Status of the Landsat Data Continuity Mission and Related Acitivities

presented by

Jim Irons

Landsat Data Continuity Mission Project Scientist

Biospheric Sciences Branch, Code 614.4

NASA Goddard Space Flight Center

at the

NASA Land-Cover and Land-Use Change Science Team Meeting

UMUC Inn and Conference Center

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Revised Implementation Strategy

- OSTP Director Marburger signed Dec. 23, 2005 memorandum with subject line, "Landsat Data Continuity Strategy Adjustment"
  - supercedes previous direction to fly Landsat sensors aboard NPOESS satellites (Aug. 04, 2004 memorandum)
  - Directs NASA to acquire free-flyer spacecraft
  - Assigns DOI / USGS the responsibility for operating the spacecraft
  - States goal of developing "a long-term plan to achieve, technical, financial, and managerial stability for operational land imaging"

LDCM Schedule

- **Jan. 09, 2007 - NASA released request for proposals (RFP) for an Operational Land Imager (OLI)**
  - Proposals were due on Feb. 23
  - The RFP did NOT include a thermal imaging option
- **June, 2007 - OLI contract award expected**
- **Summer 2007 - NASA will release a request for offers (RFO) for an LDCM spacecraft platform for the OLI**
  - Spacecraft award expected in Fall 2007
- **July, 2011 - Target LDCM launch date**

OLI Specifications

Table 1. Required Spectral Bands and Spatial Resolution

#	Band	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Center Wavelength (nm)	Maximum Spatial Resolution At Nadir (m)
1	Coastal /Aerosol	433	453	443	30
2	Blue	450	515	482	30
3	Green	525	600	562	30
4	Red	630	680	655	30
5	NIR	845	885	865	30
6	SWIR 1	1560	1660	1610	30
7	SWIR 2	2100	2300	2200	30
8	Panchromatic	500	680	590	15
9	Cirrus	1360	1390	1375	30

Thermal InfraRed Sensor (TIRS)

- **The OLI RFP does NOT include an option for a TIRS**
  - **Despite a heritage of thermal imaging from Landsat satellites, the LDCM currently carries no requirements for thermal imaging**
  - **The LDCM budget does not currently include funding for a TIRS**

- **The community of people that use fine scale thermal imagery from the current Landsat satellites are proactively calling for the continuation of thermal imaging from the LDCM**
  - **For example, the National Research Council's Decadal Survey Panel received a letter (Sept. 14, 2006) signed by 117 water managers and scientists:**
    - **"The accuracy of Landsat-scale TIR evapotranspiration (ET) estimates has improved to the point that consumptive use and water rights can be reliably monitored from space at the scale of a single irrigation system."**

- **The Landsat Science Team sent a Jan. 23 letter to the NASA Administrator and the Director of the USGS recommending the addition of a TIRS to the LDCM payload**

- **TIRS is still under consideration**

Decadal Survey

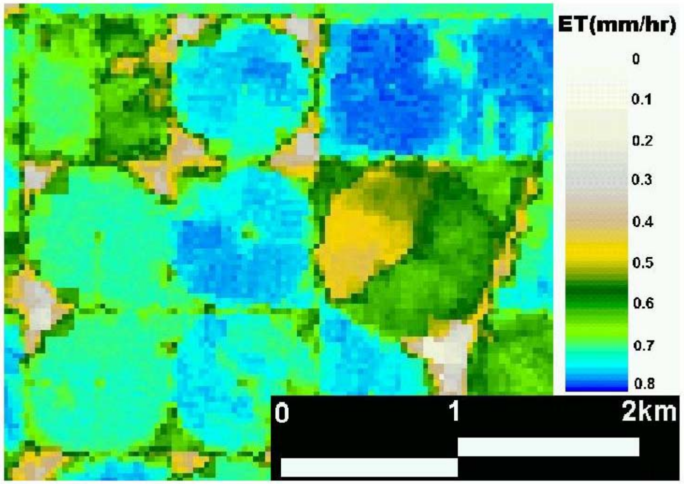
- **Executive Summary states:**
  - **"*Recommendation*: NASA should ensure continuity of measurements of precipitation and land cover by:**
    - **Launching GPM in or before 2012.**
    - **Securing replacement to Landsat 7 data before 2012."**

