National Geospatial Advisory Committee – Landsat Advisory Group
The Value Proposition for Ten Landsat Applications[1]

Landsat imagery provides the United States and the world with continuous, consistent monitoring of critically important global resources. Supplying an unprecedented record of global land cover status and change for the last 40 years, Landsat imagery is an essential "national asset" which has made and continues to make critical "contributions to U.S economic, environmental, and national security interests."[2] However, because Landsat imagery is primarily utilized by non-commercial entities – thereby not passing through a market where its value is set by market forces – estimating the economic value of Landsat data is an ongoing challenge. Accordingly, the Department of Interior recently requested that the Landsat Advisory Group of the National Geospatial Advisory Committee provide advice to the Department "concerning the economic benefits of Landsat data."[3] There are thousands of users and hundreds of applications using Landsat in the United States, with strong use internationally as well. This white paper provides estimates of the economic value of ten (10) uses of Landsat data and summarizes recent estimates of the economic value of Landsat data from two large-scale surveys. Both approaches clearly show that the annual economic value of Landsat data far exceeds the cost of building, launching, and managing Landsat satellites and sensors.

1. Productivity Savings from Ten Uses of Landsat

The reason people use Landsat is because it is more efficient than any other technology to accomplish the same decision support requirements. After nearly 40 years of operation almost all of the "kick the tire" uses have either proven successful or been discontinued because of higher costs than alternatives. The purpose of this document is to outline ten (10) decision processes that would be significantly more expensive without an operational Landsat-like program. Many of these processes are associated with the U.S. government and save significant amounts of money compared to other methods of accomplishing the same objective. They also include non-governmental science applications where scarce research dollars cannot be wasted on inefficient technologies. The estimates of annual efficiency savings are conservative and can be substantiated upon request. These ten Landsat applications alone produce savings of $178 million to over $235 million per year for the Federal and State governments.

Summary Table: Estimated Productivity Savings from Ten Uses of Landsat*

Landsat Application	Estimated Annual Efficiency Savings
1. Monitoring Consumptive Outdoor Water Usage	$20 - $73 million
2. U.S. Government Mapping	over $100 million
3. Forest Health Monitoring	$12 million
4. National Agricultural Commodities Mapping	over $4 million
5. Flood Mitigation Mapping	over $4.5 million
6. Forest Fragmentation Detection	over $5 million
7. Forest Change Detection	over $5 million
8. World Agriculture Supply and Demand Estimates	over $3 - $5 million
9. Landsat Support for Fire Management	$28 - $30 million
10. Coastal Change Analysis Program	$1.5 million

** This table shows the estimated annual efficiency savings of ten selected Landsat applications. The total annual economic value of Landsat data has recently been estimated at over $1.7 billion (see Section 2, "Recent Studies on the Economic Value of Landsat Data," Page 6).*

1. Monitoring Consumptive Outdoor Water Usage

   Western state water managers and others are increasingly turning to Landsat's thermal infrared sensor (TIRS) imagery to measure and monitor consumptive outdoor water uses. This data is used in hydrologic modeling, water planning, comparing water use when cropland is converted to urban uses, measuring agricultural water use, monitoring aquifer depletion, administering water rights (legal findings of fact, ensuring compliance with administrative orders, court decrees, and interstate compacts, as well as water right buy-back programs), endangered species, and Indian water rights settlements. The Idaho Department of Water Resources (IDWR) and the University of Idaho have partnered to pioneer these uses of TIRS data, which have been recognized with an award from the Harvard Kennedy School of Government. One of those uses is adjudicating, measuring and monitoring consumptive irrigation use by wells on the Snake River Plain Aquifer. IDWR used a power consumption coefficient method to estimate extraction and water use at an annual cost of about $500,000/5,000 wells or $100/well – before beginning to use Landsat TIR data through a process called METRIC (Mapping EvapoTranspiration with high Resolution and Internalized Calibration) to measure actual crop evapotranspiration on a field-by-field base. IDWR annual costs dropped to approximately $53,500/year for the same 5,000 wells or less than $11/well. These two options have also been compared with requiring installation of flow meters on each and every well at a capital cost of thousands of dollars per well. Given IDWR's cost experience and extrapolating the cost of using the Power Consumption Coefficient (PPC) measurement method or installing flow meters on unmetered irrigation wells in the 17 western waters, the potential annual cost savings range from nearly $20 million to over $73 million annually for measuring groundwater extraction alone (These figures represent a conservative estimate using unpublished IDWR cost figures and West-wide unmetered irrigation well numbers from USDA's 2002 Census of Agriculture). See also: http://www.agcensus.usda.gov/Publications/2002/FRIS/tables/fris03_14.pdf

