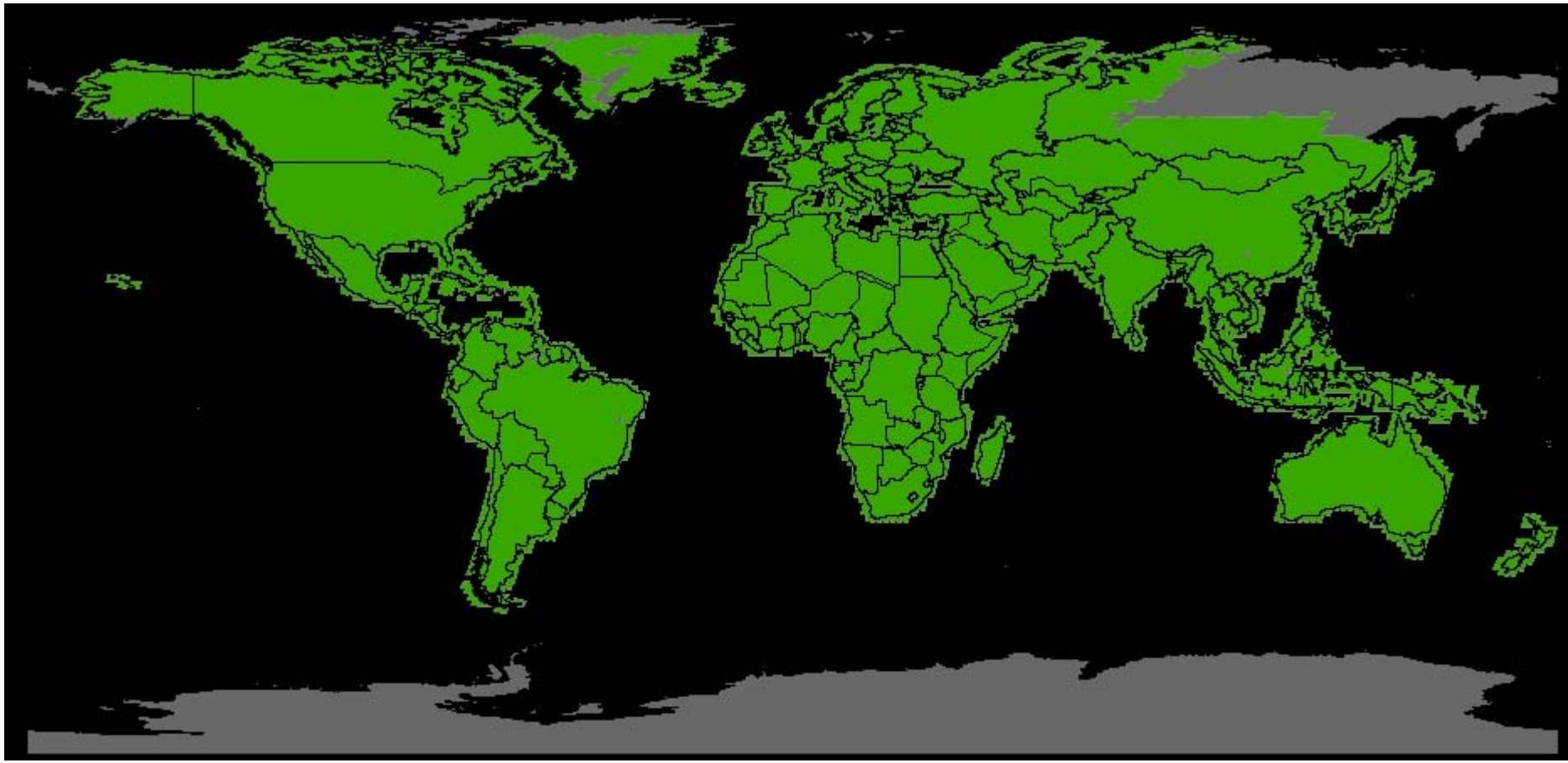
- **GLS1975, GLS1990**
  - Metadata issues resolved
  - Received final delivery in January
  - GLS1990 data validation complete
  - GLS1975 data received
- **GLS2000 processing**
  - Completed all reprocessing and validation
- **GLS2005**
  - L7 processing
    - Mostly complete – revisiting areas with difficult gap-fill issues
  - L5 processing
    - Mostly complete – some selection still in work
- **GLS2010**
  - Underway by USGS and NASA

GLS2005 Status



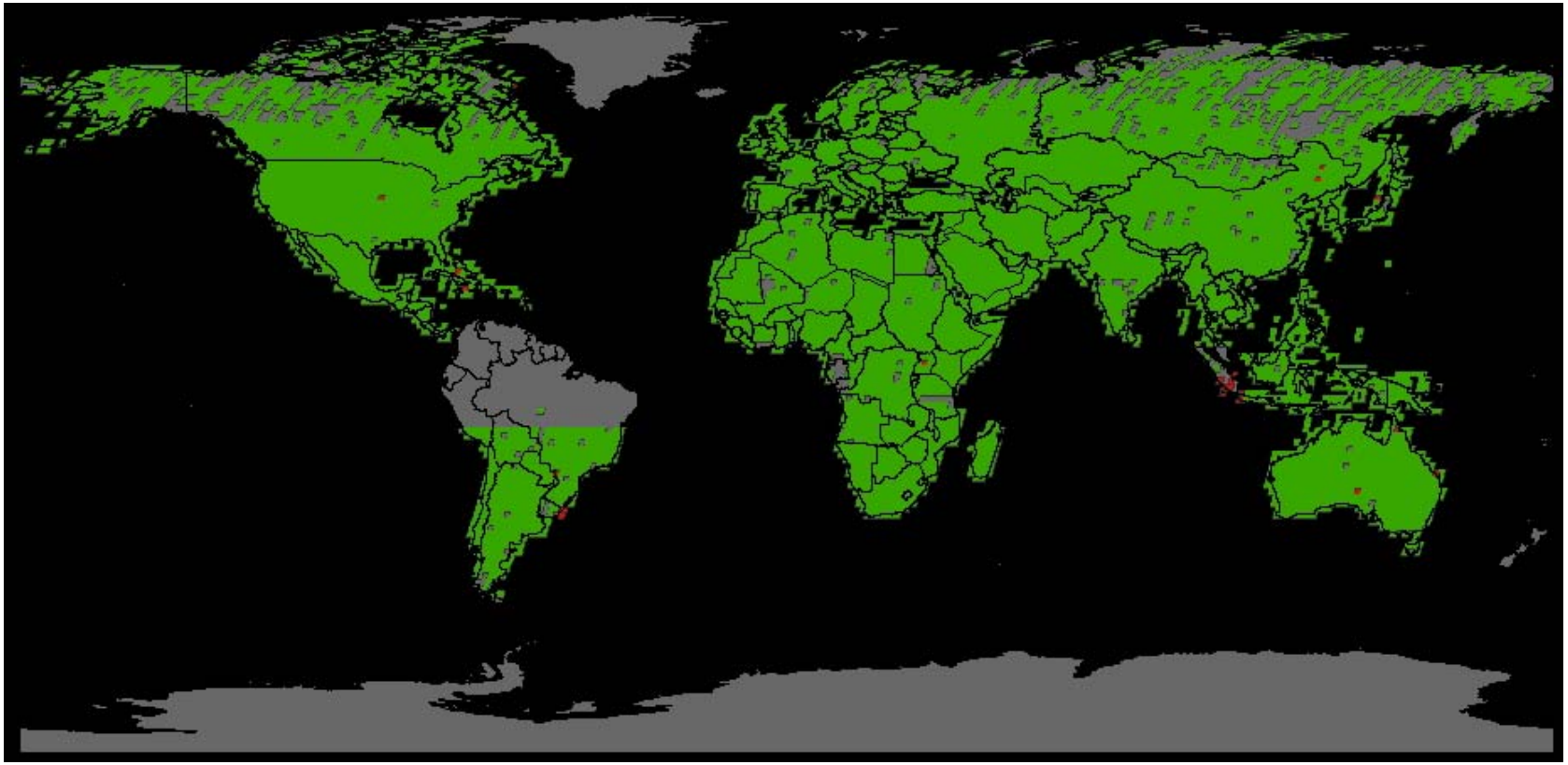
Final GLS1990 dataset

- EOSAT ‘shadow’ in Siberia (no images were taken)

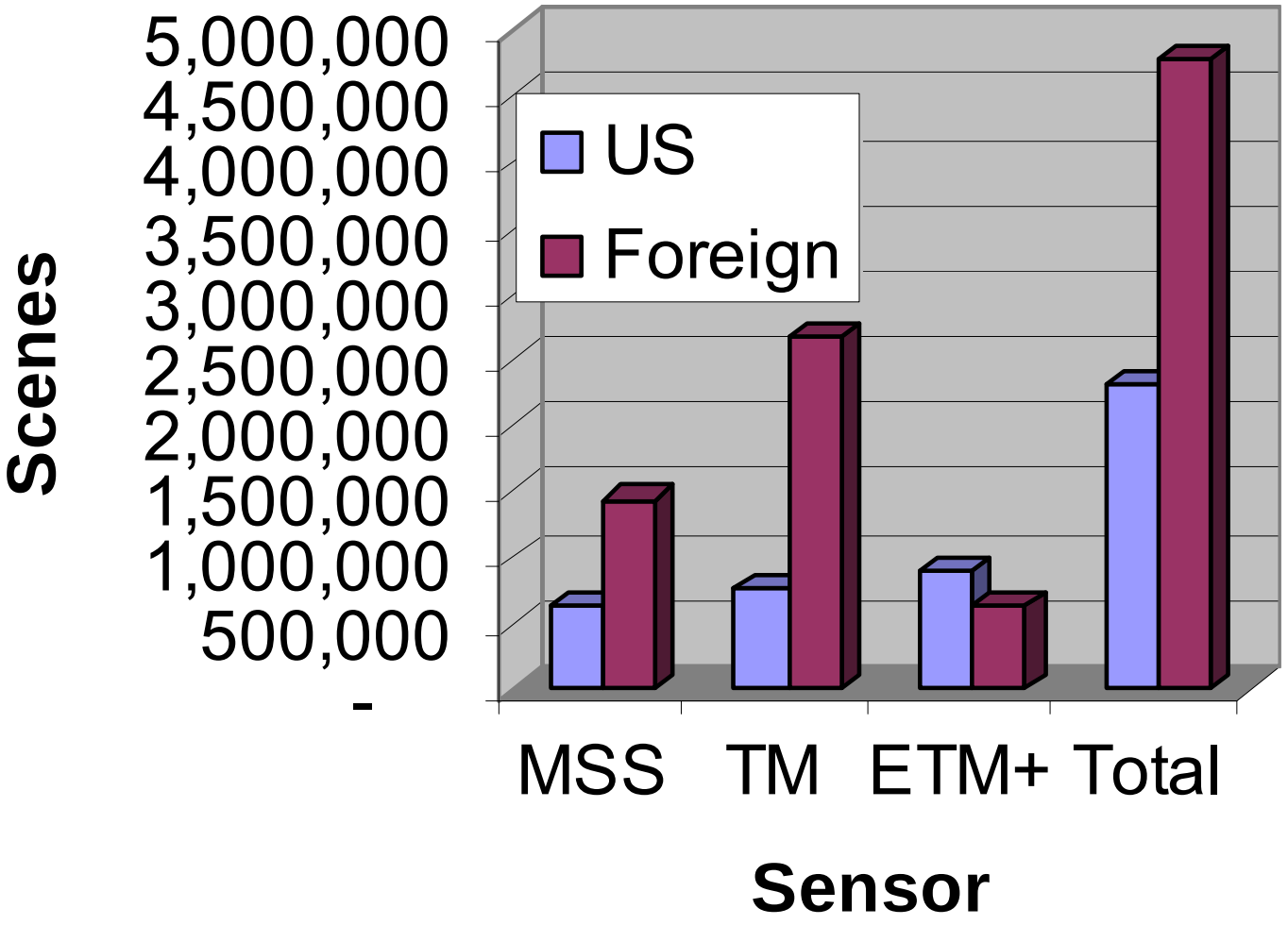


Final GLS1975 Dataset

- **Only INPE had northern S.A., and the data was ‘unrecoverable’**



Landsat Global Archive Consolidation (LGAC)