- **The Decadal Survey, pre-publication copy released Jan. 12, recommends in Chapter 6, Human Health and Security:**
  - **"Implement an effective Landsat 7 follow-on program including a slightly enhanced reflective channel selection and an <u>effective thermal band selection</u>"**

Research to Operations

- **Landsat thermal data are now used operationally to monitor water consumption on a field-by-field basis in the U.S. West and internationally**
  - **Development of operational energy-balanced-based evapotranspiration models**
    - **SEBAL**
    - **METRIC**

Evapotranspiration at time of Landsat overpass
Oakley Fan, Idaho, July 7, 1989



Using 120 m Landsat 5 Thermal Data

Courtesy of Richard Allen, Kimberly Research and Extension Center, University of Idaho

- **Water rights regulation and administration are critically tied to identification and quantification of water consumption on a field-by-field basis -** *Allen, R.G. "The Need to Continue High Resolution Thermal Imagery …"*
  – Typical irrigated field sizes in the U.S. range from 180 m to 750 m on a side

- **Quantification of water use from Landsat using thermal data is the only way to independently and consistently measure water use on a field-by-field basis** - *Morse, A., and R.G. Allen. "Water and the Critical Need for a Thermal Band on Landsat"*

Thermal Data Continuity

Land Surface Temperature and Emissivity Earth System Data Record (LSTE-ESDR)

Coverage	Spatial Resolution	Temporal Resolution	Current Data Sources	Future Data Sources
Global	**10-20 km**	**Hourly**	**AIRS GOES MSG**	**CrIS GOES MSG**
Regional	**1-5 km**	**2-4 times daily**	**MODIS AVHRR ATSR**	**VIIRS AVHRR ATSR**
Local	**30–100 m**	**Once every 8-16 days**	**ASTER Landsat**	!!

Table from S. Hook

Draft LDCM Thermal Requirements

LDCM

Band	Center Wave length (micro meters)	Spatial Resolution At Nadir (m)	NE ΔT Requirements	
			At $T_{Typical}$	At T_{High}
Thermal 1	10.8	120	0.4K	0.35K
Thermal 2	12.0	120	0.4K	0.35K

- **120 m spatial requirement derived from trade between irrigated field size and the maturity of detector technology**
  - **Sufficient to resolve most center-pivot irrigation fields in U.S. West - typically 400 to 800 m in diameter (see poster by Ryan et al.,)**
  - **Thermal data user survey by Rick Allen, U. of Idaho, supports 120 m requirement**
  - **Landsat 4 & 5 TM's provided 120 m thermal images for single thermal band**
  - **Landsat 7 ETM+ provided 60 m thermal images for single thermal band**
- **The two bands enable atmospheric correction for accurate surface temperatures**

Landsat Science Team

- USGS convened the first meeting of the USGS-sponsored science team for Jan. 09 - 11 at USGS EROS in Sioux Falls, SD
  - **Co-chaired by the USGS Landsat Project Scientist, Tom Loveland, and the NASA LDCM Project Scientist, Jim Irons**
  - **USGS selected 17 science team members in Oct.**
    - **8 funded PI's from academia and private industry**
    - **6 unfunded civil servant PI's and 3 unfunded international PI's**
  - **Team selected Curtis Woodcock, Boston U., as Team Leader**
    - **Curtis signed and sent the thermal imaging letter to NASA Administrator and USGS Director on behalf of Science Team**

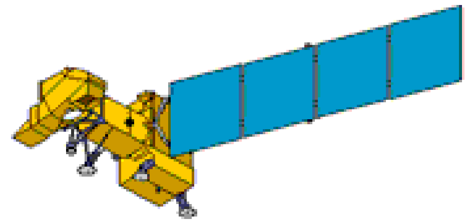
Landsat Science Team - Funded Investigators

