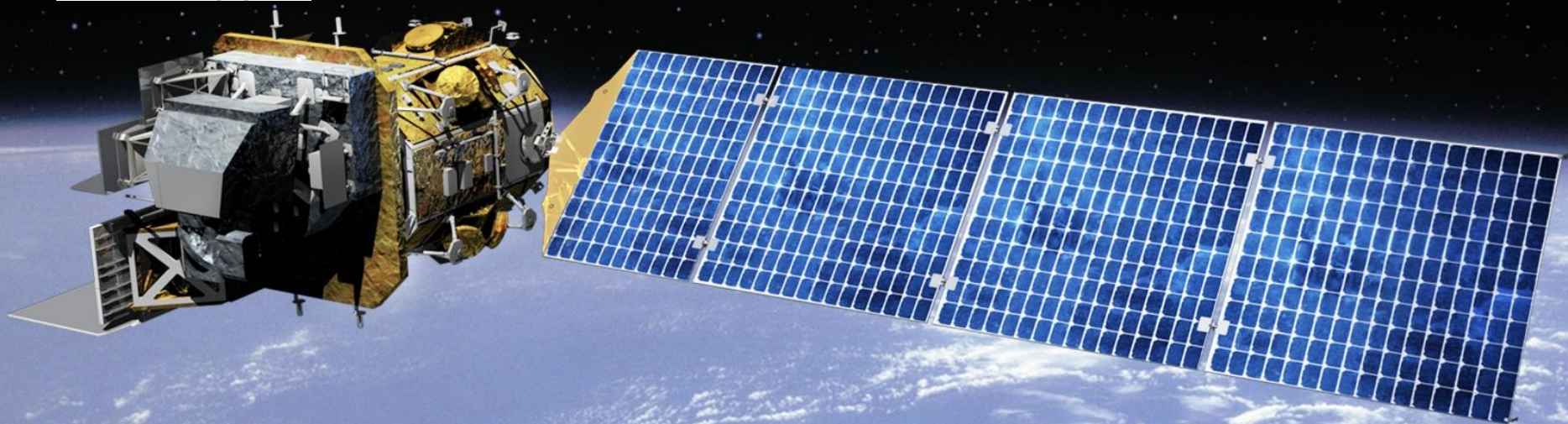




USGS Update

Briefing to the Committee on Earth Science and Applications from Space
Spring 2019 Meeting: March 26, 2019

Tim Newman

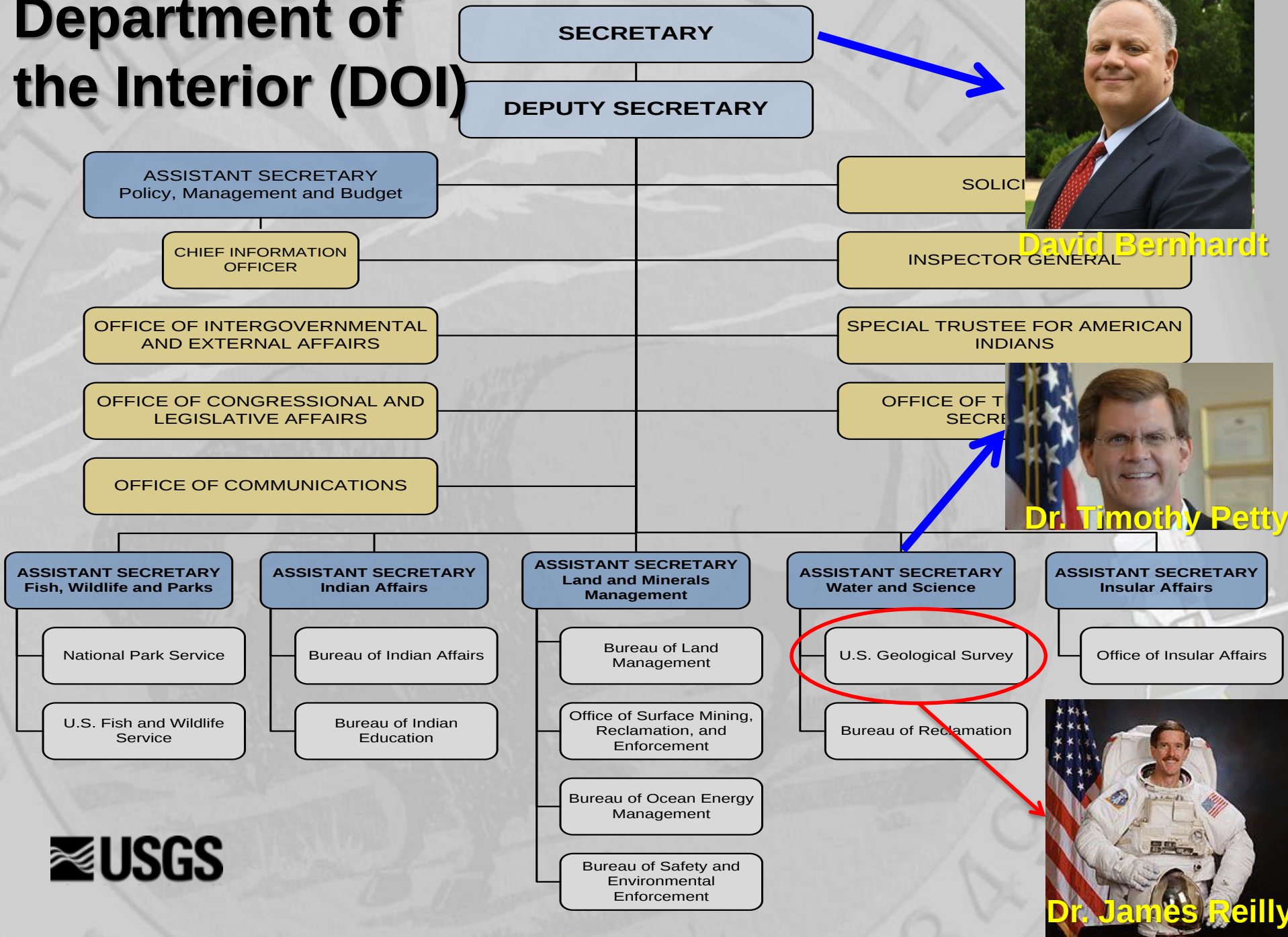
*USGS National Land Imaging
Program Coordinator*

26 March 2019

Pete Doucette

*USGS National Land Imaging
Associate Program Coordinator*

Department of the Interior (DOI)



United States Geological Survey

Mission: Provide reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.



Ecosystems



Energy and Mineral Resources and Environmental Health



Natural Hazards



Water Resources



Land Resources



Core Science Systems

USGS:

- ≈8500 employees
- 65 science centers
- 400 field offices
- 1000s of streamgauge and seismic monitoring stations
- ≈ 50 PB EROS Data Archive
- 2 orbiting Landsat satellites



National Land Imaging (NLI) Program

Roles and Responsibilities

- As defined by Public Law and National Space Policy, to carry out the Public Interest of the United States:
 - To **operate and maintain a National Land Imaging Archive** to house a Basic Data Set of global data – for historical, scientific, and technical purposes – to include data obtained from U.S. civil, commercial and foreign satellite systems;
 - To **operate and maintain the Landsat flight and ground systems**
 - To **collect, process, archive and distribute Landsat data** as Public Domain holdings of the United States;
 - To **determine U.S. civil operational requirements** for global land surface data and to conduct a national program of civil-operational land imaging;
 - In coordination with the Secretary of Defense, the Secretary of Homeland Security, and the Director of National Intelligence, to **provide remote sensing information acquired from national security space systems** to other civil government agencies;
 - To preclude duplication of acquisition processes and capabilities; and
 - To **develop civil applications and information tools** using known standards and protocols and make them available to the general public.