LDCM Milestones

- OSTP directed NASA and USGS to implement the LDCM as a “free-flyer” satellite in Dec., 2005
- NASA and USGS signed Final Implementation Agreement in April, 2007
- Operational Land Imager (OLI) contract was awarded to Ball Aerospace Technology Corporation in July, 2007
- Atlas V launch vehicle was selected in Oct. 2007
- Spacecraft contract was awarded to General Dynamics Advanced Information Systems in April, 2008
- Mission Operations Element (MOE) contract awarded to The Hammers Company in September, 2008
- Key Decision Point - B review on September 25, 2008

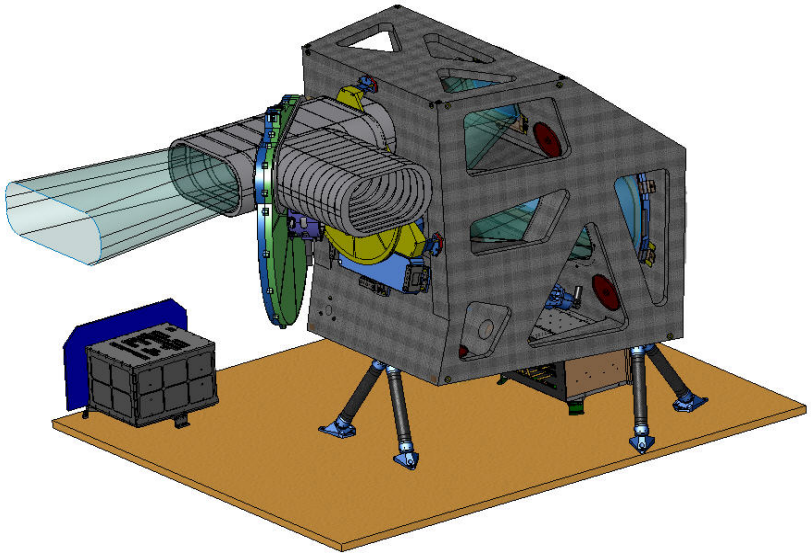
New LDCM Launch Readiness Date

- **Major finding of System Readiness Board (SRB)**
  - Original launch readiness date, July, 2011 was considered excessively aggressive and added risk to the mission
  - The existing LDCM development schedule is not achievable. There is less than a 20% chance that the July 24, 2011 Launch Readiness Date (LRD) can be achieved"
- **Mission schedules must reflect a 70% confidence level (70% chance of making launch date)**
  - Reconciliation of numerous independent schedule assessments and project's own assessment resulted in a retargeted 70% confidence launch date for LDCM
- **Through KDP-B Process**
  - Retargeted launch date to **December, 2012**

Operational Land Imager (OLI)

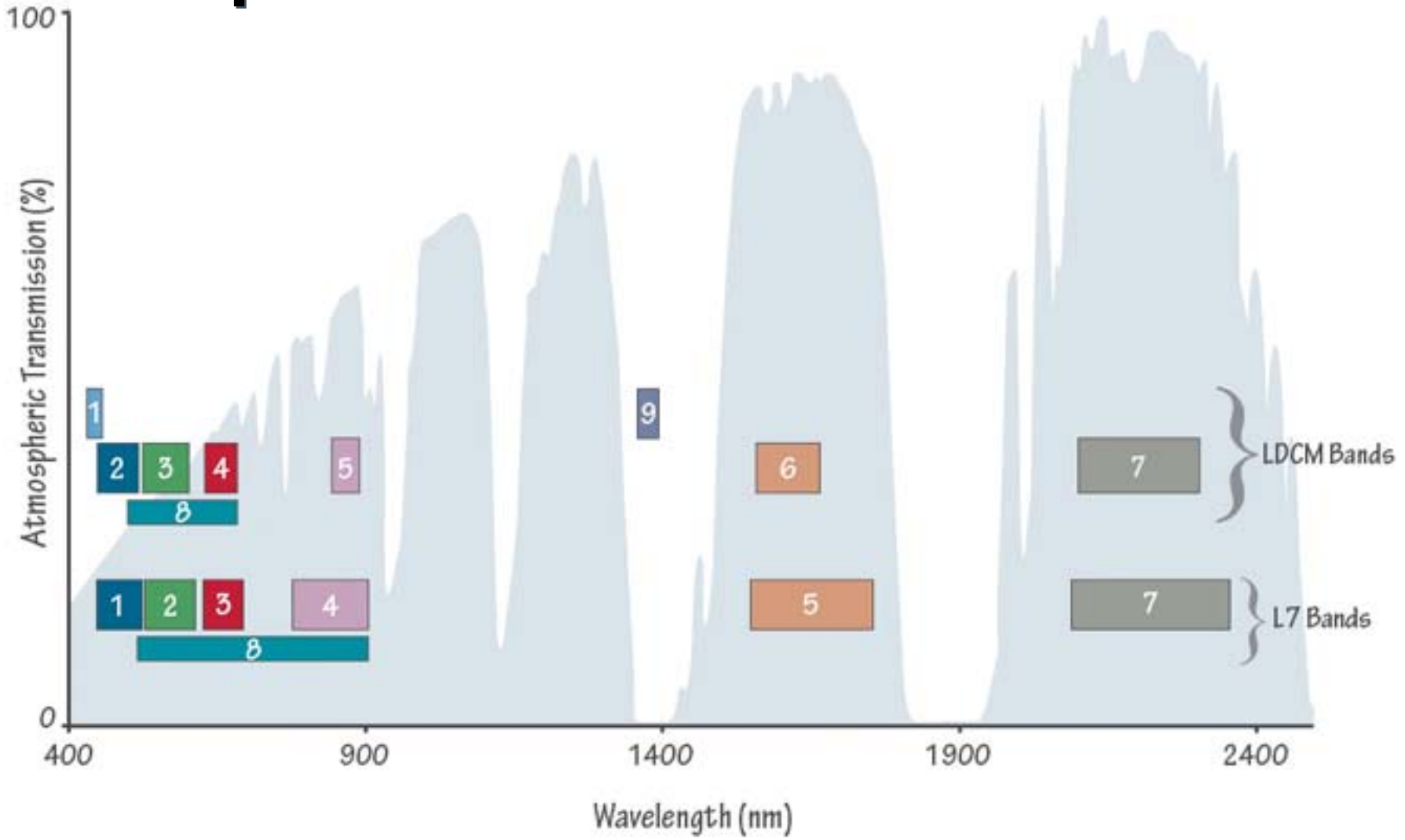
Contract awarded to Ball Aerospace Technical Corp. (BATC) July 2007
Critical Design Review Completed Oct. 2008

- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- Aperture 135 mm
- F number 6.4
- 36 um / 18 um detectors (MS / Pan)



Courtesy of BATC

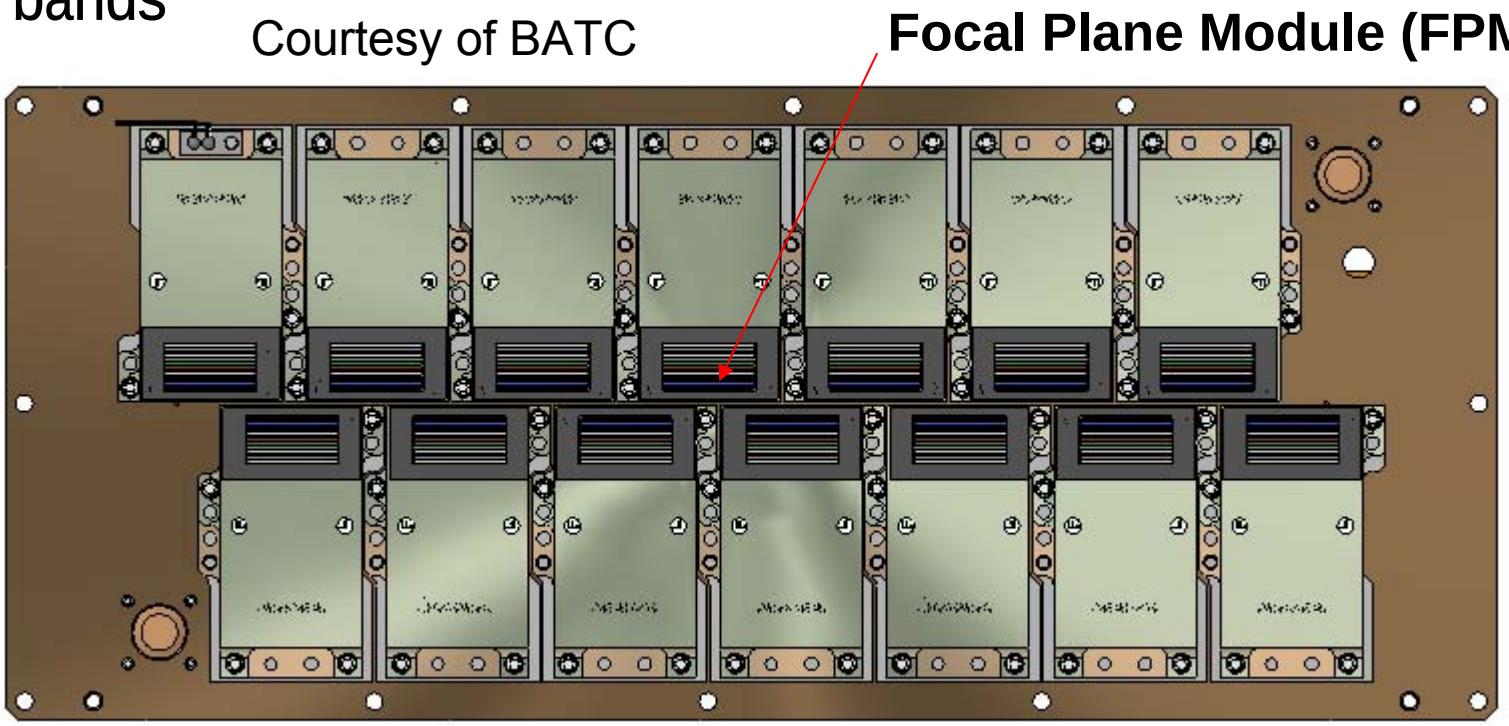
OLI Spectral Bands



Focal Plane Consists of 14 Modules

- Each Module contains Silicon and HgCdTe detectors mounted on a single readout chip (ROIC)
  - Spectral Filters above the detectors provide separation into bands

