Future Missions Working Group Report

June 22, 2009

Working Group Charter

- Develop and recommend to the USGS and NASA operational mission standards, requirements, and characteristics for future Landsat missions. This includes determining the meaning of an “operational” Landsat program, suggesting a long-term mission definition including the purpose of an operational Landsat program, providing recommendations on what the key technical elements of an operational program are, and identification of the key innovations needed in the Landsat program over the next 5-10 years.

Future Missions Working Group Report

- WG met via telecon 4 times in April and May. Outcomes include:
  - Letter to Interior Secretary Ken Salazar
  - Initial inventory of major Landsat applications
  - Identification of key data products needed from past, present, and future Landsat missions
  - Improved understanding of short- and long-term needs
  - TIRS-OCO letter to NASA

Key Points in CW Letter to Secretary Salazar

1. The DOI needs to assume leadership of the Landsat Program and request funding from Congress at the earliest opportunity to build and launch another Landsat satellite – in partnership with NASA.
2. The next Landsat satellite should be a clone of the one being currently built.
3. The DOI needs to work with Congress and OSTP to formally implement the NLIP.
4. A long-term plan for the future of the Landsat Program is needed.

Selected Landsat Mission Descriptions

- From Landsat 7 Science User's Handbook:
  - The mission of the Landsat Program is to provide **repetitive acquisition of high resolution multispectral data** of the Earth's surface on a **global basis**. Landsat represents the only source of **global, calibrated, high spatial resolution measurements** of the Earth's surface that can be **compared to previous data records**. The data from the Landsat spacecraft constitute the **longest record of the Earth's continental surfaces as seen from space**. It is a record unmatched in quality, detail, coverage, and value.

Selected Landsat Mission Descriptions

- From LDCM Level 1 Requirements Document :
  - The scientific objective of the LDCM is to provide the **baseline data required to map global land cover, land use, and change on an annual basis over multi-decadal periods of time**.
    - The LDCM mission objective is to extend the ability to detect and quantitatively characterize changes on the global land surface at a **scale where natural and man-made causes of change can be detected and differentiated**.
    - Landsat is the only U.S. or international satellite system designed and operated to repeatedly **observe the global land surface at a moderate scale**. Further, Landsat is the only national or international program committed to preserving a consistent, **long-term record of the Earth's land surface** at this scale.

NASA-USGS LDCM Major Mission Objectives:

- Collect and archive **moderate-resolution, reflective and thermal multispectral image data** affording seasonal coverage of the **global land mass** for a period of no less than five years.
- Ensure that LDCM data are **sufficiently consistent** with data from the earlier Landsat missions, in terms of acquisition geometry, calibration, coverage characteristics, spectral and spatial characteristics, output product quality, and data availability to permit **studies of land cover and land use change** over multi-decadal periods.
- Distribute standard LDCM data products to users on a nondiscriminatory basis and at no cost to the users.

USGS Landsat Program Description

- The U.S. Landsat Program provides the only **continuous** inventory of the world's land surface at a **scale where human vs. natural causes of change can be differentiated** – and change on the land surface is occurring at rates unprecedented in human history. There is no other satellite system currently in orbit, or planned, that combines the capability and commitment to **collect global land surface imagery** at the scale of Landsat. Landsat is a national resource for environmental research, land management, natural hazard analysis, and resource analysis, with applications across America in agriculture, minerals exploration, geologic mapping, forestry, and desertification, among others.

Landsat Contributions to the U.S. Global Change Research

- "…above all, it is essential to ensure the existence of a **long-term observing system** that provides a more definitive observational foundation to evaluate decadal-to century-scale **variability and change**" (National Research Council, 2001).

Landsat Contributions to the U.S. Climate Change Science Program

- Landsat data are particularly important for environmental change research because they provide a common **time series of land cover condition**, starting in 1972, for nearly the **entire Earth's terrestrial surface**.
- One of the great challenges is how to relate human incentives, behavior and action at particular localities to **land cover change** at broader (e.g., regional) geographic regions. The **fine spatial resolution** of Landsat images along with its **global geographic extent** provides the necessary data for making this linkage.