Principal Investigator	Organization	Proposal Title
John Schott	Rochester Institute of Technology	The Impact of Land Processes on Fresh and Coastal Waters
Dennis Helder	South Dakota State University	A Systematic Radiometric Calibration Approach for LDCM and the Landsat Archive
Lazaros Oraiopoulos	University of Maryland Baltimore County	Cloud Detection and Avoidance for the Landsat Data Continuity Mission
Sam Goward	University of Maryland	The LDCM Long Term Acquisition Plan: Extending and Enhancing the Landsat 7 LTAP Approach
Richard Allen	University of Idaho	Operational Evapo-transpiration Algorithms for LDCM as a Member of the Landsat Data Continuity Mission Science Team
Eric Vermote, Chris Justice, Nazmi Saleous	University of Maryland	A Surface Reflectance Standard Product for LDCM and Supporting Activities
Curtis Woodcock	Boston University	Toward Operational Global Monitoring of Landcover Change
Feng Gao	Earth Resources Technology	Developing a Consistent Landsat Data Set from MSS, TM/ETM+ and International Sources for Land Cover Change Detection

Landsat Science Team - International & Federal

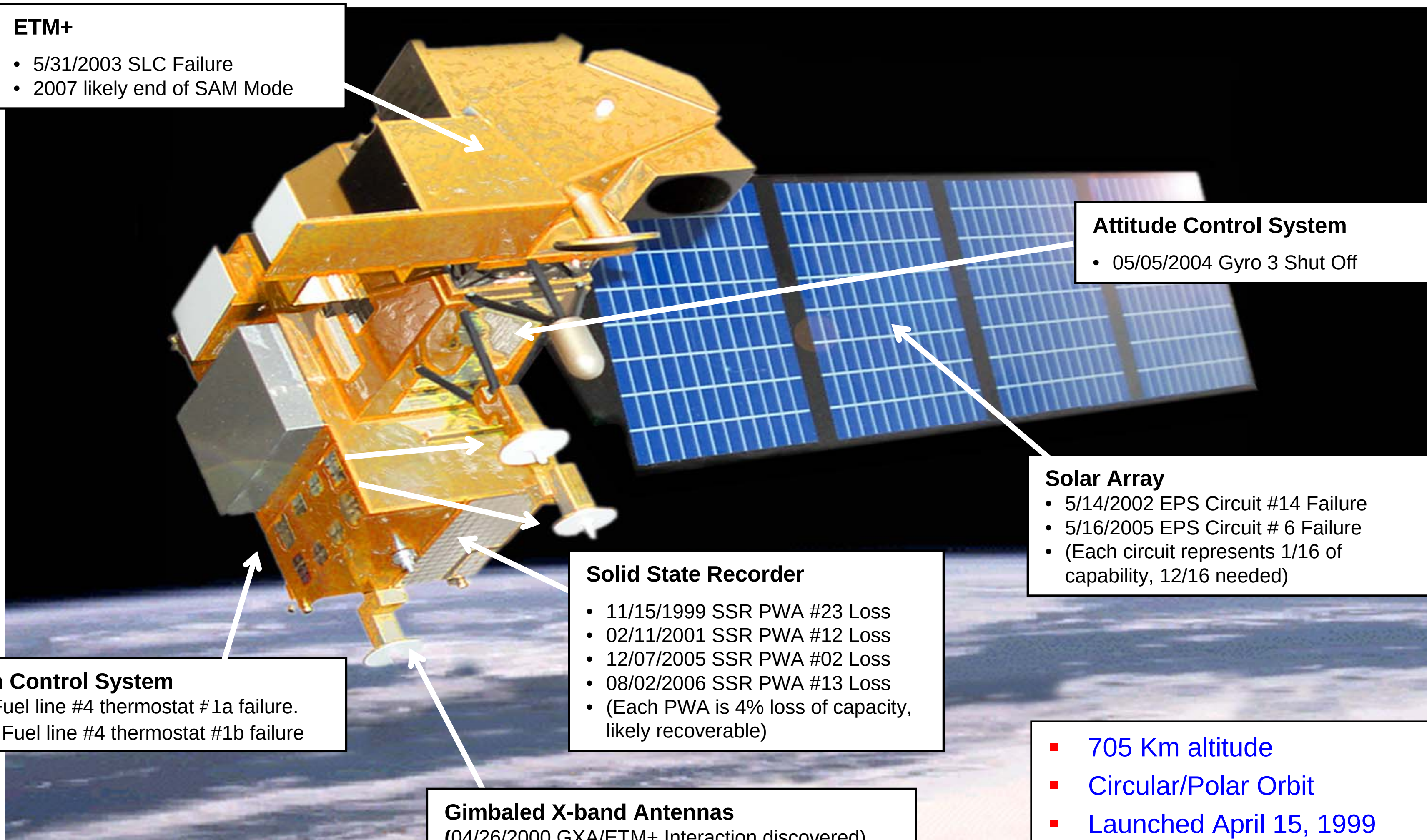
Principal Investigator	Organization	Proposal Title
Michael Wulder	Canadian Forest Service	Large-Area Land Cover Mapping and Dynamics: Landsat Imagery to Information
Eileen Helmer	U.S. Forest Service International Institute of Tropical Forestry	Cloud-Free Landsat Image Mosaics for Monitoring Tropical Forest Ecosystems
Martha Anderson	USDA Agricultural Research Service	Mapping Drought and Evapo-transpiration at High Spatial Resolution Using Landsat Thermal and Surface Reflectance Band Imagery
Alan Belward, Frederic Achard, Philippe Mayaux	EC Joint Research Center	Natural Resources Management - Meeting Millennium Development Goals
Warren Cohen	U.S. Forest Service Pacific Northwest Research Station	Landsat and Vegetation Change: Towards 50 Years of Observation and Characterization
Robert Bindshadler	**NASA Goddard**	Advancing Ice Sheet Research with the Next Generation Landsat Sensor
Prasad Thenkabail	International Water Management Institute	Global Irrigated Area Mapping using Landsat 30-m for the Years 2000 and 1975
Rama Nemani	NASA Ames	Developing Biophysical Products for Landsat
Jim Vogelmann	SAIC/EROS	Monitoring Forest and Rangeland Change Using Landsat Continuity and Alternative Sources of Satellite Data