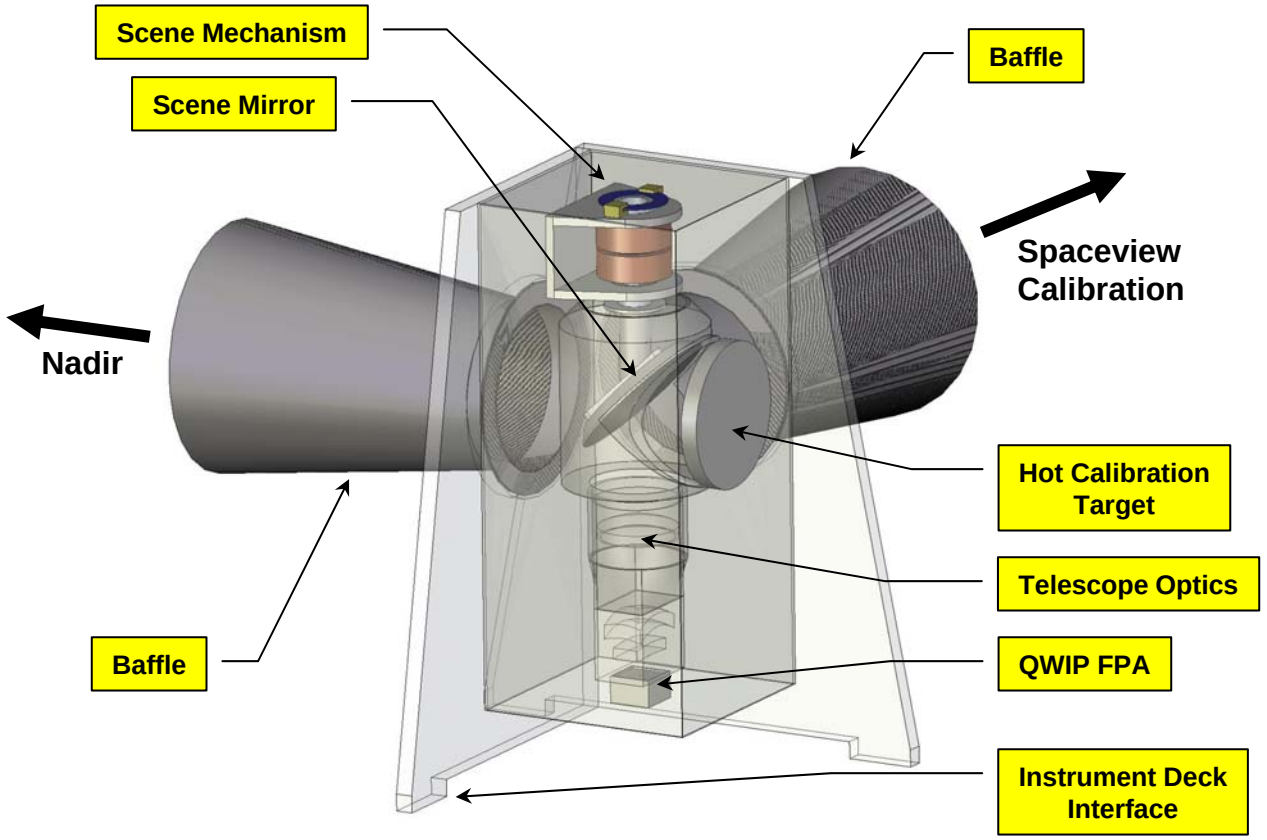
Courtesy of BATC



TIRS Status

- **The LDCM project at GSFC is ensuring that:**
  - Development of the LDCM spacecraft will not preclude the accommodation of a thermal instrument
  - Accommodation of a thermal instrument does not impact the performance of the Operational Land Imager
- **TIRS parallel with LDCM mission development, thermal instrument and technology risk reduction activities are being pursued**
  - For example, cryogenically-cooled detector technologies are now being evaluated including quantum well infrared photodiodes (QWIP's)
- **Project proceeding down path as if TIRS will be there**
  - Directed by Agency PMC at KDP-B to proceed at risk
  - TIRS team is fully integrated into LDCM team
- **TIRS Instrument implementation targets LDCM launch date of Dec, 2012**
  - Instrument delivery planned for Dec 2011, allowing 10 mos. integration and test at the spacecraft vendor

TIRS Instrument Diagram



TIRS Optical Sensor Unit

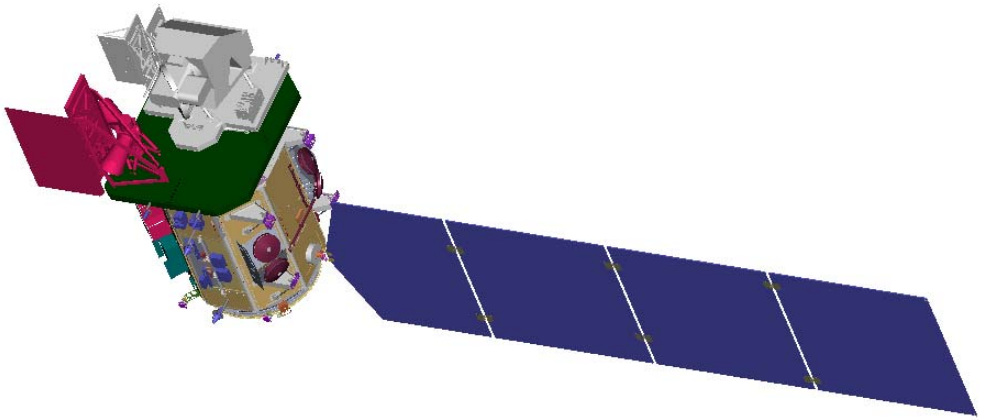
LDCM Spacecraft

COMMUNICATIONS
- *S-band to GN/LGN: 1, 32kbps uplink: and 2k,16k, 32k, or 1 Mbps downlink*
- *Omni antennas*
- *TDRSS - SA: 1 kbps return and 2 or 32 Kbps forward*
- *X-band: 384 Mbps science data*

PROPULSION
- *Hydrazine blow-down propulsion module*
- *Eight 22N Redundant Thrusters*

GUIDANCE, NAVIGATION & CONTROL
- *2 of 3 star trackers active*
- *High precision IRU*
- *Honeywell reaction wheels*
- *SADA with damper*
- *3-axis stabilized*
- *Zero momentum biased*

THERMAL CONTROL
- *Passive with heaters*
- *Constant conductance heat pipes (if needed)*



ELECTRICAL POWER
- *Single wing single axis articulated GaAs solar array provides 4300 W at EOL*
- *125 amp-hour NiH_2 battery*
- *Unregulated 22 V - 36 V power bus*
- *Two power distribution boxes*

STRUCTURE
- *Aluminum primary structure*
- *Externally mounted components*
- *Clear instrument FOVs*
- *Clear instrument radiative paths*

COMMAND & DATA HANDLING
- *cPCI architecture; RAD750 CPU*
- *3.1 Tbit (BOL) solid state recorder*
- *265 Mbps peak OLI data transfer*
- *26.2 Mbps peak TIRS data transfer*
- *High rate PB at 384 Mbps*

Courtesy of GDAIS

Spacecraft Downlink Overview

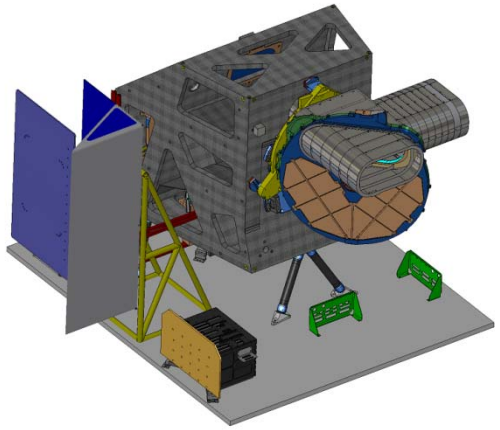
- Technical interchange activities between NASA, USGS, and General Dynamics have resulted in the definition of a very capable spacecraft
  - **Single Polarization X-band downlink (Earth Coverage Antenna)**
  - **400 scene recorder**
    - **Flexibility in needed availability and coverage of individual ground stations**
  - **2x real-time data downlink (1.55:1 lossless compression)**
    - **Less contact time required to get mission data to the ground**
  - **CFDP Class 1 used for guaranteed data delivery to US Stations**
    - **Retransmit requests sent for missing files at US Stations**
    - **IC's will follow the same model as L5 and L7**

Driving Performance Requirements

- Radiometric
  - Signal-to-noise radiometric stability (16-day, 60 sec, 5 year)
  - Pixel-to-pixel uniformity
  - Absolute radiometric accuracy
    - Absolute radiance – 5%, absolute reflectance – 3%
- Spectral
  - Spectral band edges and center wavelength tolerance
  - Integrated out-of-band (OOB) response (<2%)
  - Spectral uniformity (FWHM) (± 3%)
- Spatial
  - Edge response
  - Aliasing
  - Light rejection and internal scattering
  - Ghosting
- Geometric
  - Band-to-band co-registration (4.5 m)
  - Absolute geodetic accuracy (65 m)

OLI Band and SNR Specs

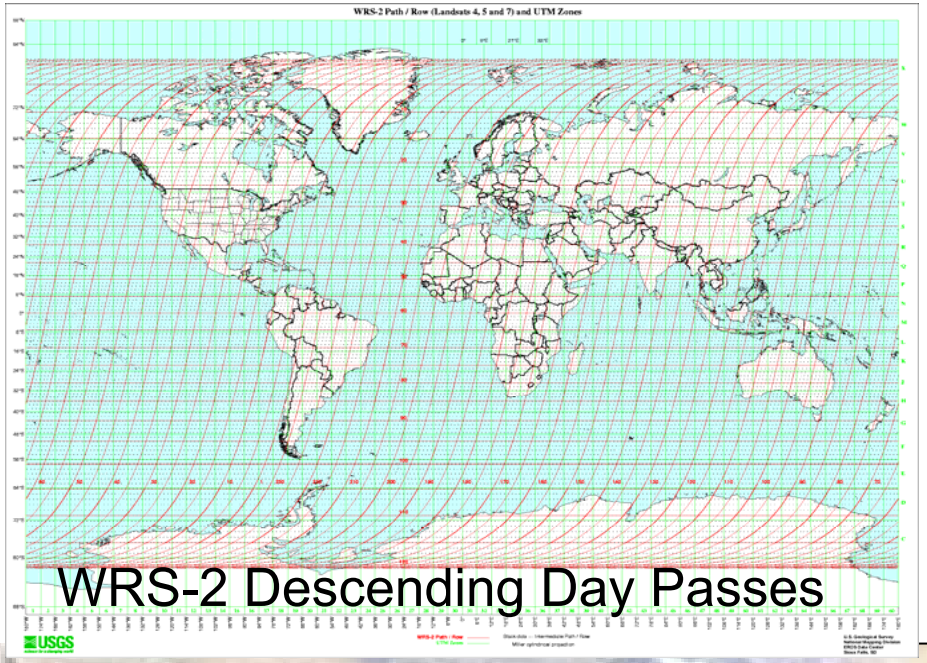
#	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	SNR at LTypical	SNR at LHigh
1	433	453	130	290
2	450	515	130	360
3	525	600	100	390
4	630	680	90	340
5	845	885	90	460
6	1560	1660	100	540
7	2100	2300	100	510
8	500	680	80	230
9	1360	1390	50	N/A



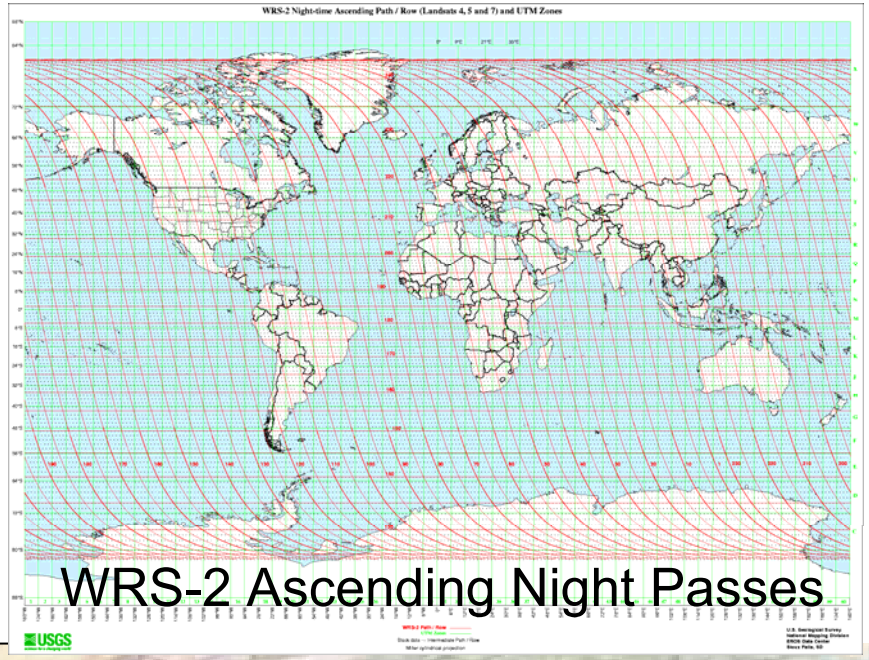
LDCM WRS-2 Operational Orbit

Sun-synchronous, near-circular frozen orbit:

Altitude	**705 Km**
Inclination	**98.2 degrees**
Repeat Cycle	**16 days**
Mean local time of descending node	**10:00 a.m. +/- 15 minutes**
Ground track error	**+/- 5 Km cross track at descending node**