Recurring Themes

- Map and monitor global land cover and land cover change over time
- Long-term record of Earth's conditions (continuity of measurement)
- Scale of measurement permits detection of man-made and natural land change
- Global in extent
- Repetitive in coverage over time
- Multi-spectral data

LST Input on Overall Mission Drivers

- Understanding the rates, extent, and consequences of land use and land cover change
- Monitor the state and dynamics of the Earth's terrestrial vegetation system
- Meet resource management needs (adaptive management, ecosystem management requirements for ongoing monitoring and assessments of effectiveness of management practices and resource conditions)
- Provision of long-term climate data records or essential climate variables to meet international science and treaty requirements

LST Input on Applications

- Global agricultural monitoring
- Global forest land use monitoring for carbon assessments, REDD and biodiversity treaties
- National land cover mapping and monitoring
- Resource management
  - Wildfire management
  - Ecosystem condition and trends
- Emergency response and disaster assessment
  - Fires and floods
  - Severe storms
- Food security

LST Input on Product Requirements

- Orthorectified data (L1T)
- Surface reflectance
- Cloud free merged observations at weekly, monthly, and seasonal time steps
- Tiled or seamless datasets rather than WRS2 scenes
- Global vegetation disturbances
- Statistically rigorous validation of product accuracy
- Essential Climate Variables (ECV's)
  - Variables that are currently feasible for global implementation for the global climate observing system, and have high impact on the UNFCCC and IPCC requirements.

ECV's and Candidate Satellite Inputs

- Landsat-class:
  - Land cover (including vegetation type)
  - Glaciers and ice caps
  - Lakes maps, lake surface temperature
- Landsat- or MODIS-class:
  - Leaf area index (LAI)
  - Albedo
  - Fraction of absorbed photosynthetically active radiation (fAPAR)
- MODIS or similar instruments:
  - Biomass
  - Fire disturbance
  - Soil moisture (RADAR, Laser altimeter)

Landsat Requirements

- Short-term priority is ensuring mission continuity – with no gaps in coverage
  - This means that Landsat 9 development is urgent
  - For sake of the shortest possible development time, Landsat 9 specifications should match Landsat 8 - including thermal imaging capabilities
- Longer term priorities (Landsat 10 and beyond) include:
  - Increasing frequency of temporal coverage
  - Expand acquisitions capabilities to coverage greater percent of land surface per orbit
  - Investigate, test, and implement advanced systems and technologies that improve image quality and consistency
  - Incrementally improve spectral coverage

Observation Requirements Needed to Meet Key Applications

- Ensure continuity of measurements
- Increase temporal frequency of coverage to <8 days
- Adjust spatial dimensions – for example, 15m red and NIR, 30m TIR
- Expanded global acquisition/coverage capabilities
- Improved instrument performance (radiometric resolution, S/N, etc.)
- Incremental spectral additions – for example, improve consistency with Sentinel 2

Ground System and Product Improvements

- Improved query and ordering capabilities
- Improved capabilities for bulk data access
- Make Level 0 data available to anyone
- Improved product specifications – such as top of atmosphere reflectance
- Process all images regardless of cloud cover
- Increase on-line storage
- Expand the contents of the US Landsat archive through global archive consolidation
- Generate operational monitoring products

Discussion

- Has the Landsat mission changed or is it fundamentally the same?
- Are the current specifications meeting today’s needs or should they change?
- Are the priorities identified for future enhancements to Landsat capabilities appropriate?
- What does operational mean?