Landsat 7 Mission Status



- Spacecraft
  - Gyro 3 Failure (Shut down May 5, 2004)
    - Flight Operations team implemented software gyro
    - Working additional improvements for software gyro
  - Other Spacecraft Issues (non-critical)
    - Solid State Recorder – 4 memory boards
    - Electrical Power Subsystem – shunt #14 and shunt #6
    - Fuel Line Thermostat
- ETM+
  - Scan Line Corrector Failure (May 31, 2003)
    - Continue to operate with SLC off; no impacts to radiometric or geometric performance
    - Expect to release Segment-based Fill product in Feb, 2007
  - Bumper Mode Operations (April 01, 2007)
    - The ETM+ began imaging in an alternate mirror-scanning control mode
    - Landsat 5 TM has collected data in bumper mode for 5 years with no significant impact on data quality

Landsat 7 Spacecraft Status



ETM+
- 5/31/2003 SLC Failure
- 2007 likely end of SAM Mode

Attitude Control System
- 05/05/2004 Gyro 3 Shut Off

Solar Array
- 5/14/2002 EPS Circuit #14 Failure
- 5/16/2005 EPS Circuit # 6 Failure
- (Each circuit represents 1/16 of capability, 12/16 needed)

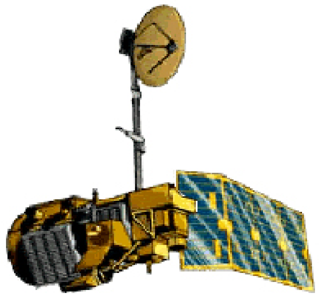
Solid State Recorder
- 11/15/1999 SSR PWA #23 Loss
- 02/11/2001 SSR PWA #12 Loss
- 12/07/2005 SSR PWA #02 Loss
- 08/02/2006 SSR PWA #13 Loss
- (Each PWA is 4% loss of capacity, likely recoverable)

Reaction Control System
- 1/7/04 Fuel line #4 thermostat #1a failure.
- 2/24/05 Fuel line #4 thermostat #1b failure

Gimbaled X-band Antennas
(04/26/2000 GXA/ETM+ Interaction discovered)