USGS NLI Program Components

- ≈\$99M annual budget
- ≈145 Gov't employees
- ≈300 Contractors
- HQ + 6 science centers
- ≈ 50 PB EROS Archive
- 2 orbiting Landsat satellites

Satellite Operations

Develop and operate systems to acquire, produce, preserve, and deliver products and services to meet civil Earth observation research and operational requirements

- Collect, archive, process & disseminate Landsat & Landsat-like data (Landsat 1-8, S-2)
- Operate the Landsat 7 and 8 satellites, calibrate and validate the incoming data
- Develop the Landsat 9 ground system in concert with NASA for 2020 launch
- Collect, maintain and analyze user requirements; inform 2019 Landsat 10 decision

Science, Research & Investigations

Conduct science, research and technology investigations to improve upon and develop new products and services

- Applied science & applications, including drought monitoring, global cropland estimates
- Remote sensing research and development, including unmanned aircraft systems

Manage National Civil Applications activities

- Provide National Security Space system geospatial data supporting USGS applications
- Facilitate Federal civil agency use of these systems via Civil Applications Committee



Fundamental goal: Ensure public availability of a primary data record about the current state and historical condition of the Earth's land surface

2019 Enacted Budget

Total USGS FY19 Budget: \$1.161 Billion

National Land Imaging (NLI): \$98,894,000

- Satellite Operations: \$84,337,000
 - Includes final \$5.8M step-up in Landsat 9 ground system development profile
- Science, Research & Investigations: \$14,557,000
 - Funds the National Civil Applications Center
 - Funds the Remote Sensing Grant

2020 President's Budget

Total USGS Budget: ~~\$1.161B (FY19)~~ \$983M (FY20)

**National Land Imaging (NLI): ~~\$98,894,000 (FY19)~~
\$88,955,000 (FY20)**

- **Satellite Operations: ~~\$84,337,000 (FY19)~~ \$73,432,000 (FY20)**
 - Fully funds Landsat 9 ground system development
 - Reduces \$11M from non-Landsat 9 satellite operations functions
- **Science, Research & Investigations: ~~\$14,557,000~~ \$15,364,000**
 - Adds \$8M in transfer of Land Change Science projects to NLI
 - Fully funds National Civil Applications Center
 - Reduces \$7M in science research and product development
 - Eliminates the Remote Sensing Grant

What is Landsat?

Our longest-lived series of land imaging satellites, providing a 46+ year archive of natural and human-induced changes to the global landscape, informing land and natural resource management decisions, and helping us understand Earth system change



Multi-spectral coverage in VNIR-SWIR-TIR

-> to map surface composition and temperature

15 / 30 / 100 meter spatial resolution

-> to resolve human-scale land dynamics

16-day revisit frequency (8-days w/ two operational satellites)

-> global, seasonal coverage

Broad area collection => 12,000+ square miles per image

-> 1200 images/day = 15 million square miles/day

Highly-calibrated “science quality” data

-> to resolve long-term trends & retrieve biophysical variables

Free and Open Data policy since 2008

-> 20 million products distributed by USGS last year

Common Uses of Landsat data by Federal Agencies, States, and the private sector:

- | | | |
|------------------------------|----------------------------|---------------------------|
| ● Agriculture and Forestry | ● Water Resources Planning | ● Famine Early Warning |
| ● Regional Land Use Planning | ● Global Change Science | ● Carbon Assessment |
| ● Mapping | ● Flood Management | ● Drought Monitoring |
| ● Fire/Disaster Management | ● National Security | ● Transportation Planning |
| ● Land Use/Land Cover | ● Ecosystem Monitoring | ● Calibration/Validation |

Landsat Users and Applications

Landsat is the most widely used land remote sensing data source within Federal civil agencies

Users:

- **Federal Agencies (USDA, EPA, DOI, NASA, DOD, NOAA)**
- State Agencies (Planning, Natural Resources, Transportation)
- University Researchers
- International Organizations (UNEP, WCRP, FAO, EC JRC, CSIRO, GA, DLR)
- Non Governmental Organizations (TNC, WRI, WWF, Resources for the Future)
- **Commercial (Exxon-Mobil, MapBox, Descartes Labs, ESRI, Gallo, Harris Corp, ITT, MDA Federal)**
- Foreign space agencies and U.S. and foreign commercial operators
- **Cloud Service Providers** (Amazon Web Services, Google)
- General Public

Major Operational Programs Using Landsat:

- USDA National Agricultural Statistics Service Crop Type Mapping
- USDA Foreign Agricultural Service Commodity Forecasting
- USDA Risk Management Agency (Crop Insurance)
- USGS/EPA National Land Cover Dataset (NLCD)
- DOI/USDA LANDFIRE Program
- Western States Consumptive Water Use
- NOAA Coastal Change Analysis Program
- Global Forest Watch Forest Change Products

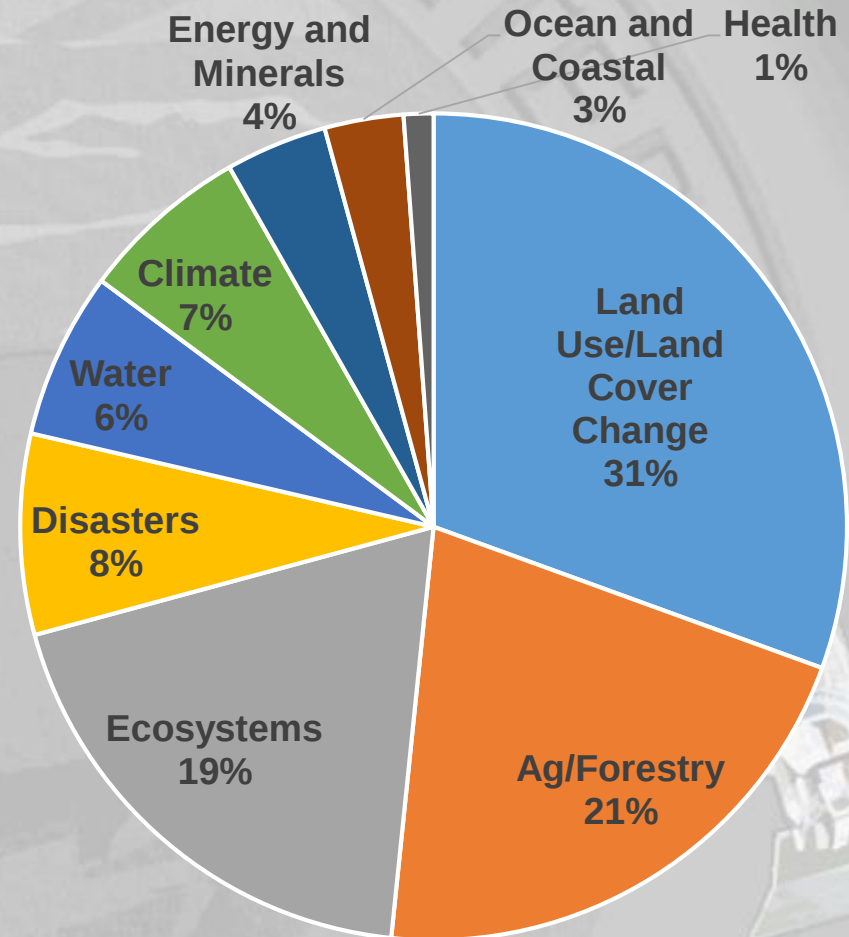
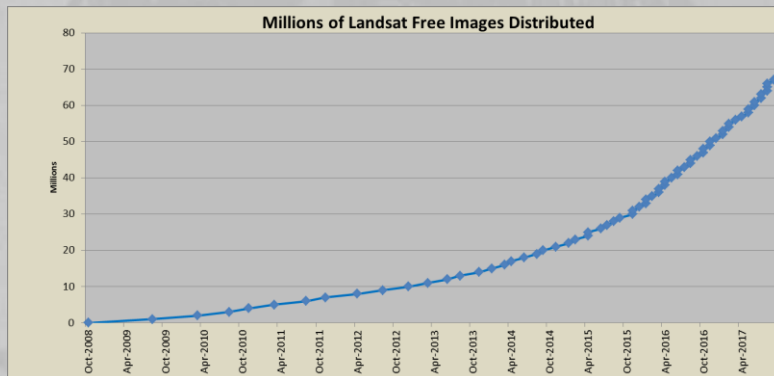