   Result: Annual efficiency saving with Landsat: $20 - $73 million

2. U.S. Government Mapping

   U.S. Government defense mapping agencies are estimated to spend over $300 million annually to create digital maps of roads, buildings, airports, foreign military sites and other defense-related mapping applications. Until recently, the method of updating these maps was to simply redo them or to manually scan high resolution images for new features. Because of the very large areas (global) and associated high costs involved, it is conservatively estimated less than 5% of these maps were updated annually meaning most were more than 20 years old (average of 10 years). This situation created a significant problem in supporting overseas military activities with maps of this age. Consequently only the most urgent areas were updated. Recently a new technology called Correlated Land Change (CLC) has been developed by a US company which locates these new features at a few pennies per sq. km. The primary input to CLC is new and archive Landsat images. With CLC, the analyst is targeted only to areas of recent change, where high resolution imagery is then used to identify and extract new features. Using this process, it is conservatively estimated that analysts can update 10 (ten) times the area in the same labor time, a 1,000% efficiency improvement. Agencies are adapting their map updating approach to take advantage of this process. Over 100,000 Landsat scenes going back 14 years and covering 2/3rd of the Earth's land area will be processed this year. Annual consumption of Landsat will be 20,000 scenes per year. It is expected that over time the average age of DoD/IC digital maps will decrease from over 10 years to just 1 year. To accomplish the same feat without Landsat would cost over $1 billion annually; a fiscal improbability in the current economic climate. More likely the average age would stay or increase beyond 10 years. See also: http://issuu.com/kmi_media_group/docs/gif_10-4_final?mode=window&pageNumber=24

   Result: Annual efficiency saving with Landsat: over $100 million

3. Forest Health Monitoring
   The US Forest Service (USFS) of the US Department of Agriculture (USDA) uses an average of over 500 Landsat scenes per year to evaluate potential risk due to insects and diseases on forest lands in the U.S. Based upon this risk assessment, the USFS can allocate resources to mitigate the overall effect of the insect and disease losses. An alternative to Landsat would be a more expensive high resolution imagery costing at least $300,000 or more per Landsat equivalent area. The additional analysis cost of higher resolution images would add over $5,000 per Landsat equivalent area. With an average of over 500 Landsat scenes analyzed per year the increased cost to the US Government without Landsat source data would be conservatively estimated at $12,500,000 annually. See also: http://www.fs.fed.us/rm/analytics/about/history/remotesensingafim.pdf

   Result: Annual efficiency saving with Landsat: $12 million

4. National Agricultural Commodities Mapping
   The USDA National Agricultural Statistics Service (NASS) creates a Cropland Data Layer (CDL) for the Contiguous U.S. (CONUS) identifying crop type by farm field. "The purpose of the CDL is to (1) provide acreage estimates to the Agricultural Statistics Board for the state's major commodities and (2) produce digital, crop-specific, categorized geo-referenced output products." Major commodity acreage is used by farmers and manufacturers to better estimate crop yields to help in planting and selling decisions. Landsat is used because of its ability to identify crop type with sufficient accuracy at low-cost. With the demise of Landsat 5, the USDA must acquire supplemental imagery from foreign sources costing an additional $1.2 million in FY12. Should the foreign sources fail, the accuracy of the CDL will plummet with consequences that are difficult to measure. Efficiency savings from Landsat are estimated at $4 million per year. See also: http://calval.cr.usgs.gov/JACIE_files/JACIE11/Presentations/TueAM/1135_Reynolds_JACIE2011.pdf