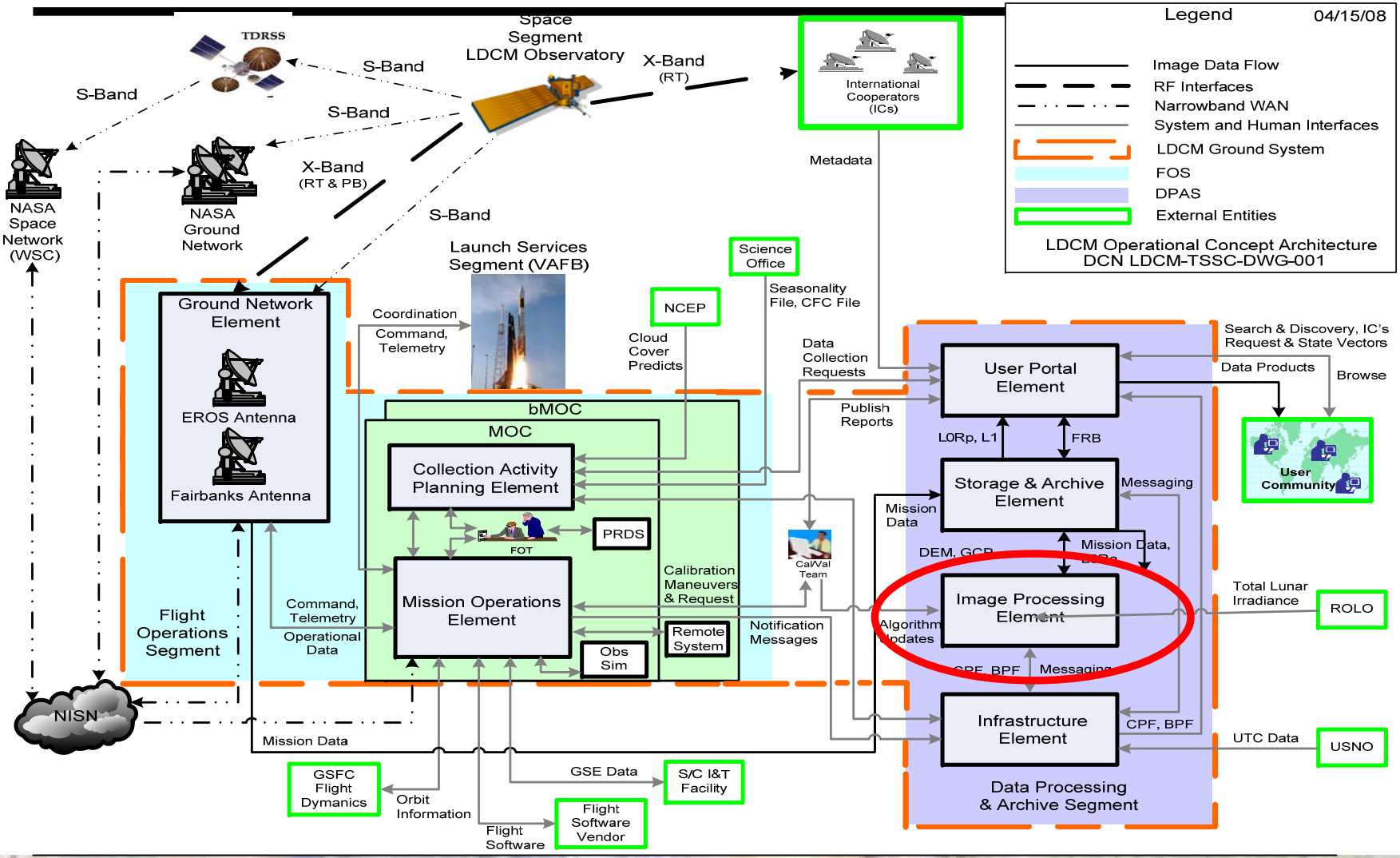


WRS-2 Descending Day Passes

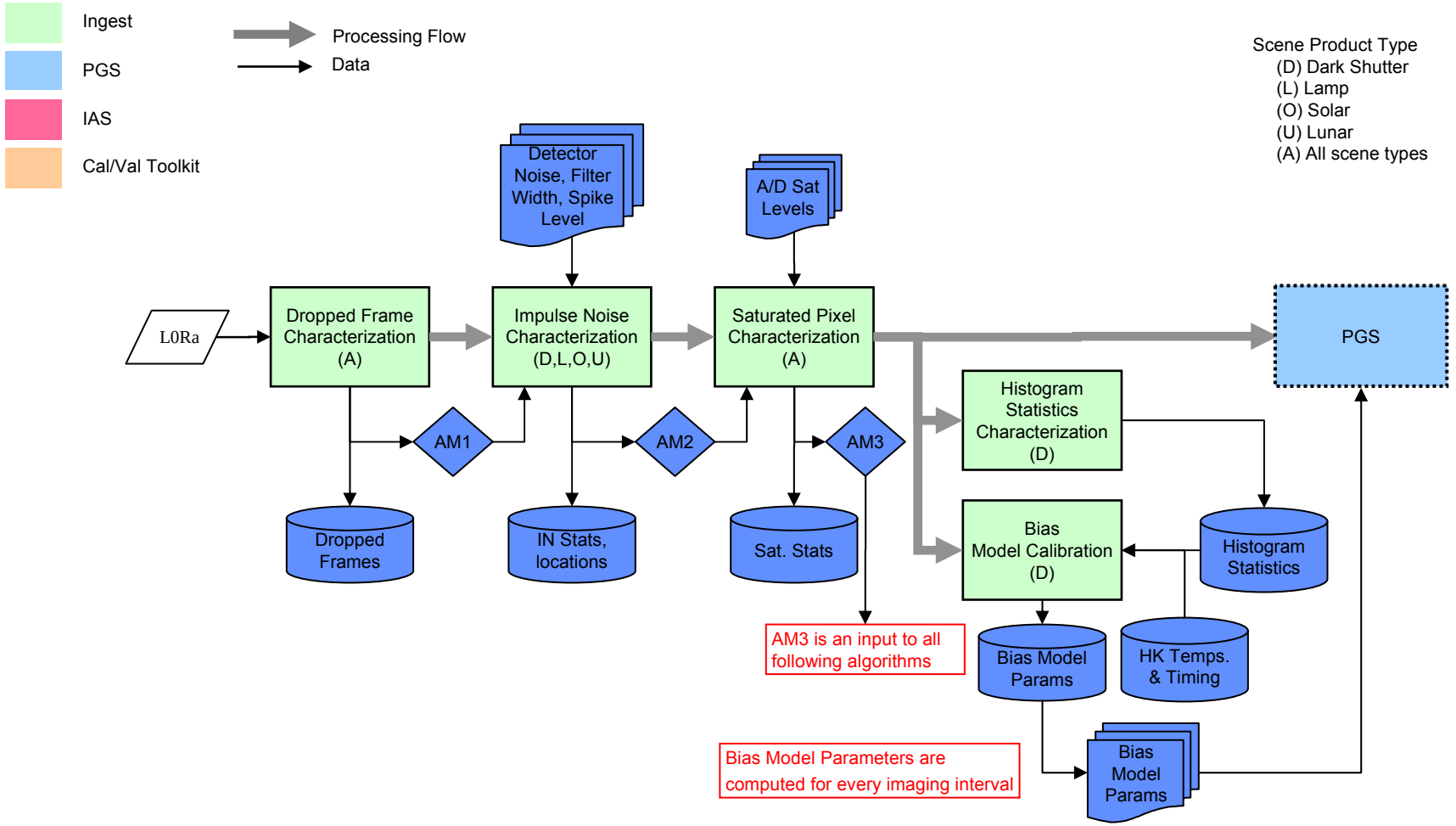


WRS-2 Ascending Night Passes

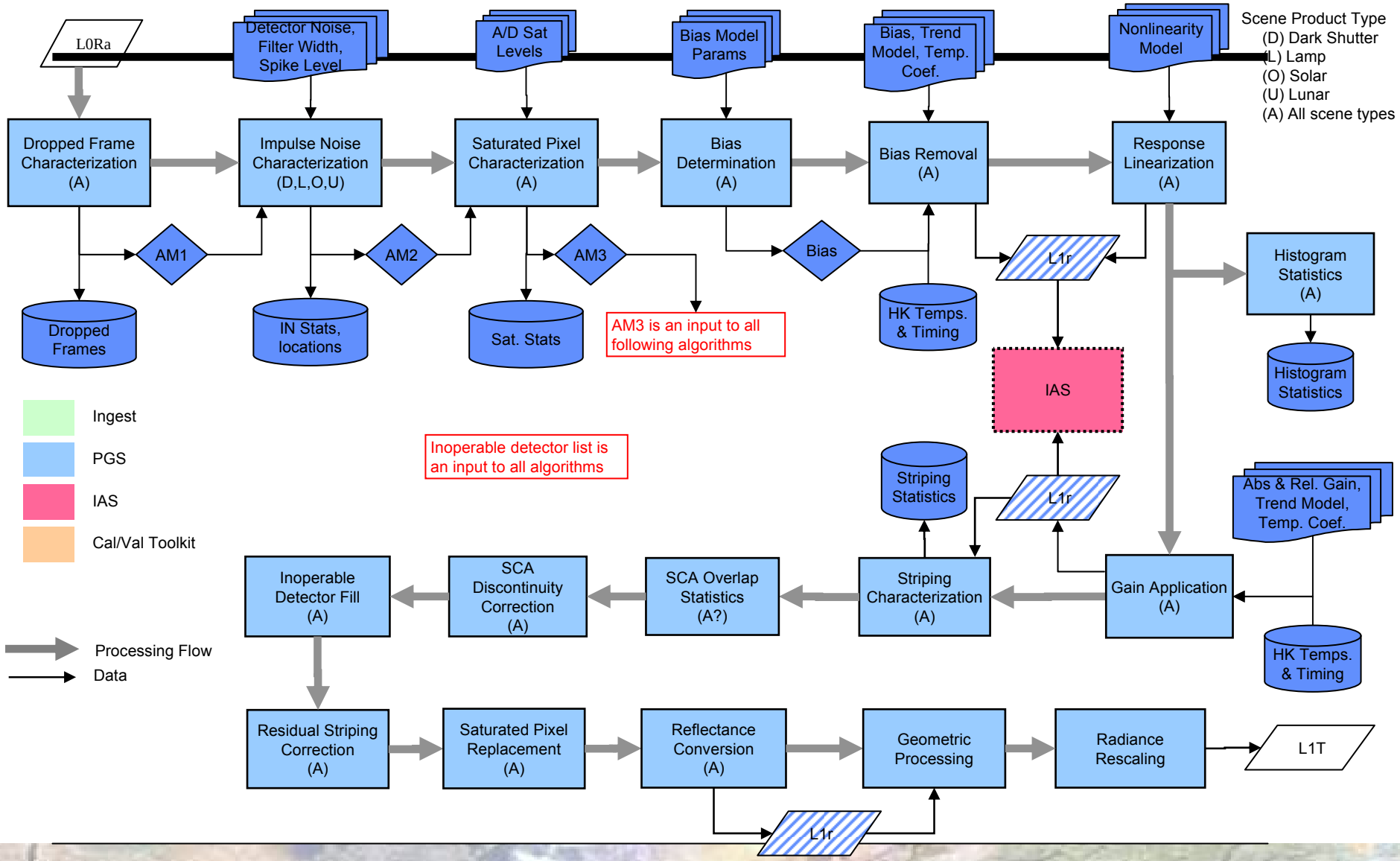
LDCM Ground System Overview



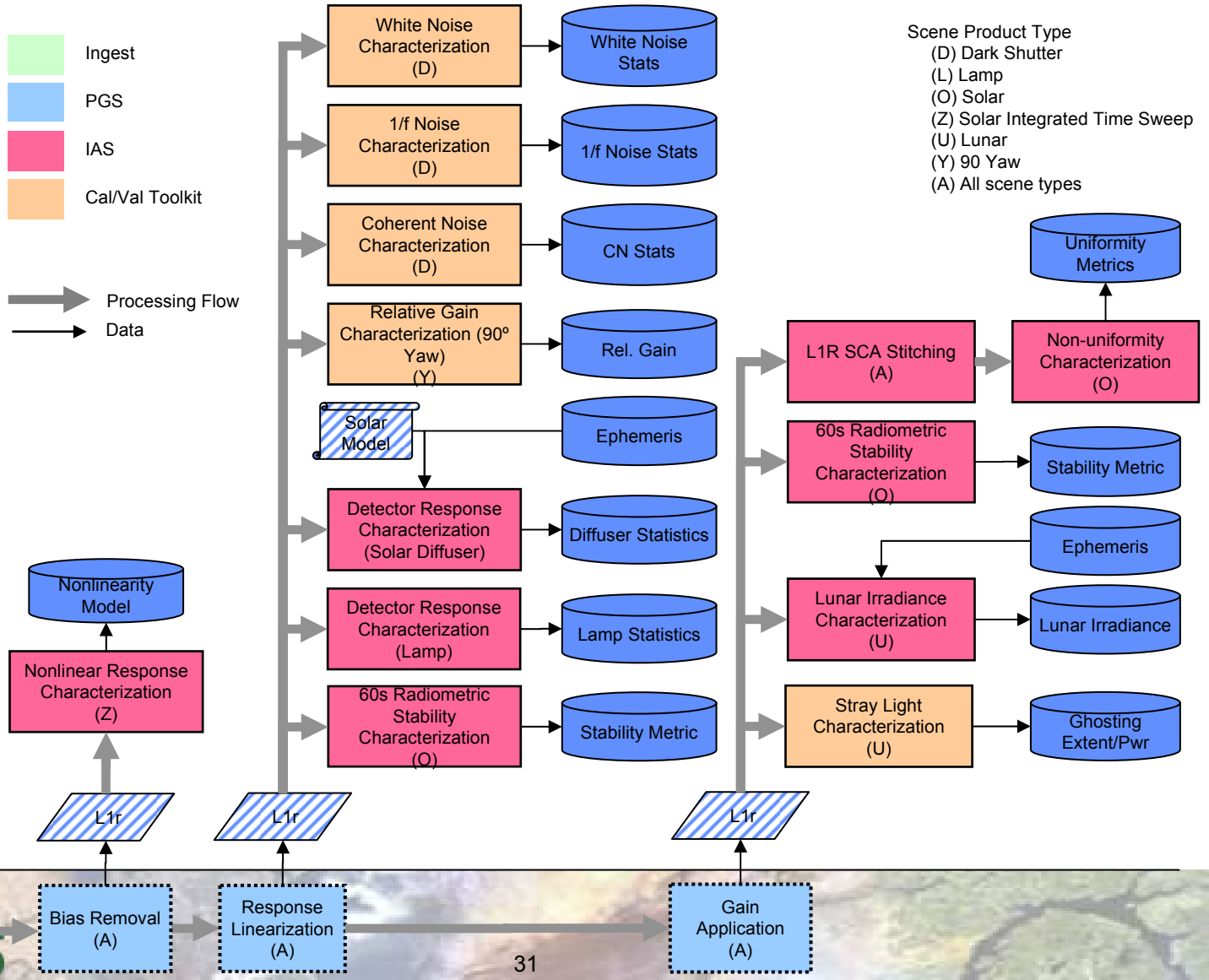
Radiometric Algorithm Flow Overview 1/4



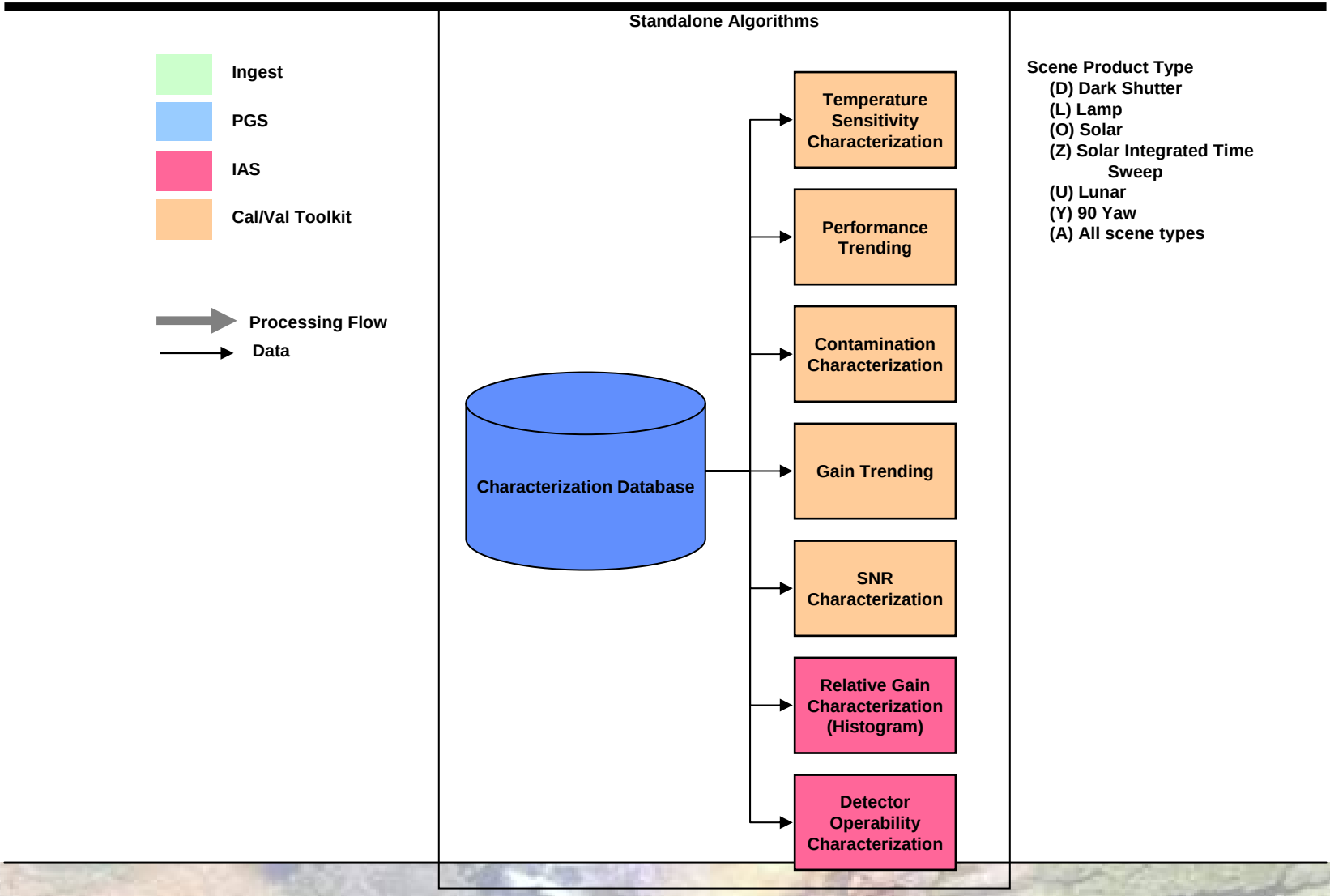
Radiometric Algorithm Flow Overview 2/4



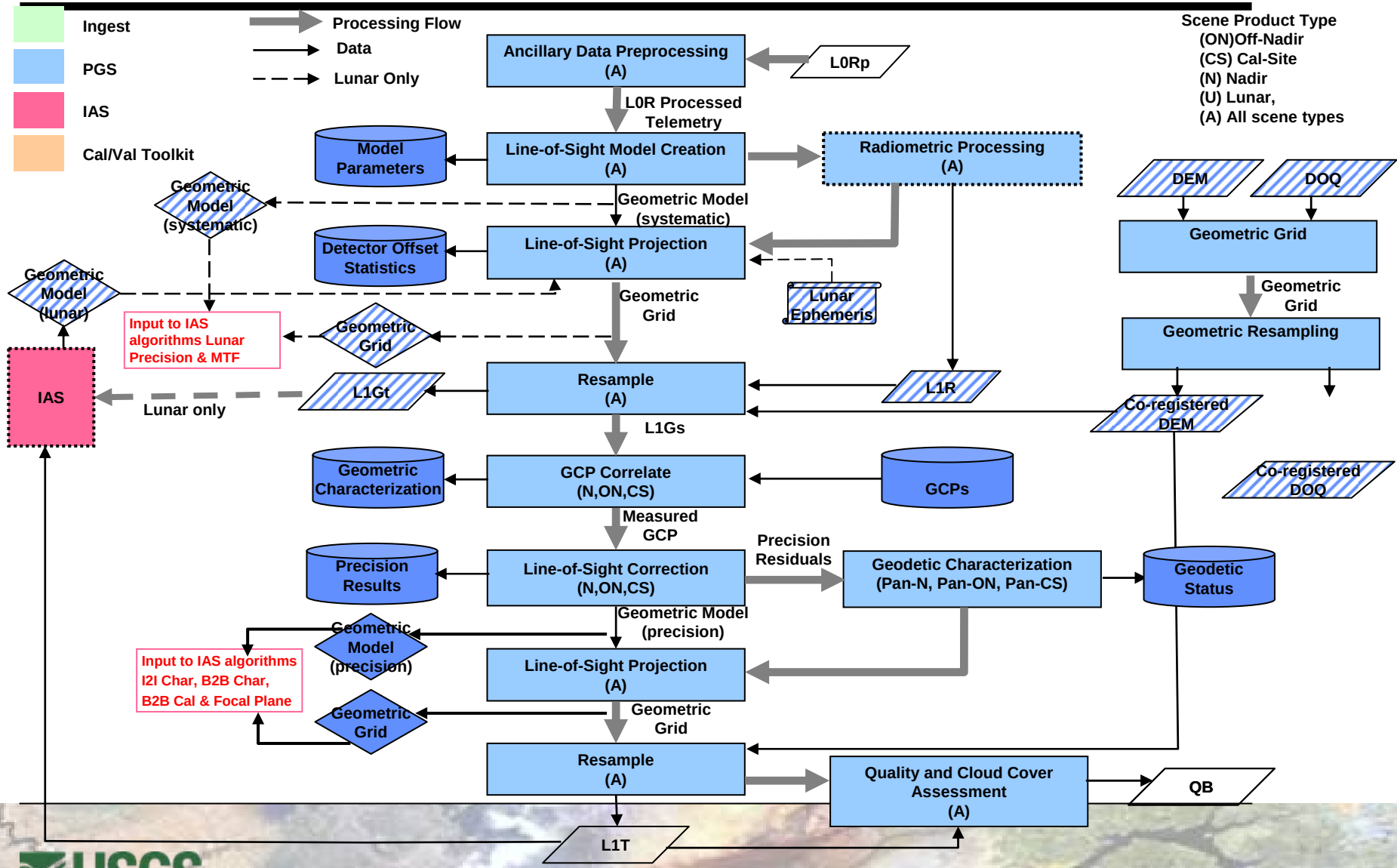
Radiometric Calibration Products



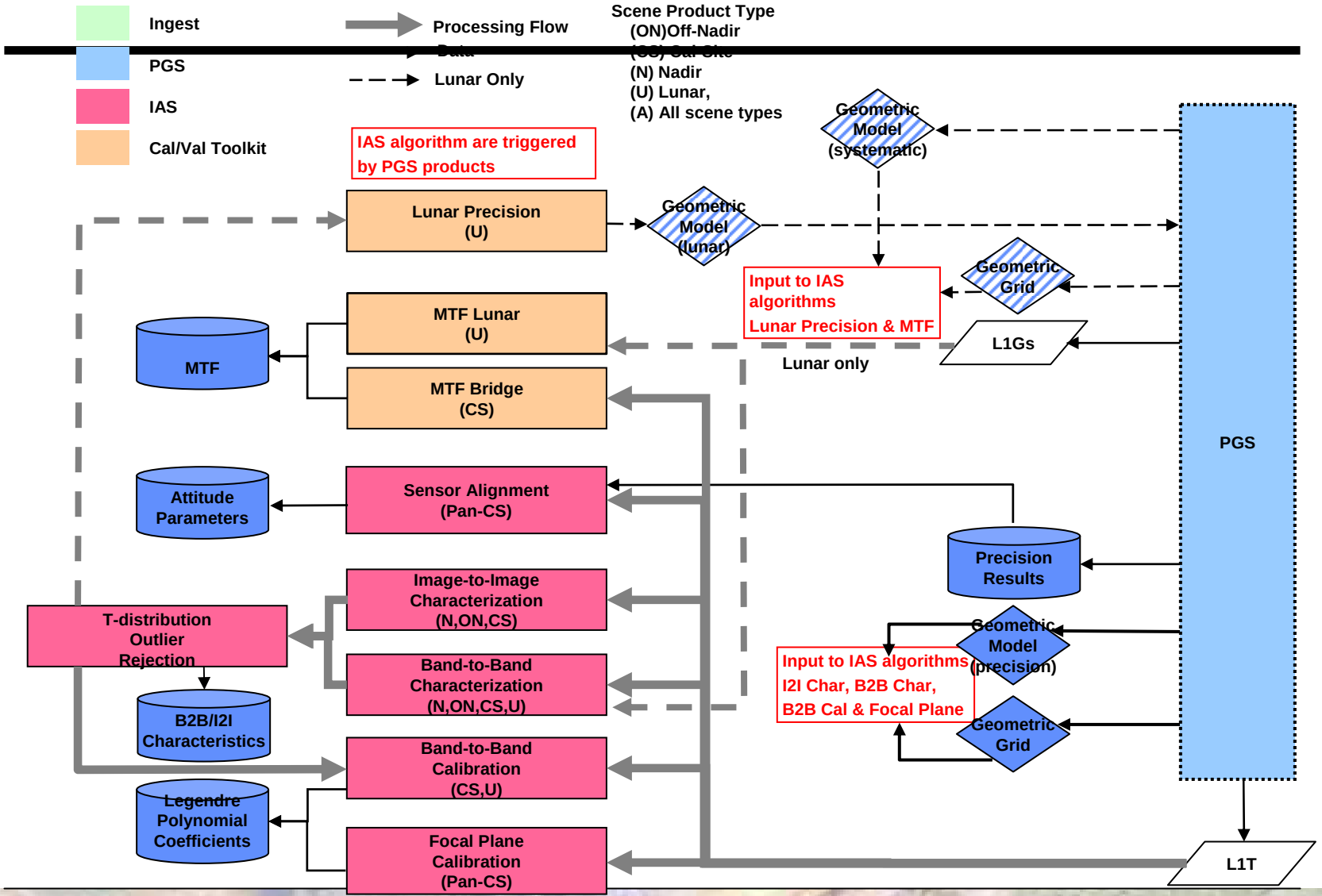
Radiometric Calibration Analysis



Geometric Algorithm Flow Overview 1/2



Geometric Algorithm Flow Overview 2/2



Landsat Science Team

http://landsat.usgs.gov/science_LST_Team_Meetings.php

- **USGS is co-chairing and funding the Landsat Science Team**
  - 1st Science Team meeting: January 9-11, 2007