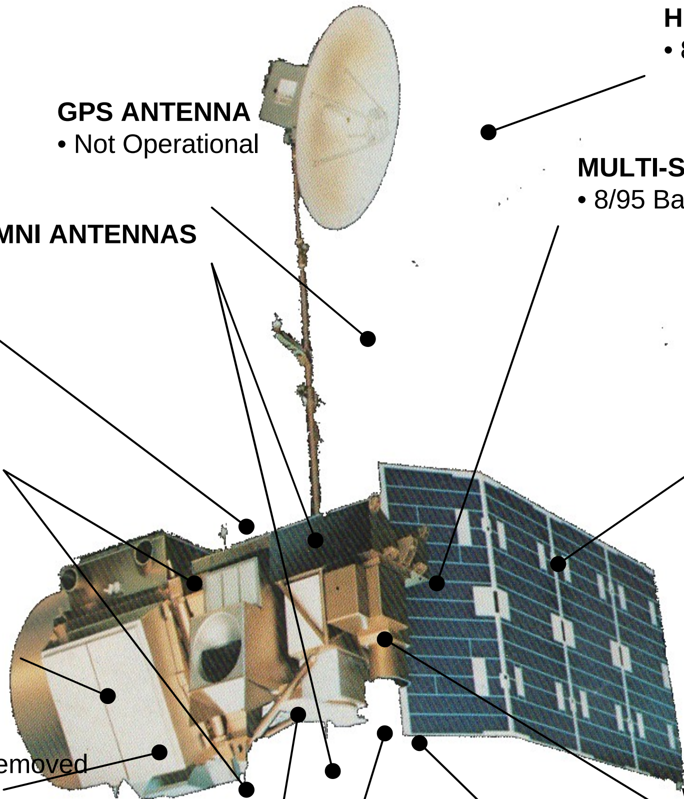
- 705 Km altitude
- Circular/Polar Orbit
- Launched April 15, 1999

Landsat 5 Mission Status



- **Spacecraft**
  - **Solar Array Drive Malfunction**
    - **Fixed array operations – Aug 2006**
  - **X-band Transmission (March 2006)**
    - **Power spikes associated with TWTA (Traveling Wave Tube Amplifier)**
    - **New turn on procedure to avoid spikes**
- **TM**
  - **Functioning normally in bumper-mode**

Landsat-5 Flight Segment Overview



HIGH GAIN ANTENNA
- 8/85 Transmitter A failure

GPS ANTENNA
- Not Operational

COMM & DATA HANDLING MODULE
Transmitter A failure

OMNI ANTENNAS

MULTI-SPECTRAL SCANNER
- 8/95 Band 4 failure

ACS MODULE
- 07/03 FHST#1 Degradation
- Skew wheel tack anomaly 10/92
- 11/92 Earth Sensor 1 failure
- 02/02 Earth Sensor 2 failure
- Intermittent operations possible

SOLAR ARRAY DRIVE / PANELS
- 01/05 Primary Solar Array Drive failure
- 11/05 Redundant Solar Array Drive Malfunction
- 08/06 Transitioned to Fixed Array Operations

COARSE SUN SENSORS

PROPULSION MODULE
- 3/84 Primary Thruster D failure

POWER MODULE
- 05/04 Battery 1 failure / Removed from power circuits

WIDEBAND COMM. MODULE
- 07/88 Ku-band TWTA Prime failure (OCP)
- 07/92 Ku-band TWTA Redundant failure (OCP)
- 08/87 X-band TWTA Prime failure (OCP)
- 03/06 X-band TWTA Redundant Anomaly