   Result: Annual efficiency saving with Landsat: over $4 million

5. Flood Mitigation Mapping
   FEMA spends over $200,000,000 annually to update flood maps to mitigate losses from future flood events. Less than 3% of these maps are updated per year. While flood plain contours don't often change, the impervious surface adjacent to flood plains regularly increases due to new home and business construction. Increased impervious surface increases runoff into the flood plain and will increase the size of the flood zone near these new developments, and possibly put new homes at risk. Having an accurate, consistent, and cost-effective method to assess impervious surface change going back decades will help DHS/FEMA to target areas of highest potential flood zone change. FEMA has begun using a recently developed process called Correlated Land Change (CLC) to consistently map the lower 48 States for new construction going back over 25 years. FEMA calls the dataset the National Urban Change Indicator (NUCI). NUCI is completely compiled with over 12,000 Landsat images and will consume 1,500 Landsat images each year going into the future. The alternative to NUCI is a much more costly and time-consuming manual interpretation of historical aerial images. It is estimated that manual interpretation would cost in excess of $5,000,000 per year. Not doing the prioritization based upon consistent empirical data could mean lower flood insurance premiums in potentially new flood zone extent. The cost to create NUCI for ½ CONUS is $550,000 annually. See also: http://www.fgdc.gov/participation/coordination-group/meeting-minutes/2011/july/excom-liaison-report-dan-cotter.pdf

   Result: Annual efficiency saving with Landsat: over $4.5 million

6. Forest Fragmentation Detection
   The University of Maryland is tracking forest fragmentation through time for biodiversity applications. Loss of forest has the effect of isolating some species from natural habitats leading to significant biodiversity issues. For this effort, global forests are being mapped at 5 year intervals involving a total of over 50,000 Landsat scenes. Lower resolution satellite imagery is too inaccurate. Higher resolution satellite imagery is orders of magnitude more expensive to acquire and process. Landsat provides the most efficient data for mapping global deforestation. See also: http://glcf.umiacs.umd.edu/library/pdf/rse78_p118.pdf

   Result: Annual efficiency saving with Landsat: over $5 million

7. Forest Change Detection
   The University of Maryland is developing an annual data set for the US to track forest disturbance (fire, insect, harvest, etc.) through the lower-48 for each of the last 26 years in an effort called North American Forest Dynamics (NAFD). This effort will ultimately require 25,000+ Landsat scenes. NAFD supports the North American Carbon Program and is funded through NASA Terrestrial Ecology. Landsat is the most cost efficient means to quantify forest changes covering the entire USA. See also: http://www.geog.umd.edu/projectprofile/US%20forest%20disturbance%20history%20from%20Landsat%3A%20North%20American%20Forest%20Dynamics%20(NAFD)%20-%20Phase%20III

   Result: Annual efficiency saving with Landsat: over $5 million

8. World Agriculture Supply and Demand Estimates
   The USDA Foreign Agriculture Service (FAS) Production Estimates and Crop Assessment Division (PECAD) has used satellite imagery to assess agriculture in foreign countries since 1975 to support the USDA World Agriculture Supply and Demand Estimates (WASDE). The numbers produced by WASDE are critical to decision making by the USDA and US farmers/growers on when and at what price to sell crops for export. With the recent failure of Landsat 5, the effective ground observation increases from 40 to 60 days, an unacceptable level. USDA has estimated it will take $1.5 to $2.5 million to purchase foreign data to replace Landsat 5. If Landsat 7 fails, it would take $3 to $5 million per year to purchase replacement satellite imagery. See also: http://www.usda.gov/oce/commodity/wasde/

   Result: Annual efficiency saving with Landsat: over $3-$5 million

9. Landsat Support for Fire Management
   Landsat images are used for developing vegetation and wildland fuel data used in wildland fire management decision support systems. Currently 15 Western States are using a Landsat derived product called LANDFIRE to develop a wildfire risk assessment and planning system. Nine southern states already have a similar system in place fed by LANDFIRE data. Landsat is also commonly used in post-fire burn severity mapping.