  - 2nd Science Team meeting: June 12-14, 2007
  - 3rd Science Team meeting: January 8-10, 2008
  - 4th Science Team meeting: July 17-17, 2008
  - 5th Science Team meeting: Jan 6-8, 2009

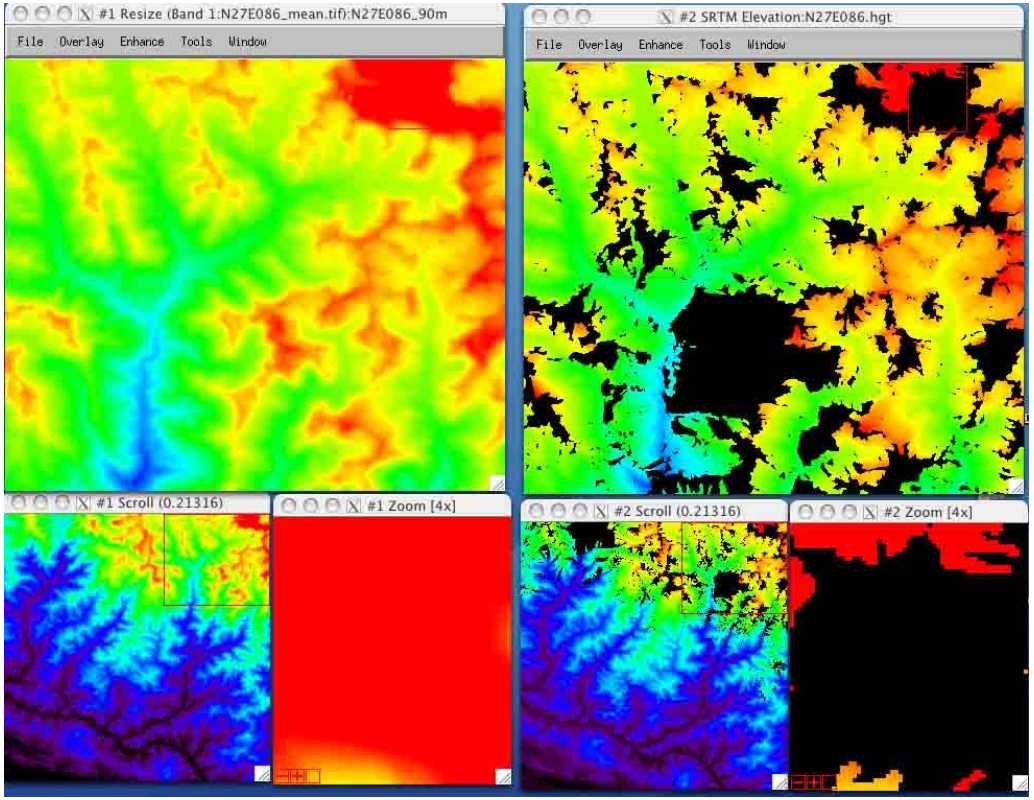
- **The Science Team is funded to conduct research and provide feedback to the LDCM in several areas**
  - Applied research in natural resource monitoring and algorithm development
  - Participation in ground system requirements reviews
  - Definition of product specifications
  - Development of LTAP-8
  - Instrument Engineering
  - Communications and Outreach & Policy recommendations

Key Outcome – Working Groups Established

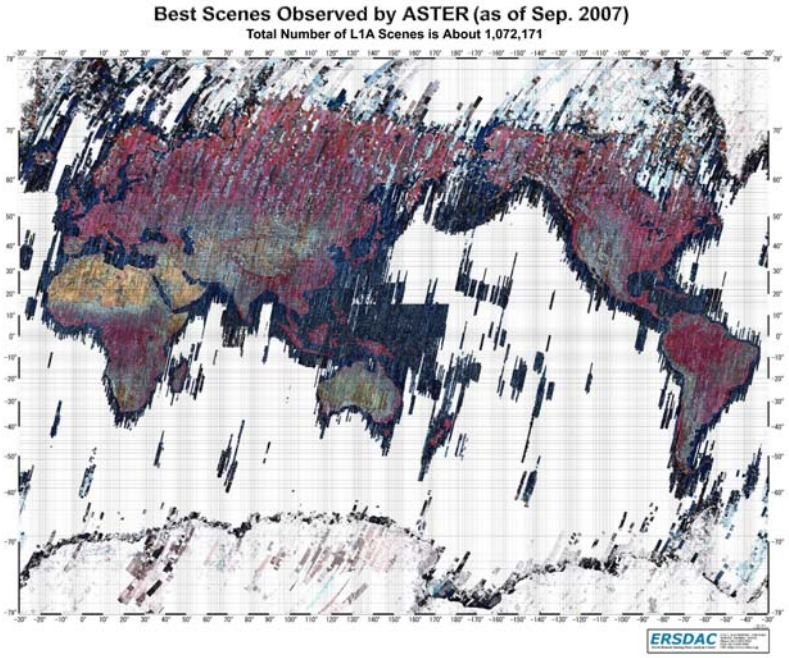
- **Landsat Global Archive Consolidation – evaluate priorities for data acquisitions**