Applications:

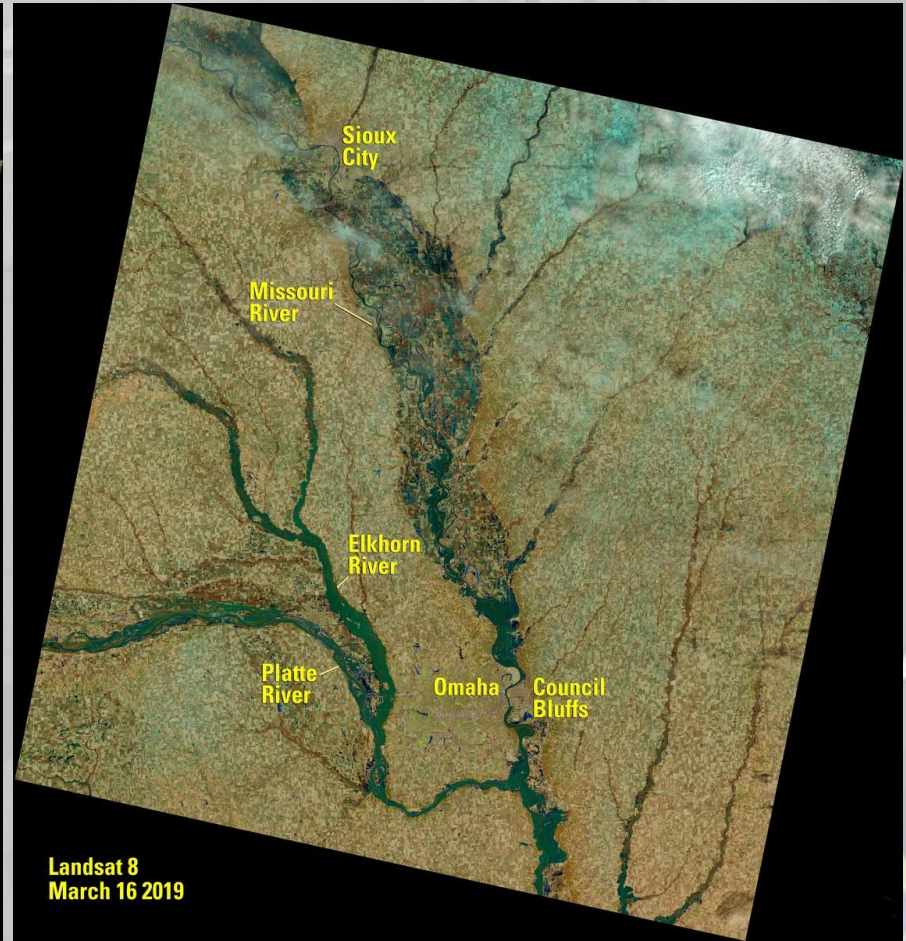
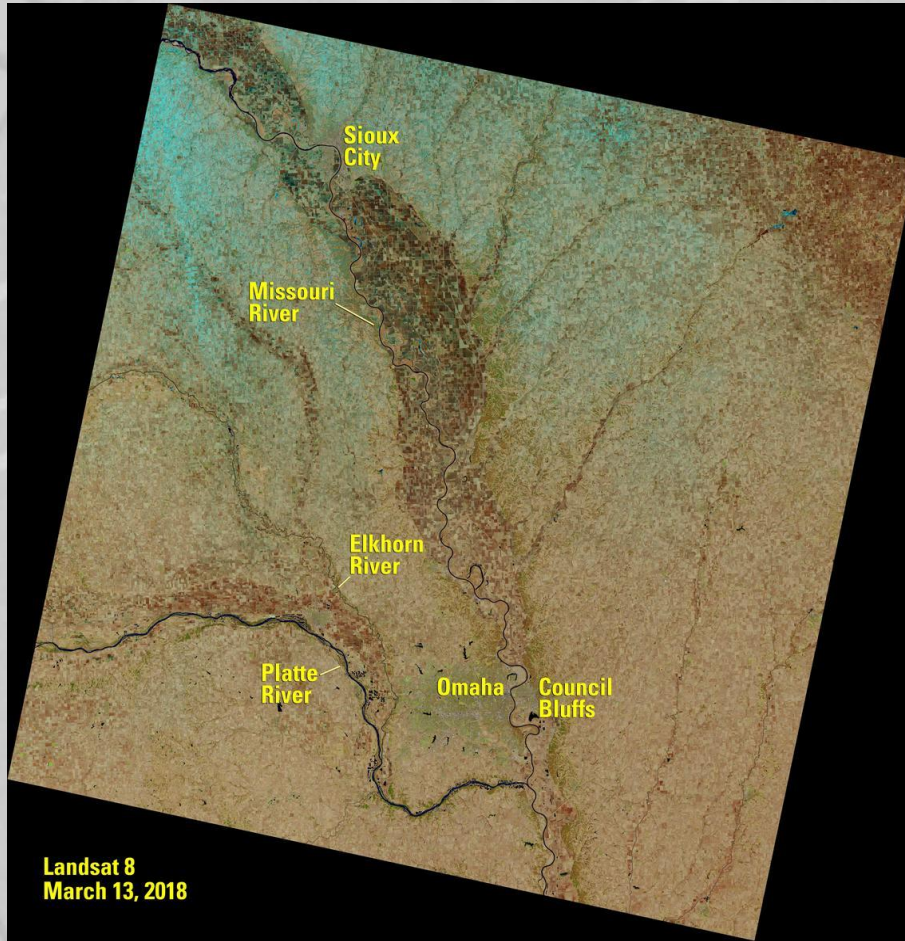
- Land use, land cover change
- Agriculture monitoring, forecasting, litigation
- Water resource management, availability, quality, usage
- Forest health, forest productivity, wildfire mapping, severity and remediation
- Crop type mapping, yield estimation, efficacy of nutrients and pesticides
- Vegetation dynamics, ecosystem services, rangeland condition
- Land resource management
- Energy exploration and production
- Geologic mapping and mineral resource assessment
- Hazards monitoring and mitigation
- Emergency response, disaster assessment, risk mitigation
- **Reference for instrument calibration**
- **Base data layer for more advanced products**
- Natural resource inventorying and monitoring
- Recreational planning & site suitability analysis
- Urban planning and development

Who Are the Landsat Data Users?

- Landsat is the most widely used, and widely cited, land remote sensing data set in the world
- Used by scientific researchers, private industry, and Federal/State/Local land managers.