   Landsat data are also used to perform immediate post fire assessments of soil burn severity and vegetation mortality, usually by Burned Area Emergency Response (BAER) teams. The restoration work performed by BAER teams mitigates effects on hillslope stability, water quality and supply, and the spread of invasive species, as well as other ecosystem services, such as habitat for fish and wildlife. BAER teams use Landsat data as a geospatial foundation for plans that address emergency stabilization where post-wildfire effects pose immediate and significant threats to human life and property. This information helps define the short-term and possibly longer-term management needs of burned areas, such as erosion control, re-vegetation or seeding, and pasture deferment.

Both current and archived Landsat data are used to develop wildland fire atlases across the United States by evaluating differences in pre-fire and post-fire Landsat imagery. A national database of Landsat derived fire information is maintained by the Monitoring Trends in Burn Severity (MTBS) project, a joint DOI and U.S. Forest Service activity. The MTBS database allows a national level evaluation of vegetation management practices used to mitigate hazardous fuels. These evaluations occur in two primary ways. First, wildland fires in treated areas are expected to have relatively lower burn severities. This can be determined for specific fires, over time, from MTBS data. Secondly, the effective duration for a hazardous fuel treatment can be determined by monitoring vegetation vigor indexes as surrogates to fuel condition (biomass accumulation and growth) and comparing this with untreated areas or areas with alternative treatment approaches. The Landsat archive is the only comprehensive and consistent data stream that provides this monitoring potential for the United States.

Landsat imagery is the foundation for the vegetation and fuels information in the LANDFIRE database. LANDFIRE data products are a foundational element used in the Federal Government's Wildland Fire Decision Support System (WFDSS). WFDSS is used to model fire behavior and is used to make tactical decisions during specific wildland fire incidents. LANDFIRE is also critical for the Interagency Fuels Treatment Decision Support System, a web-based software and data integration framework that organizes previously existing and newly developed fire and fuels software applications to make fuels treatment planning and analysis more efficient and effective. See also: http://www.landfire.gov/version_comparison.php

Result: Annual efficiency saving with Landsat: $28-$30 million

10. Coastal Change Analysis Program

The National Oceanic and Atmospheric Administration (NOAA) monitors land cover and land cover changes in the coastal regions of the United States, as part of its Coastal Change Analysis Program (C-CAP). This data is provided to coastal managers in order to better understand the effects of past management decisions, document recent trends, and provide a better baseline of current conditions to which they can consider impacts of future planning decisions. This change analysis is often also used as a screening-level tool to provide other, more detailed mapping initiatives and information on where changes to their own products may have occurred and are likely to be in need of updating. C-CAP products are updated every five years.

Landsat is used because of its systematic collection of larger footprint imagery, the larger number of spectral bands it provides, and the historic archive of complimentary data available. This provides NOAA with a consistent, reliable source of image data that can be processed and classified in a consistent, repeatable, cost-effective way. This cannot be said of more commercial sensors that are tasked to acquire some areas and not others. Not only does this reduce the cost in creating C-CAP land cover, it improves the accuracy in several of the classes mapped, such as the improved discrimination of wetland features seen due to the infrared bands Landsat supplies (and that are not available elsewhere).