- **Data Gap Issues – identify operational and scientific data requirements and issues associated with data acquisition options**
- **Surface Reflectance and Temperature – identify and evaluate algorithms and inputs needed to generate advanced products from Landsat data**
- **Gridded Data Sets – evaluate feasibility and technical advantages for processing Landsat data to a standard grid**
- **Cloud and Shadow Masking – identify and evaluate approaches for improving cloud and shadow masking**
- **Future Landsat Missions – define operational mission standards and identify requirements for future Landsat missions**

ASTER Global DEM Project

Stacked ASTER SRTM

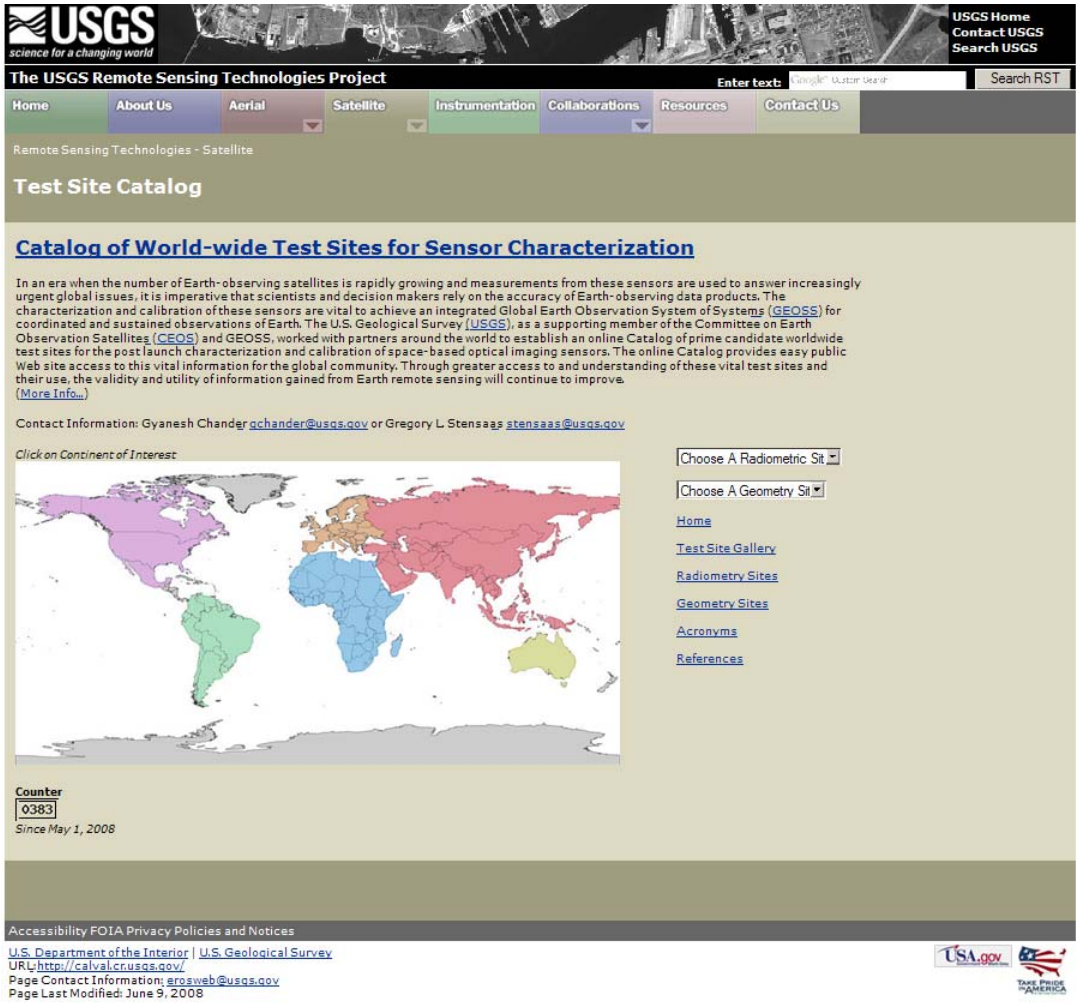


- **203 scenes used**
- **No holes for ASTER DEM**
- **Many large holes for SRTM**