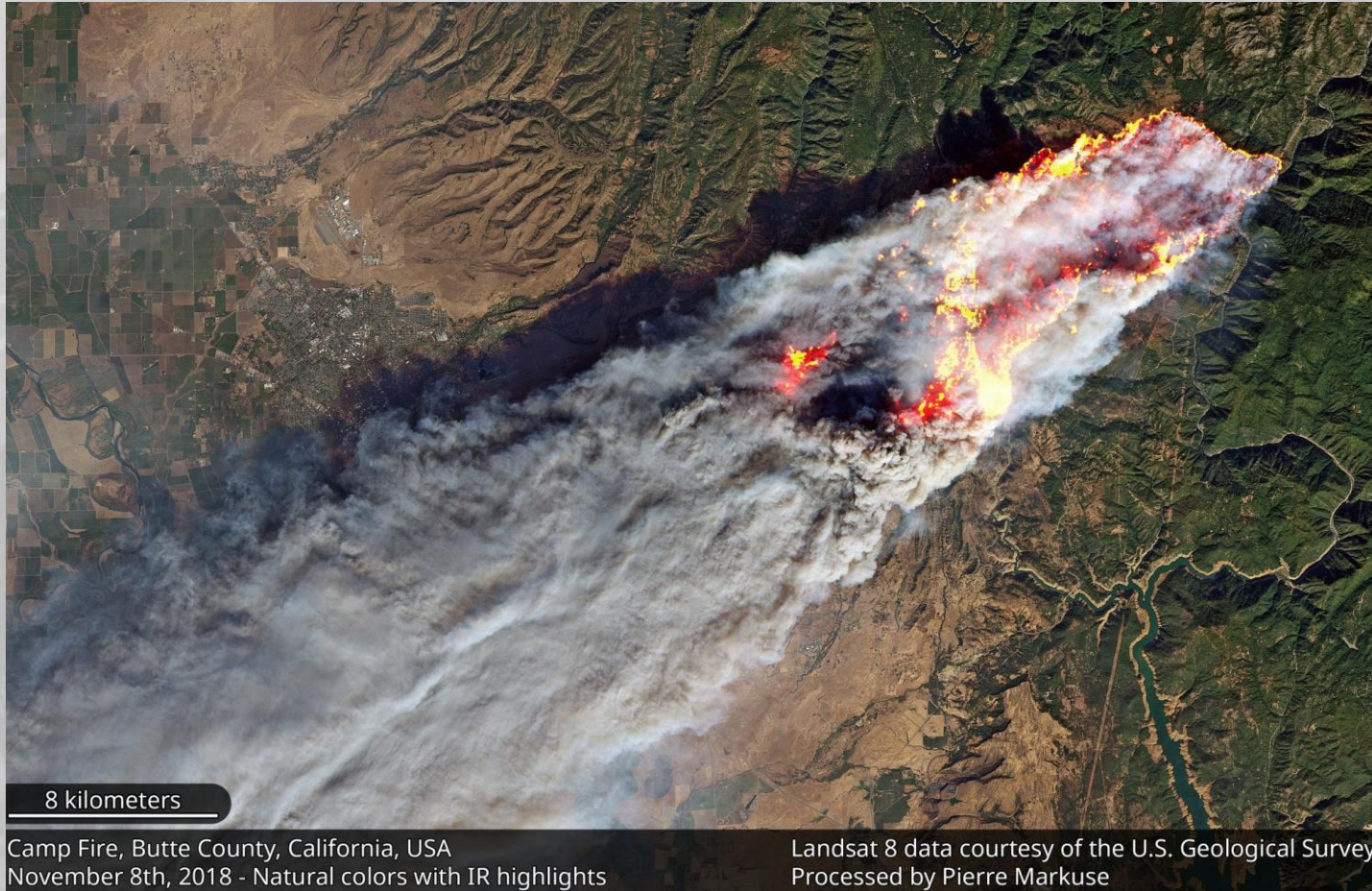


Flooding in Nebraska



Landsat and the Camp Fire

The Camp Fire is California's deadliest fire, killing 86 people and burning more than 14,500 homes and businesses in the town of Paradise



Camp Fire, Butte County, California, USA
November 8th, 2018 - Natural colors with IR highlights

Landsat 8 data courtesy of the U.S. Geological Survey
Processed by Pierre Markuse

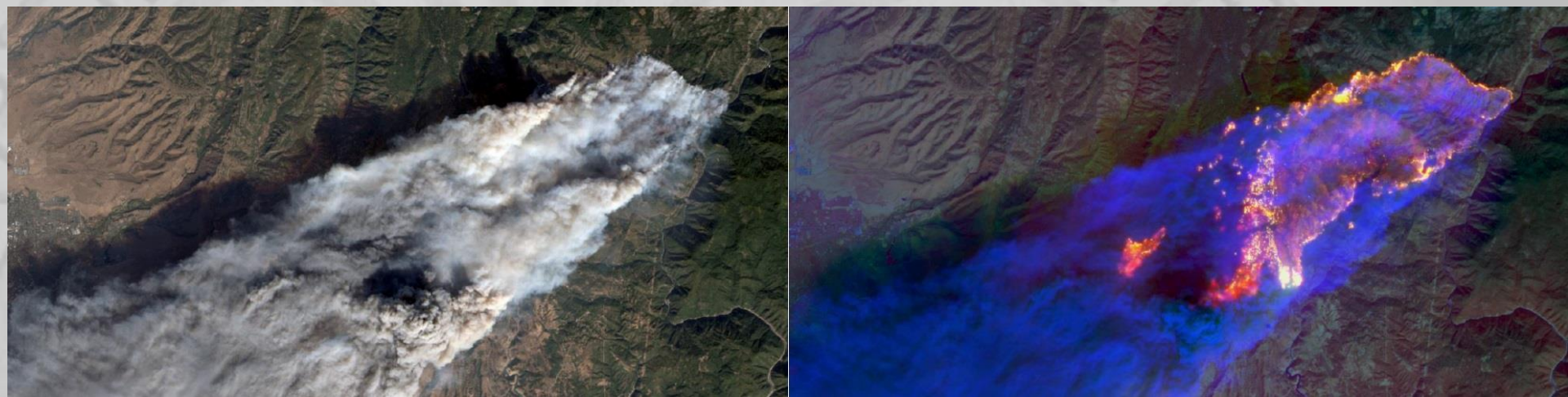
“Landsat is an invaluable tool for people working in our field of community wildfire safety.”



Zeke Lunder, a pyrogeographer and founder of Deer Creek GIS,

The Synoptic View of California's Camp Fire: A Scorching Reality of Today's Fires, Feb 19, 2019 12

Landsat and the Camp Fire



This Landsat image was used to calculate fire speed and verify “leapfrog” behavior.

- While smoke obscures the ground in RGB, the fire’s extent was visible via SWIR & TIR
- SWIR and TIR data show the active fire front and hotspots below the smoke cover
- Image revealed half of the town of Paradise was already burning 4 hours after ignition
- Fire speed then estimated using known ignition time and wind speed
- Image also showed how embers blown by 30mph easterly winds started spot fires as far as 2.5 miles ahead of the main fire front.

Image credit: Matt Montanaro and Aaron Gerace/Landsat.

Landsat and the Camp Fire



Lunder used the Landsat 8 image of the Camp Fire together with topographic and road network data to create this image, used in public safety meetings and featured in the [Wildfire Today](#) publication.