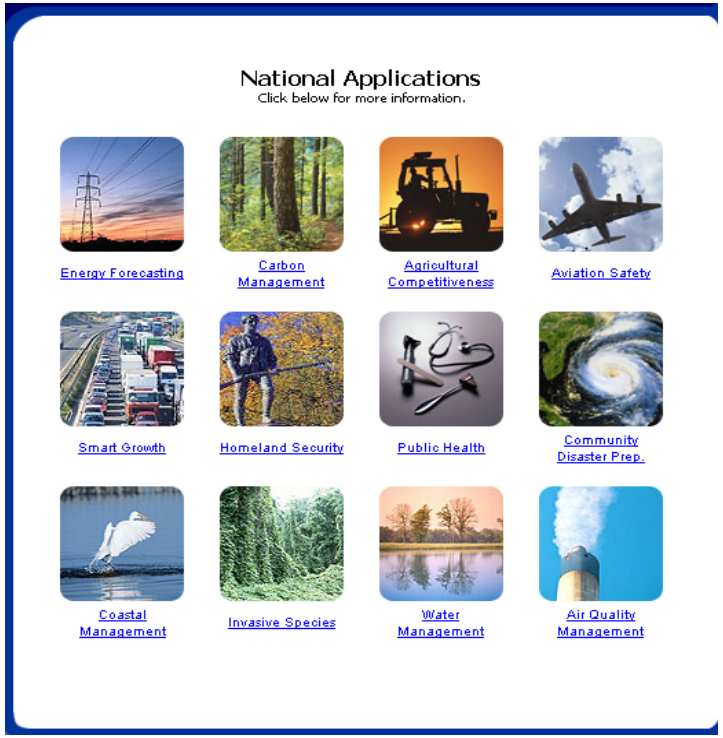
Extras – From Darrel Williams

Role of Landsat in the 12 National Applications

The 15 / 30 m "spatial context" provided by Landsat data make it a valuable component of practically any basic data set being pulled together in support of the --

12 National Applications

- Energy forecasting
- Carbon management
- Agricultural competitiveness
- Aviation safety ("digital airspace")
- "Smart growth" for infrastructure
- Early warning for homeland security
- Early warning for public health
- Air quality management
- Water management and conservation
- Biological invasive species management
- Community preparedness for disaster management



Did You Know? The National Geospatial-Intelligence Agency (NGA) routinely develops Landsat mosaic base maps for regions of "strategic interest" such as Afghanistan, Somalia, Bosnia, Iraq, etc.

Every one of the above applications benefit from having access to up-to-date base maps derived from current Landsat data.

Some Examples of Landsat Use in Support of 12 National Applications

- **Energy forecasting** - Landsat imagery heavily used, both past and present, for mineral exploration; assessment of surface mining; monitoring of urban spread/population growth; assessment of deforestation
- **Carbon management -** e.g., Australia uses Landsat for assessing above ground carbon stocks for Kyoto compliance
- **Agricultural competitiveness** - USDA is the biggest user of Landsat's global coverage
- **Aviation safety** - Landsat imagery is heavily used to create realistic flight simulations, especially when combined with digital terrain data
- **"Smart growth" for infrastructure** - Landsat's 30^{+} year coverage is ideal for monitoring this; provides up-to-date spatial context base map
- **Early warning for homeland security** - Landsat provides up-to-date spatial context base map
- **Early warning for public health** - Landsat provides up-to-date spatial context base map
- **Air quality management** - Landsat provides up-to-date spatial context base map
- **Water management and conservation** - Landsat's repetitive coverage can be used to monitor seasonal fluctuations in reservoir levels, snow pack, and crop stress; irrigation use / mis-use; water quality / turbidity; run-off and discharge.
- **Biological invasive species management** - Landsat provides up-to-date base maps; plant communities may be directly mapped using Landsat's multispectral, seasonal capabilities
- **Community preparedness for disaster management** - Landsat provides up-to-date map
- **Environmental indicators for coastal management** - Landsat provides up-to-date base map of shoreline and changes in shoreline; some shoreline plant communities can be monitored; assessment of water turbidity, effluent and thermal discharge; oil slicks easily detected

Summary: Importance of Landsat Continuity to Science

- **Global land cover / land use changes are occurring at rates unprecedented in human history**
  - **Deforestation, urbanization, glacial and ice shelf retreat, species invasion, coral reef destruction, and many other forms of land cover change, disturbance, and recovery are rapidly altering the appearance, productivity, and function of the global land surface**
- **The Landsat program provides the only inventory of the global land surface over time at a scale where human vs. natural causes of change can be differentiated**
  - **Only Landsat data are acquired to provide global land coverage on a seasonal basis**
    - **No other satellite system is capable or committed to even annual global coverage at the Landsat scale**
  - **The USGS National Satellite Land Remote Sensing Data Archive (NSLRSDA) preserves a 32^{+}-yr archive of Landsat data**
    - **No other nation is committed to acquiring, maintaining, preserving, and extending a global archive of land observations**
- **The value of the Landsat program is not only due to the satellite and sensor technology but also resides in the long-term calibrated data archive, global data acquisition strategy, open data policy, and commitment to data continuity.**