The 30 meter resolution of this imagery is about the coarsest that mangers tasked with tracking changes in these coastal environments can utilize. NOAA spent $3,200,000 on the original baseline mapping and currently spends ~$1,300,000 on each update cycle. Production of an equivalent C-CAP product using a smaller footprint sensor with fewer spectral bands are estimated to more than double these existing costs ($4,000,000 over the same 5 year period) or would require that NOAA would decrease the specifications associated with these maps (i.e. coarser resolution, fewer categories, less

accuracy), which would potentially impact their availability and/or usefulness. See also: http://www.cop.noaa.gov/stressors/resourcelanduse/past/lu-ccap.aspx

Result: Annual efficiency saving with Landsat: $1.5 million

2. Recent Studies on the Economic Value of Landsat Data

Two recent studies have estimated the economic value of Landsat data:

- In 2007, the American Society of Photogrammetry and Remote Sensing (www.asprs.org) estimated the economic value of Landsat data in support of the Office of Science and Technology Policy's (OSTP) *"A Plan for a U.S. National Lands Imaging Program."*[4] A summary of the ASPRS study[5] was published in *Photogrammetric Engineering and Remote Sensing* (PERS) and is included as an Exhibit in the OSTP Plan. The APSRS report is based on a web survey of 1,295 Landsat data users. Key findings of the report are:
  - 72% of the respondents stated that Landsat data is a *primary*, *critical data set* for their applications.
  - 82% of Landsat data users work for government, academic, or not for profit organizations, with 50% of the work performed *directly for the government sector*.
  - Respondents estimated the economic value of Landsat data to be worth *over $935 million/year*.
- In April of 2012, the consulting firm Booz, Allen, Hamilton reported on their study for USGS on the economic value of Landsat data.[6] The study monetizes the value of Landsat data. Key findings of the report are:
  - Loss of Landsat data would lead to *devastating impacts worldwide in our ability to assess critical infrastructure vulnerability, illegal resource extraction, climate change impacts, and land use change*.
  - The economic value of Landsat data for monitoring land use change, wildfire analysis and management, emergency/disaster management, monitoring coastal wetlands, climate change adaptation, and agricultural forecasting and management *is estimated at $1.7 billion/year*.

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[1] This paper was approved by the NGAC Landsat Advisory Group on June 22, 2012 and adopted by the NGAC as a whole on September 18, 2012. The members of the Landsat Advisory Group are: Kass Green (Chair) Kass Green & Associates; John Copple, Sanborn Map Co.; David Cowen (NGAC Chair), Univ. of South Carolina; Joanne Irene Gabrynowicz, Univ. of Mississippi; Rick Landenberger, Americaview; Roger Mitchell, MDA Information Systems, Inc.; Tony Spicci, State of Missouri; Cory Springer, Ball Aerospace & Technologies Corp.; Darrel Williams, Global Science & Technology, Inc.; Tony Willardson, Western States Water Council.

[2] Marburger, J. 2005. Landsat Data Continuity Strategy Adjustment. Executive Office of the President. Office of Science and Technology Policy. December 23, 2005.

[3] NGAC Landsat Advisory Group Update. April, 2012. http://www.fgdc.gov/ngac/meetings/april-2012/landsat-subcommittee-report-green-ngac-apr-2012.pdf

[4] OSTP – Future of Land Imaging Interagency Working Group. 2007. A Plan for a U.S. National Land Imaging Program.

[5] Green, K., J. Plasker, G. Nelson, and D. Lauer. 2007. Report to the White House Office of Science and Technology Policy - Future of Land Imaging Working Group on the American Society for Photogrammetry and Remote Sensing Survey on the Future of Land Imaging. Published in *PERS* vol. 73(1) and as Exhibit 9 of the OSTP 2007 Plan for a U.S. National Land Imaging Program.

[6] V. Adams and E. Pindilli. 2012. Improving the Way Government Does Business. The Value of Landsat Moderate Resolution Imagery in Improving Decision-Making. http://calval.cr.usgs.gov/wordpress/wp-content/uploads/Pindilli_JACIE_Presentation_final.pdf