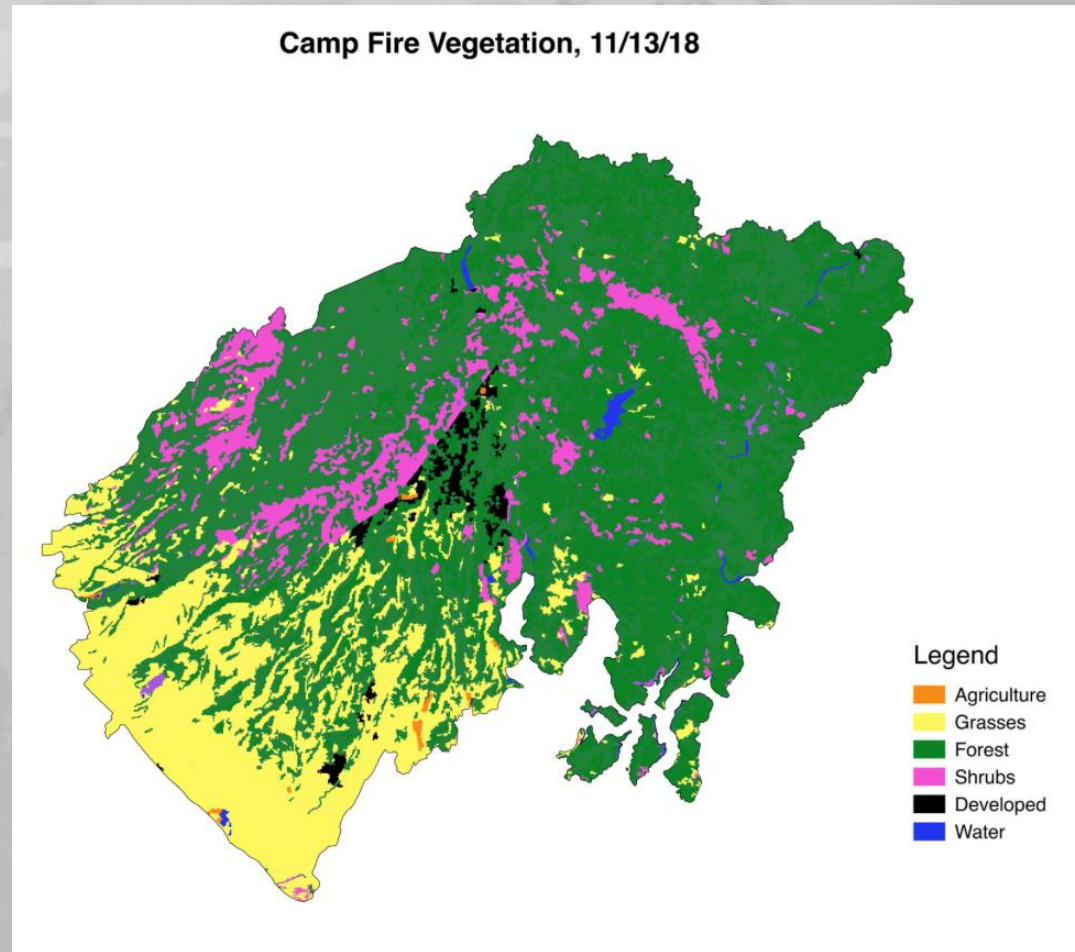
Image credit: Zeke Lunder, Deer Creek GIS/Landsat/Google Earth

Landsat and the Camp Fire

Firefighters must pay close attention to land cover because it affects how a fire behaves

Land cover maps are derived from a mix of Landsat data, aerial data, and field information

The Camp Fire was fueled by a patchwork of vegetation that after years of drought had become a dry fuel load

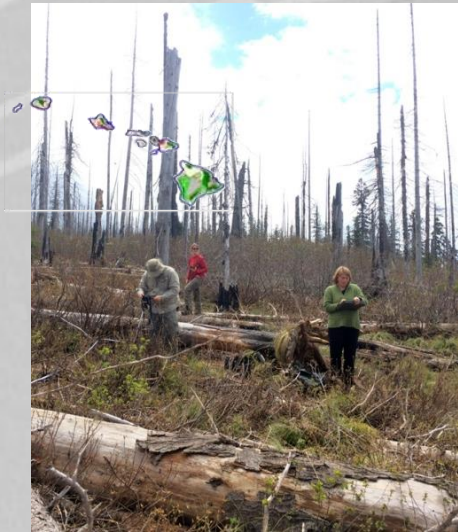


Land cover map created using “Classification and Assessment with Landsat of Visible Ecological Groupings” (CALVEG) dataset

Landsat and Fire

- Although Landsat's revisit makes it rare to image a fire within hours of its onset, Landsat's long archive and well-calibrated data set makes it essential for fire management
- In addition to informing land cover data sets such as CALVEG, Landsat is integral to a number of fire management programs including:
 - [LANDFIRE](#), an interagency endeavor that provides **vegetation fuel data** for the entire U.S.
 - [Monitoring Trends in Burn Severity](#), or MTBS, a program that uses Landsat to **map burn severity and fire extent**, watching for fire behavior trends
 - [Burned Area Emergency Response](#) program, which puts teams on the ground armed with Landsat-based burn severity maps immediately following fires to aid in **post-fire remediation efforts**

Landsat data supports LANDFIRE: Vegetation & Fire-Fuels mapping (DOI/USDA)



LANDFIRE team members
gathering field data in a remap
prototype area of central Idaho

LAND

- land cover/disturbance change
- endangered species monitoring
- climate-carbon-ecological modeling/research
- wildlife/habitat activities

regional/national use

- informs budgets
- natural resource management
- strategic decision support
- updated regularly

FIRE

- fuel treatments
- fire suppression
- fire management planning
- active fire management

LANDFIRE provides a common "all-lands" data set of vegetation and wildland fire/fuels information for strategic fire and resource management planning and analysis.

-- 20+ national geospatial layers, databases, eco-models



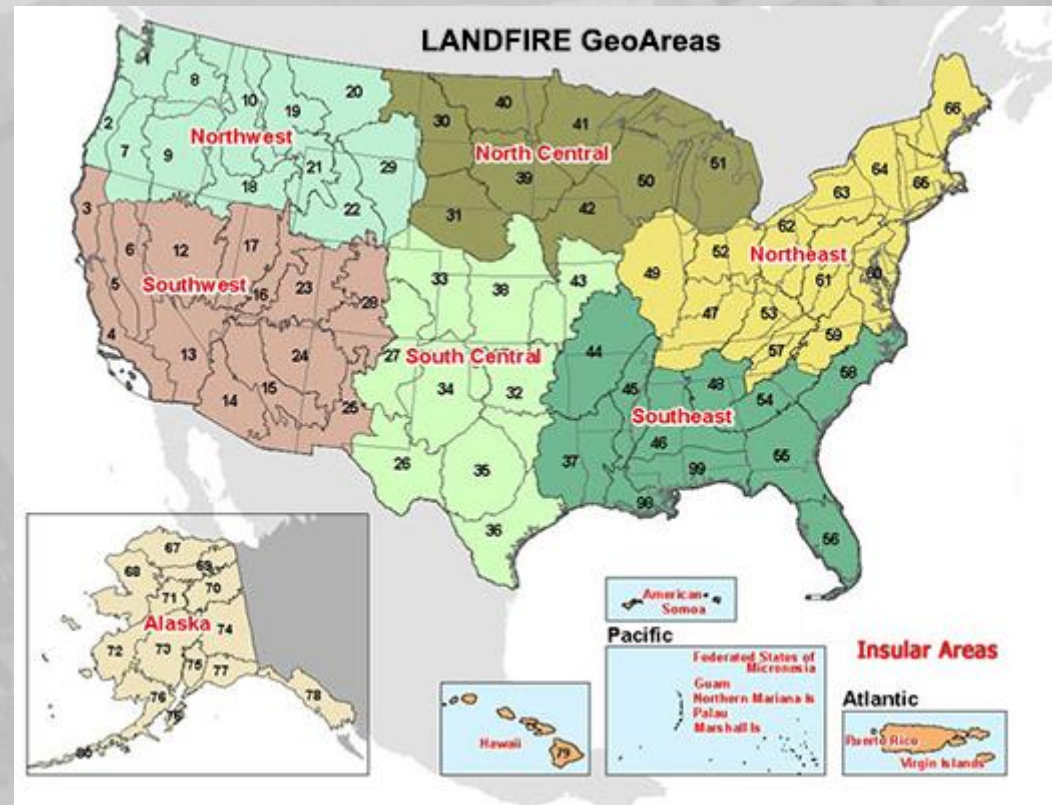
LANDFIRE Remap Begins to Roll Out

Release Date: FEBRUARY 22, 2019

With a vegetation and fuels base map that was over 15 years old and a commitment to keep LANDFIRE data relevant, USGS EROS has produced a new base map product suite, representing 2016 ground conditions.

USGS has produced a new base map product suite, representing 2016 ground conditions. Called [LF Remap](#), the first of 10 increments—this one covering the northwestern U.S.—has just been released, with the other nine increments to follow throughout 2019 and 2020.