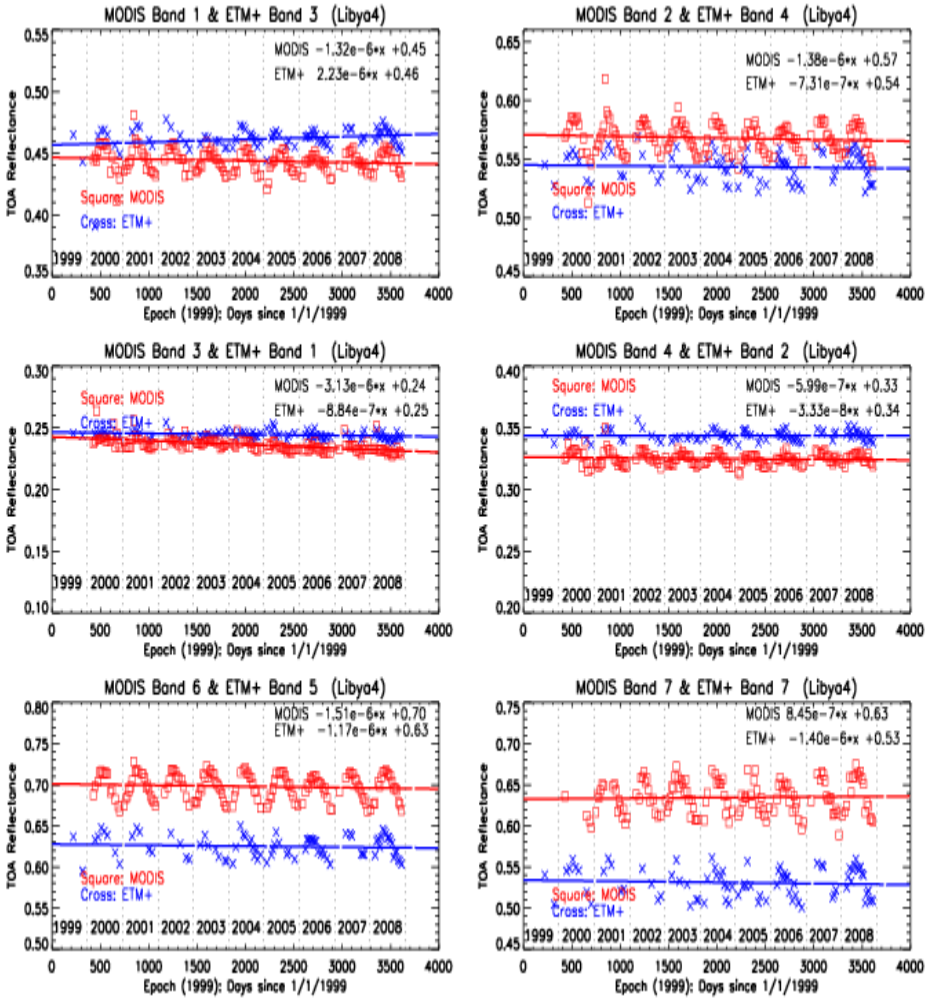


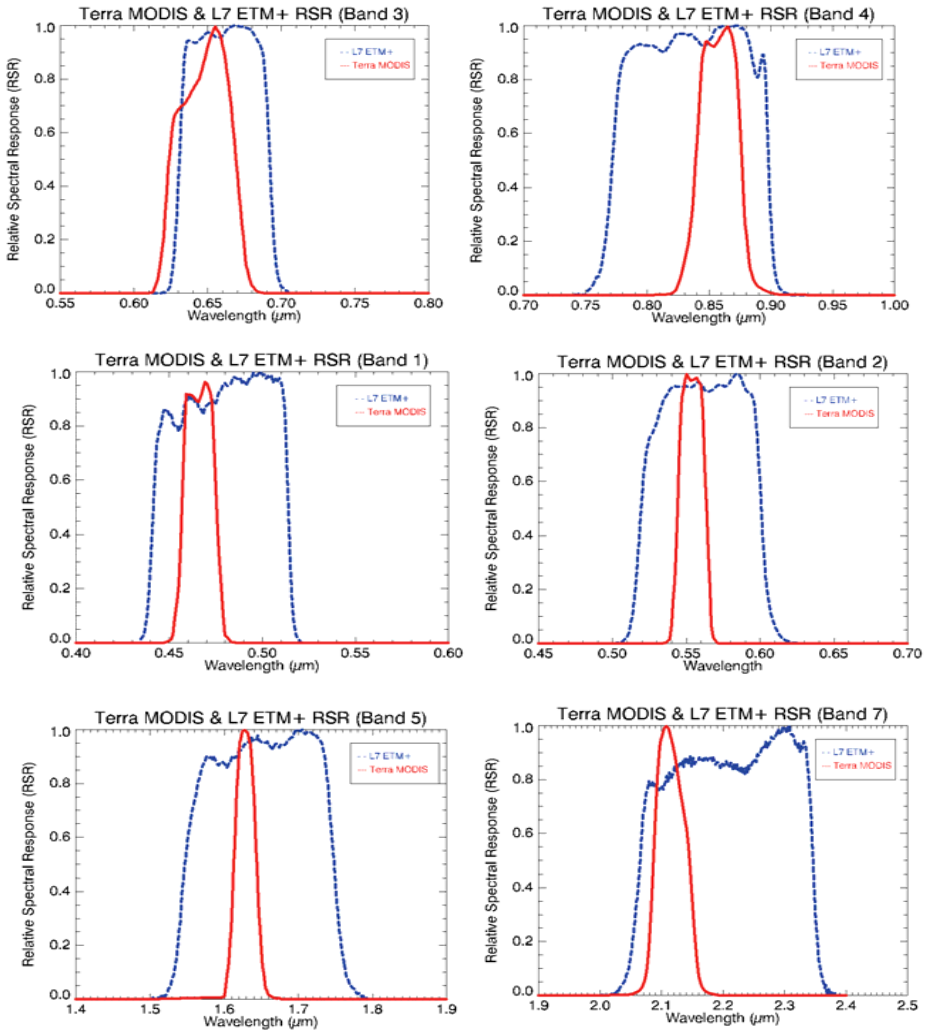
- 22,895 1° x 1° tiles
- 83° N to 83° S
- 10 m Zrms
- May 2009 release

http://calval.cr.usgs.gov/sites_catalog_map.php

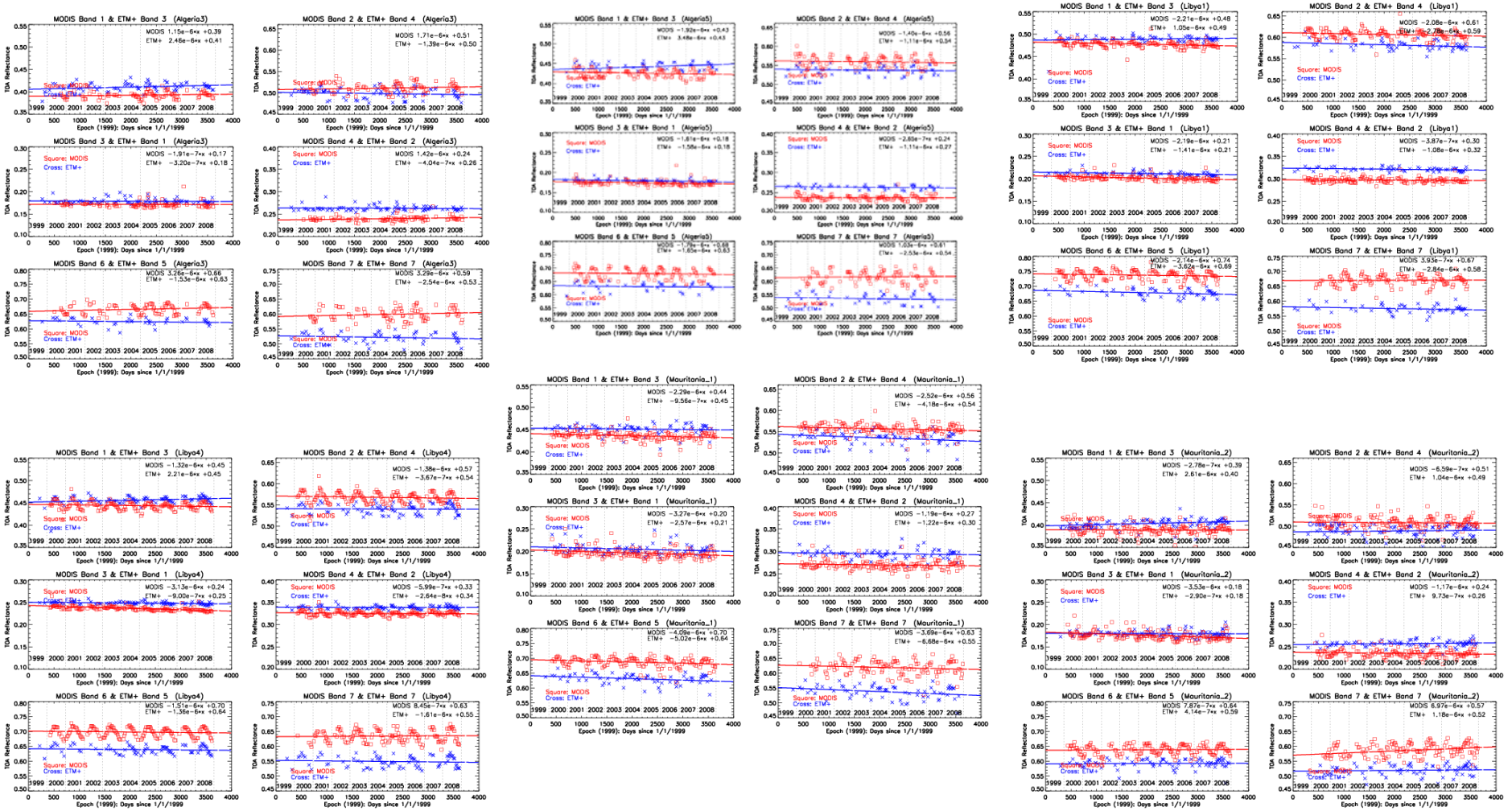


Time Series: Libya 4





TOA Reflectance Trending (CEOS)



NASA LCLUC Project

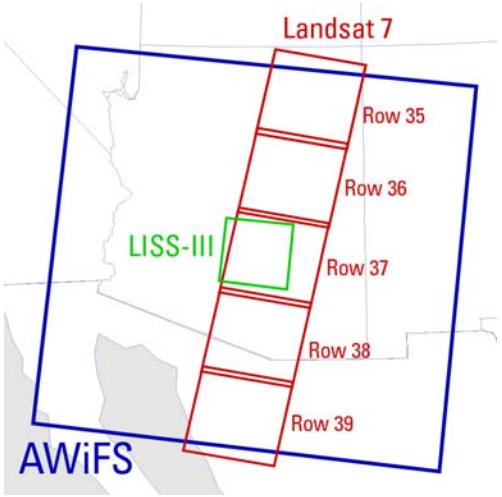
- **Goal: The goal of this proposal is to extend our theoretical and applied understanding of radiometric cross-calibration of multiple sensors in support of continued long-term studies of the Earth's land surfaces**

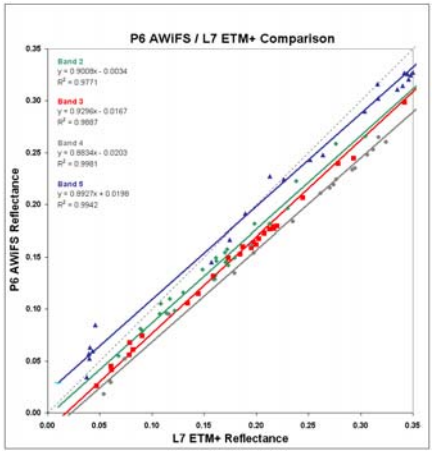
- **Research & Development (R&D):** Develop a robust approach for CC sensors with an initial focus on Landsat 5/7 and the IRS-P6 sensors