X-BAND ANTENNA

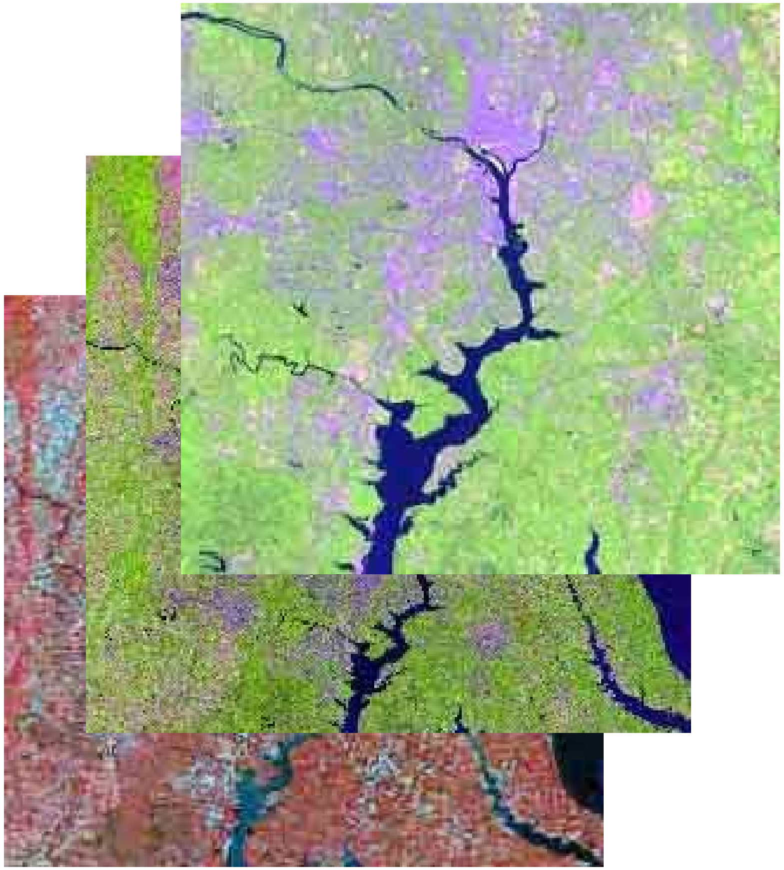
THEMATIC MAPPER
- 10/94 Power Supply 1 stuck switch
- 06/02 TM switched to bumper mode

DIRECT ACCESS S-BAND
- 03/94 Side A FWD Power Sensor failure

U.S.G.S. EROS Landsat Archive Overview

(Marketable Scenes through September 25, 2006)

- **ETM+: Landsat 7**
  - 654,932 scenes
  - 608TB RCC and L0Ra Data
  - Archive grows by 260GB Daily
- **TM: Landsat 4 & Landsat 5**
  - 671,646 scenes
  - 336TB of RCC and L0Ra Data
  - Archive Grows by 40GB Daily
- **MSS: Landsat 1 through 5**
  - 641,555 scenes
  - 14TB of Data



Archive reached 2 million scenes on Feb. 20, 2007

Pilot Project: Web Enabled Standard ETM+ Product

- Processed product / Level 1Gt
- Automatically generated
  - Predetermined parameters
    - e.g., Terrain-corrected, GeoTIFF
- Available via FTP / Targeted for April 2007
- Pilot Dataset
  - US only – includes Alaska and Hawaii
  - L7 ETM+ SLC-off only – 2003 to present (and ongoing)
  - < 10% cloud cover, 9 quality

Landsat Data Gap Study Team

- **USGS release a Request for Information (RFI) for data to mitigate the impact of a Landsat data gap**
  - **seeks to identify potential suppliers of moderate resolution satellite data with characteristics reasonably similar to those of Landsat to cover the global landmass at least twice per year**
  - **If procured, baseline data would be placed in the U.S. national archive and distributed to the Landsat user community under the current unrestricted data-use policy. However, some licensing restrictions might be acceptable on data obtained from a commercial source**
- **Responses were due April 02**

Future of Land Imaging - Interagency Working Group

- **Beginning in January 2006, a Future of Land Imaging Interagency Working Group (FLI IWG) began to meet weekly to explore future U.S. options for acquiring Landsat-type data**
  - **A Landsat instrument would no longer be flown on NPOESS, the earlier approach to making land imaging operational**
  - **A single free-flyer satellite, like LDCM, is not an operational solution**
  - **NSTC was commissioned to develop a plan to achieve programmatic stability**
- **What began as an examination of management alternatives to ensure sustained Landsat-type imaging became a broader and deeper discussion about the failed policy history of Landsat**
- **A call to establish a National Land Imaging Program (NLIP), hosted by the U.S. Department of the Interior, emerged from these discussions**

NLIP Management Characteristics

- Focused Federal Leadership for the U.S. Land Imaging Community
  - Unified planning and operations responsibility
  - Coordination responsibility for:
    - Determining U.S. land imaging needs
    - Primary Source data acquisition and distribution
    - Technology R&D and system acquisition
  - Broker-agent for U.S. Civil Government and commercial sources of data
  - Single U.S. point-of-contact for International partnerships and arrangements
- Point-of-accountability for performance
- Flexibility as technical, fiscal, and political variables change
- Above all else, “Ensure availability, access, and ease of use of land imaging data for the Nation”