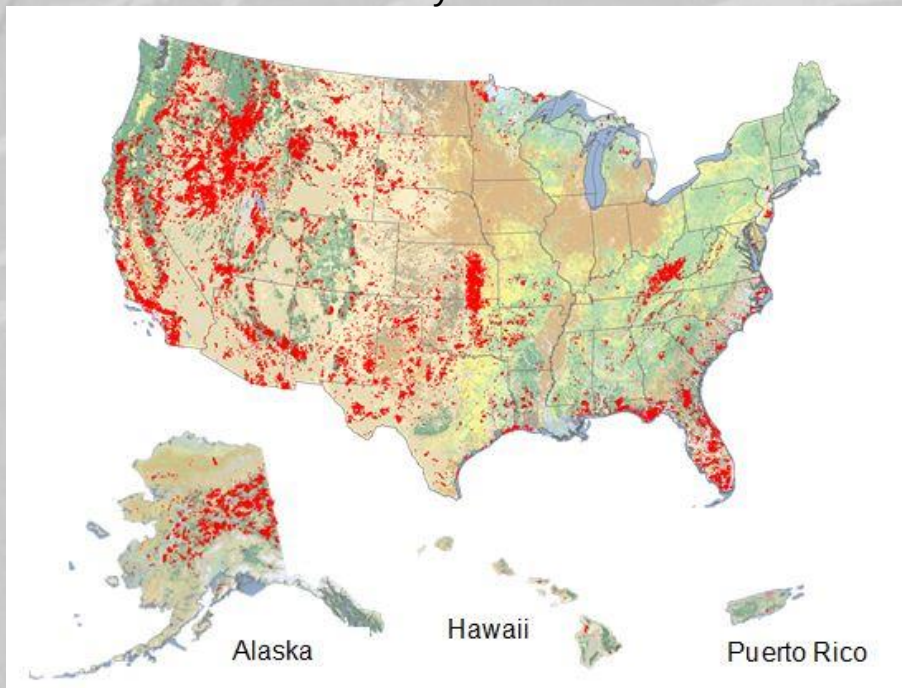
LF Remap produces vegetation and fuels data that inform wildland fire and ecological decision support systems. LF Remap will offer significant enhancements to previous LF versions, including historical disturbance, national vegetation classification, fuel vegetation type, height and cover.



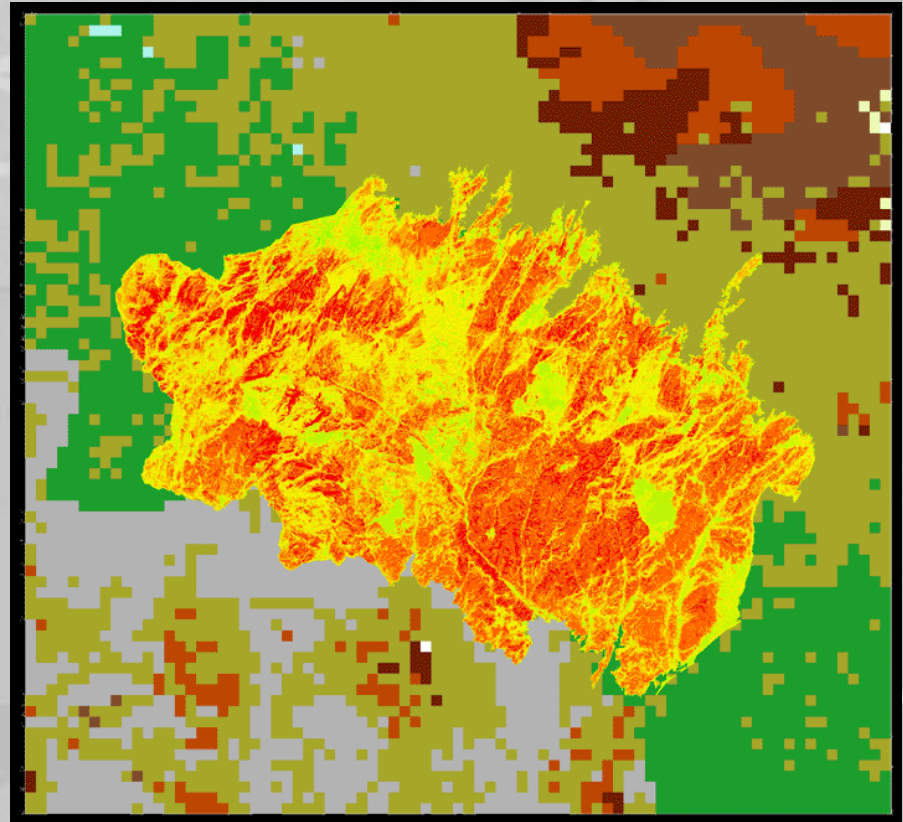
Use of Landsat for U.S. Fire Monitoring

Monitoring Trends in Burn Severity (MTBS) Fire burn severity map by NPS National Burn Severity Mapping program (MTBS website)

21,673 large fires mapped by the MTBS by 10/3/2018



<https://eros.usgs.gov/doi-remote-sensing-activities/2018/fires-mapped-monitoring-trends-burn-severity-project-approaches-20000>



Burn Severity

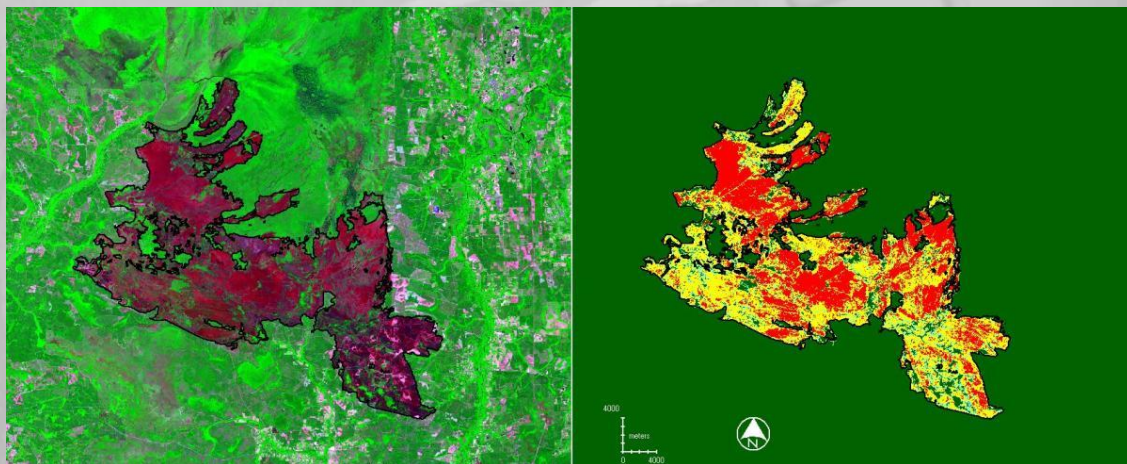
- Enhanced regrowth, high (-500 to -251)
- Enhanced regrowth, lo (-250 to -101)
- Unburned (-100 to +99)
- Low severity (+100 to +269)
- Moderate-low severity (+270 to +439)
- Moderate-high severity (+440 to +659)
- High severity (+660 to +1300)

FCCS Description

- 0 (Urban - Agriculture - Barren)
- 27 (Ponderosa pine - Two-Needle Pine - Juniper Forest)
- 30 (Turbinella Oak - Ceanothus - Mountain Mahogany)
- 55 (Western Juniper / Sagebrush Savanna)
- 56 (Sagebrush Shrubland)
- 210 (Pinyon - Juniper Forest)
- 211 (Interior Ponderosa Pine Forest)
- 236 (Tobosa - Grama Grassland)
- 273 (Spruce - Fir - Pine)

Remote Sensing Support for DOI Burned Area Emergency Response (BAER) Teams

- USDA Forest Service & DOI agencies use BAER to manage post-fire response actions within 1 year of wildfire containment
- BAER Teams are required to evaluate wildland fire effects and develop mitigation plans within 2 weeks of a fire event
- USGS EROS rapidly (within 2 days) produces burn maps based on Landsat and other satellite data
- From 2003-2016, USGS and the USFS have mapped 1,759 wildfires, totaling 48.8 million burned acres



Landsat 8 post-fire image (May 16, 2017; left) and preliminary soil burn severity map (May 19, 2017; right) for the May 2017 West Mims fire in Georgia/Florida's Okefenokee National Wildlife Refuge

New RSE Paper: Current status of Landsat program, science, and applications

April 2019

The Landsat free and open data policy led to a rapid **expansion of science and operational applications**, serving government, private sector, and civil society.