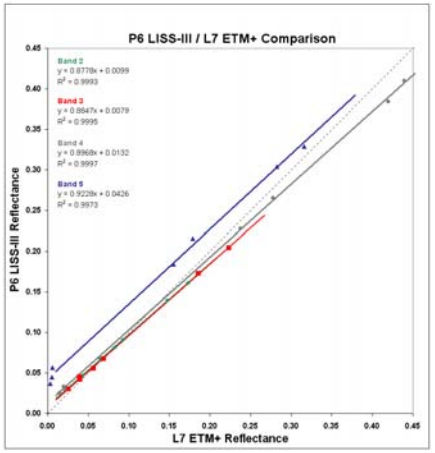
- **Sensitivity Studies:** Investigate & quantify the uncertainties inherent in the CC process. These include error sources such as differing spectral profiles, spatial and radiometric resolution differences, geometric registration, BRDF and atmospheric effects

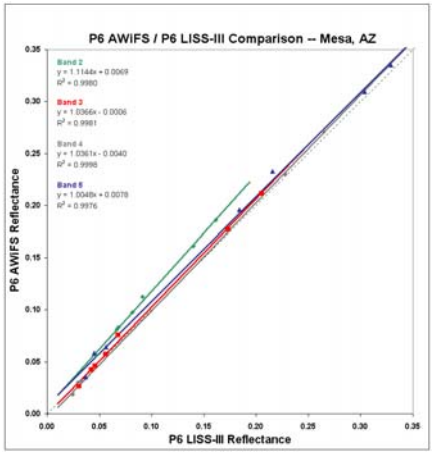
- **Land Cover Validation:** Validate the CC approach by analyzing the LCLUC products produced from cross-calibrated scenes. The suitability of IRS sensors for land cover applications (e.g., quantifying fractional landscape components, and land change analysis) will be evaluated

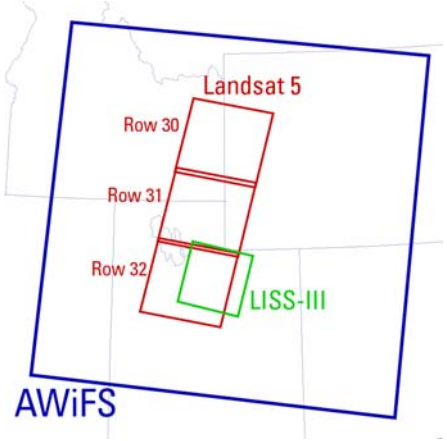
Cross-comparison with Landsat

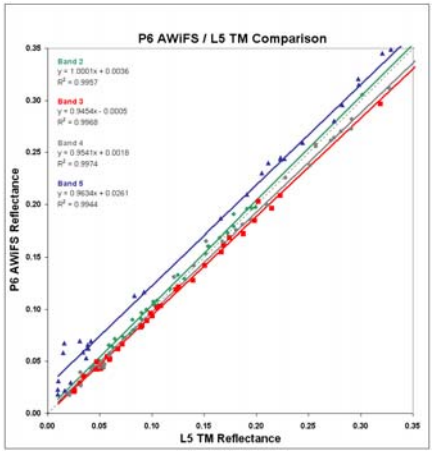


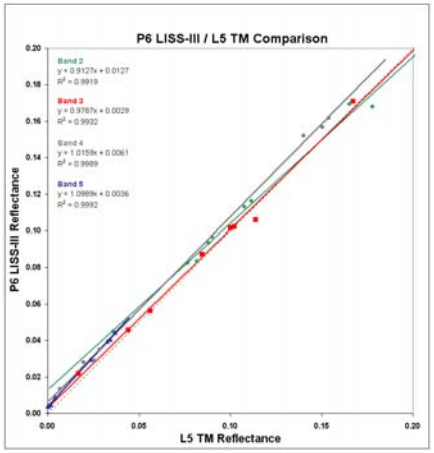


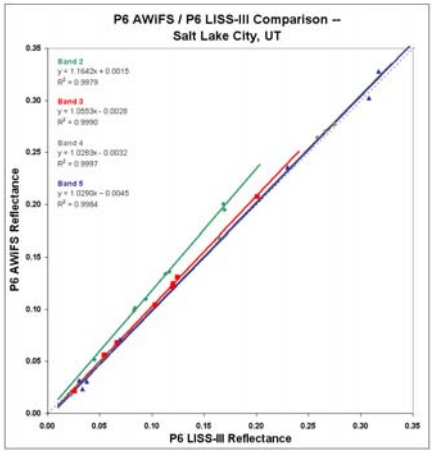








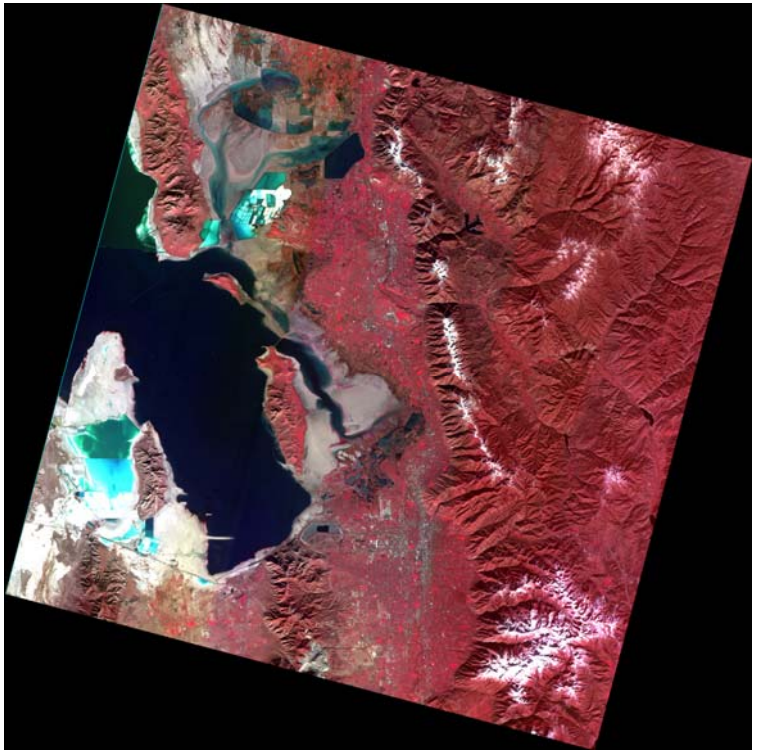




CBERS Downlink at USGS

- CBERS-2 test downlink was successfully performed at the USGS EROS Center on March 26-April 02, 2006
- CBERS-2B test downlink was successfully performed on Nov 24-28, 2008

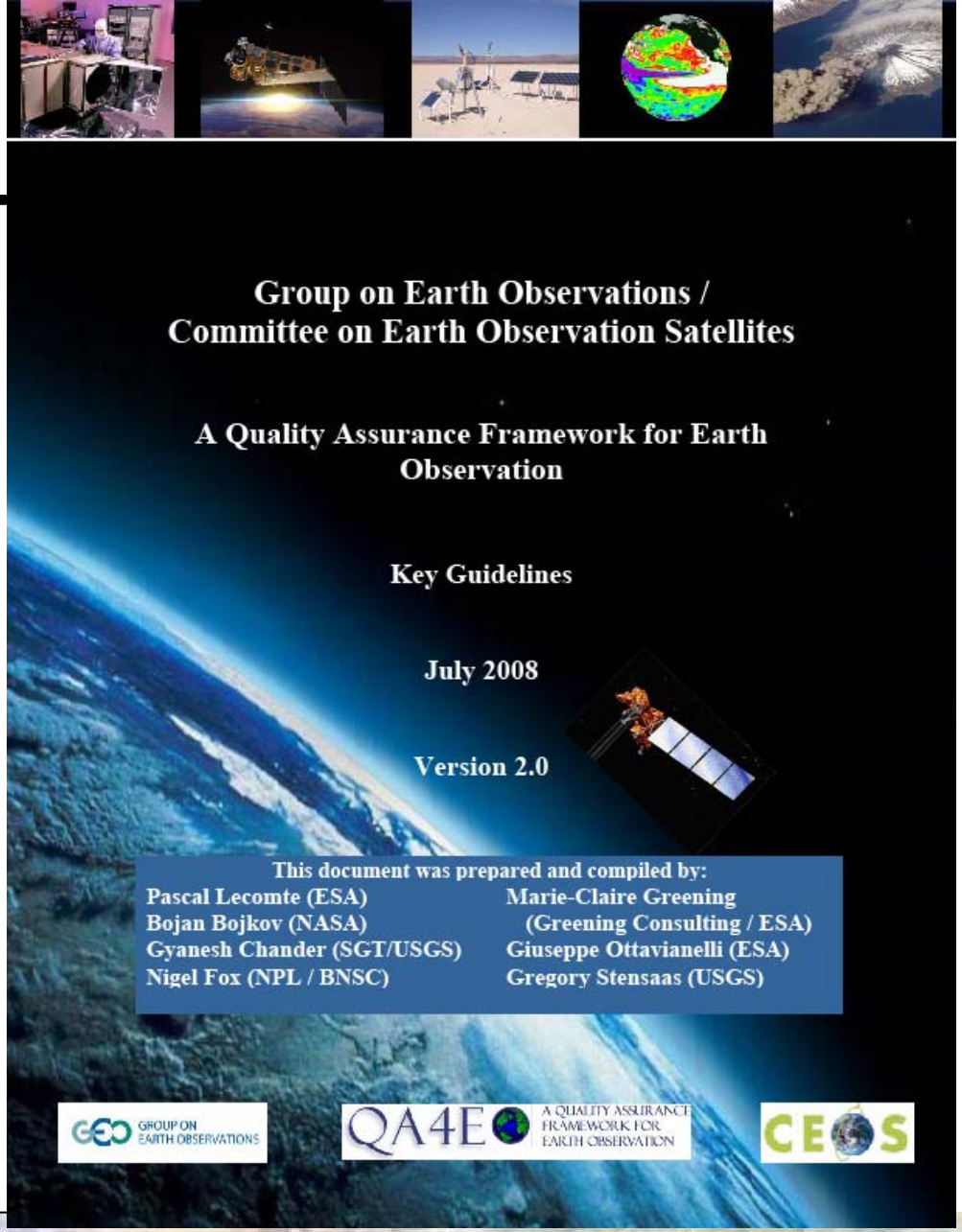
Acquisition
Date: Nov 25, 2008
Path: 238
Row: 054
Salt Lake City, Utah
CB2BCCD23805420081125



QA4EO Support

CEOS WGCV/GEO QA4EO WS1
GEO/WMO, Geneva, Switzerland
September 30 to October 3, 2007

CEOS WGCV/GEO QA4EO WS2
NIST/NASA, Gaithersburg, Maryland May 3-5, 2008.



USGS Recommendations

- **Coordinate and provide world-wide Cal/Val sites**
  - Coordinate and plan vicarious calibration field campaigns
- **Maintain a fully accessible Cal/Val portal to provide**
  - instrument characteristics of current & future systems,
  - seamless access of Cal/Val site data for users
  - database of in-situ data, documentation of best practices
  - Info regarding co-incident imagery
- **Work with others to enhance and implement QA4EO processes**
- **Work with other agencies to characterize and cross-calibrate sensors using QA4EO processes and document processes**
- **Encourage Cal/Val support for LSI activities**
- **Update CEOS WGCV web pages with membership information and technical links (being worked)**
- **Make sure that on orbit and operational instruments maintain a calibration characterization processing capability**

Summary

- This year, the USGS EROS Remote Sensing Technologies (RST) team, has completed the data characterizations for IRS-P6, CBERS-2B, SPOT-5, WorldView-1, and RapidEye
- Future Analysis: Continued data assessments for RapidEye 1 - 5, GeoEye-1, WorldView-2, THEOS
- The JACIE organizations are committed to assessing the Civil and Commercial sensors of the remote sensing industry. http://calval.cr.usgs.gov/
- Imaging campaigns over geometric and radiometric test sites can use one of the Worldwide Test Sites for Sensor Characterization. http://calval.cr.usgs.gov/sites_catalog_map.php

Questions?