The paper describes important aspects of the Landsat free and open data policy and **highlight the importance and continued relevance of this policy**.

Free and open access has greatly benefited operational applications, scientific studies, and discoveries informed by analyses of large numbers of Landsat images. For example,

Global mapping of annual forest change reported a net forest loss of 1.5 million km² ([Hansen et al., 2013](#)).

Location and persistence of global surface water extent have been mapped finding both >180,000 km² of new permanent water bodies and a loss of nearly 90,000 km² ([Pekel et al., 2016](#)).

Other global maps, including of human settlements ([Pesaresi et al., 2016](#)) and land cover ([Chen et al., 2015](#); [Gong et al., 2013](#)) have been generated using large amounts of Landsat data.

The spatial detail and temporal range of Landsat data is routinely utilized at local levels and many continental, national, and regional projects have been implemented ([Wulder et al., 2019](#)).



[Michael A. Wulder, Thomas R. Loveland, David P. Roy, Christopher J. Crawford, Jeffrey G. Masek, Curtis E. Woodcock, Richard G. Allen, Martha C. Anderson, Alan S. Belward, Warren B. Cohen, John Dwyer, Angela Erb, Feng Gao, Patrick Griffiths, 21 Dennis Helder, Txomin Hermosilla, James D. Hipple, Patrick Hostert, Zhe Zhu](#)



Annual statistics of price, downloads, and number of publications related to Landsat

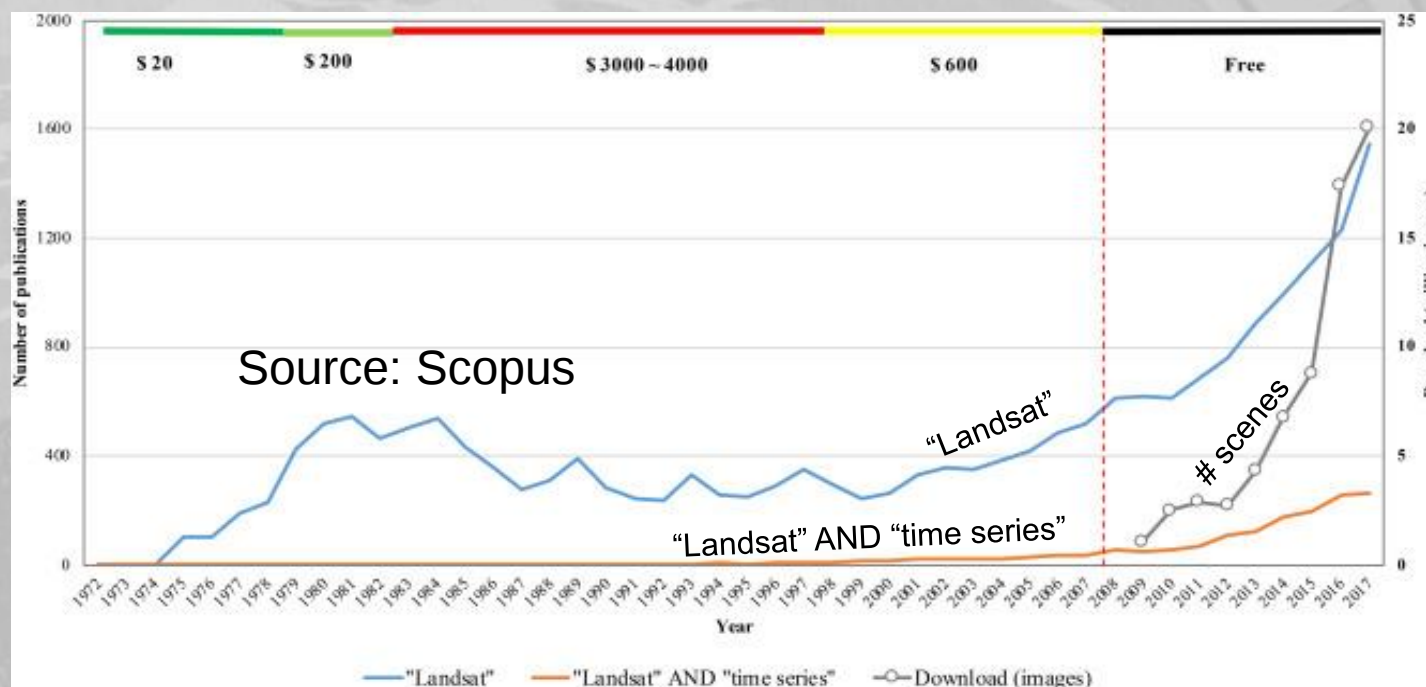


Fig. 1. [Landsat](#) image cost (top color bar, values from [Wulder et al., 2012](#)), number of downloads of Landsat images from the U.S. Landsat archive (gray line), and the number of annual publications from 1972 to 2017 in the **Scopus database** that have “Landsat” (blue line) or “Landsat” AND “time series” (orange line) in their title, abstract, or keywords. Remote Sensing of Environment, April 2019

Landsat Data Policy Study for 2018-2019

- Landsat Advisory Group (LAG) Task topic title: “Considerations of cost sharing models for Landsat data”
- DOI leadership is seeking to better understand economic and data policy considerations and impacts in relation to user needs, as well as the potential for public-private partnering (“P3”), with respect to various cost sharing models for Landsat data.
- The “fee recovery” issue has been looked into as recently as 2012 by the LAG—that paper can be found online at the NGAC website.
- This represents a good opportunity to inform current leadership on a number of Landsat data policy issues, in particular, the interplay with ESA’s adoption of a free and open policy for Sentinel.
- Feedback and information: Email account (Landsatdatapolicy@usgs.gov) and FAQ section on EE website.

New Landsat Case Studies eBook

Forest Management

Spotting deforestation. Landsat has been used for decades to identify areas of global deforestation.

Bathymetry

On the most recent nautical chart of the Dry Tortugas, a grouping of islands that lies seventy miles west of Key West, FL, Landsat data provided the estimated water depths for areas too shallow and difficult to be reached by NOAA's surveying ships.

Agriculture

Water Consumption mapping. Evapotranspiration (ET) mapping at the Landsat spatial resolution (100 m) is essential to fully understanding water use and water availability at the field scale.

Water

Monitoring lakes and reservoirs for HABs. Landsat spatial and spectral resolution enables monitoring of reservoirs and lakes across the Nation.

Climate

Mapping the skin of ice. Glaciers and ice sheets move in unique and sometimes surprising patterns; satellite-based technology maps the speed of flowing ice in Greenland, Antarctica, and mountain ranges around the world.

Fire

Mapping fire damage for use for post-fire mitigation efforts.



Landsat Operations and Development Status

Landsat 7 Flight Operations (1999-)

- Collecting about 470 new scenes per day; latest fuel estimate projects operations into 2021.

Landsat 8 Flight Operations (2013-)

- Collecting up to 740 new scenes per day; frequent night and off-nadir imaging of volcano and fire imaging.

Landsat Archive Operations

- Over 8 million Landsat scenes available; many other datasets: ResourceSat-2 over US, Sentinel-2, Commercial satellite data, aerial photography, UAS data.

Landsat 9 (December 2020 launch)

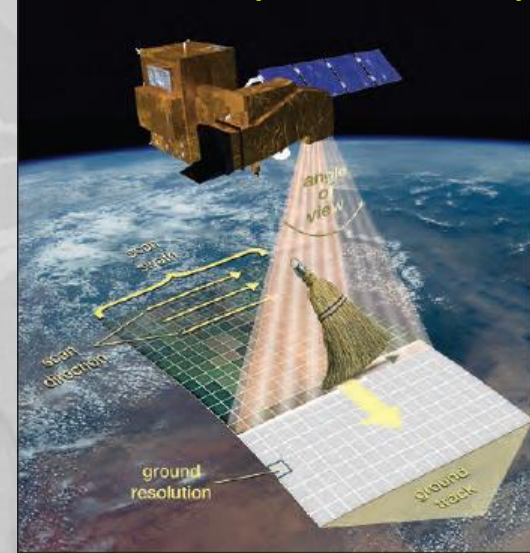
- Essentially a copy of Landsat 8, but with important improvements for accuracy and resiliency (upgrade to fully Risk Class B); 14-bit data.

Landsat 10 (~2025-2030 launch)

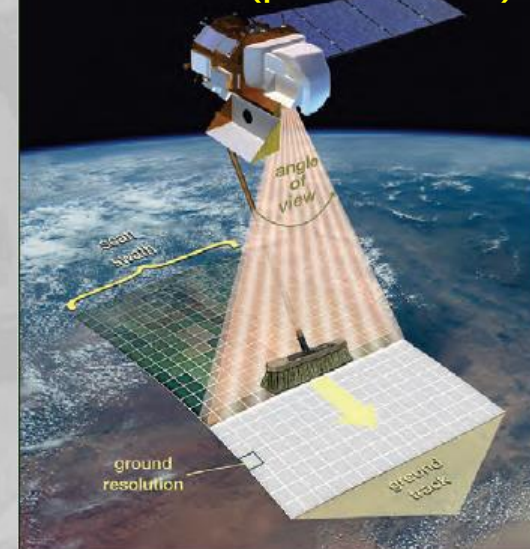
- Technology and user needs studies over the past year led to standup of an architecture study team.
- Everything is on the table at this point (e.g., smallsats, hyperspectral, data buys, Public-Private Partnerships).



Landsat 7 (whiskbroom)



Landsat 8 (pushbroom)



The Road to Sustainable Land Imaging

2012 – OSTP-led Earth Observation Assessment determined Landsat was the second-most impactful space system for Earth Observation, behind only GPS

2013 – National Research Council: The U.S. Government should establish a “Sustained and Enhanced Land Imaging Program” with persistent funding for current & future needs; a “comprehensive, integrated program that capitalizes on NASA and USGS strengths, maintains current capabilities, and enhances imaging capabilities and data products via emerging technology.”

2013 – 2014 – NASA/USGS Sustainable Land Imaging Architecture Study Team explored hundreds of architecture alternatives to accomplishing the Landsat mission

2014 – U.S. National Plan for Civil Earth Observations: “The NASA Administrator, together with the Secretary of the Interior through the Director of USGS, will implement a 25-year program of sustained land-imaging...fully compatible with the 42-year record of Landsat observations.”

2015 – President’s 2016 Budget called for a “Sustainable Land Imaging” program with a thermal imaging free-flyer first, followed by a Landsat 9 launch in 2023, and technology investments

- Thermal imaging free-flyer to mitigate potential thermal gap, followed by a low programmatic risk implementation of a proven full-spectrum system to assure observational continuity
- Congress demurred on thermal free-flyer; directed earlier Landsat 9 launch to minimize gap with Landsat 7
- NASA and USGS initiate Landsat 9 development

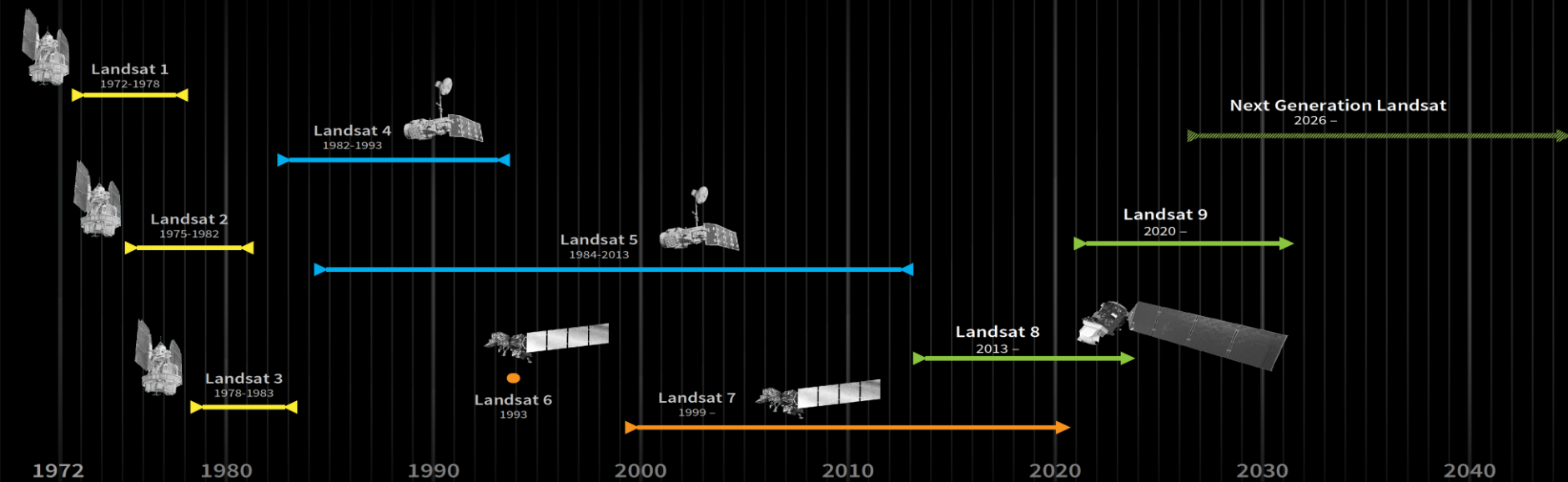
2016 – President’s 2017 Budget accelerated the Landsat 9 launch into Fiscal Year 2021

2016 – Second, more comprehensive OSTP-led Assessment confirmed Landsat’s #2 impact rank

2017 – 2019 – President’s 2018-2020 Budgets endorsed Landsat 9 timeline, fully funded mission



BUILDING ON THE LANDSAT LEGACY



- **Sustainable Land Imaging (SLI)** is a partnership between DOI/USGS and NASA to maintain a sustainable program for spaceborne land imaging
- ❑ Landsat-9 development is on track to meet a December 2020 launch date
 - ❑ USGS documented user requirements across Federal agencies; NASA conducted technology investigations to reduce cost and risk in future missions
 - ❑ Joint SLI Architecture Study Team (AST) underway to define the next mission(s)
 - » AST briefed Checkpoint #1 to NASA/USGS Leadership on 15 March; need to ensure Earth Observation Continuity while meeting new user needs and injecting new technology

2019 NASA/USGS Sustainable Land Imaging Architecture Study

Purpose

- Execute a feasibility study for the design and implementation approach of a spaceborne system to provide global, continuous Landsat-quality multispectral and thermal infrared measurements for approximately a fifteen-year period starting in 2026

Approach

- Establish study trade space via formulation activities, building block information, expert knowledge, intensive AST discussions, and industry input (RFI responses)
- Trade space is explored via three design cycles
 - Design Cycle 1 incorporates broad architecture alternatives and is now complete
 - Design Cycle 2 incorporates risk as well as partnership modeling assumptions
 - Design Cycle 3 emphasizes roadmap conclusions
- Trade space is narrowed and adjusted through each remaining design cycle
- Viable architectures that are likely to satisfy budget constraints are further refined and assessed

Deliverable

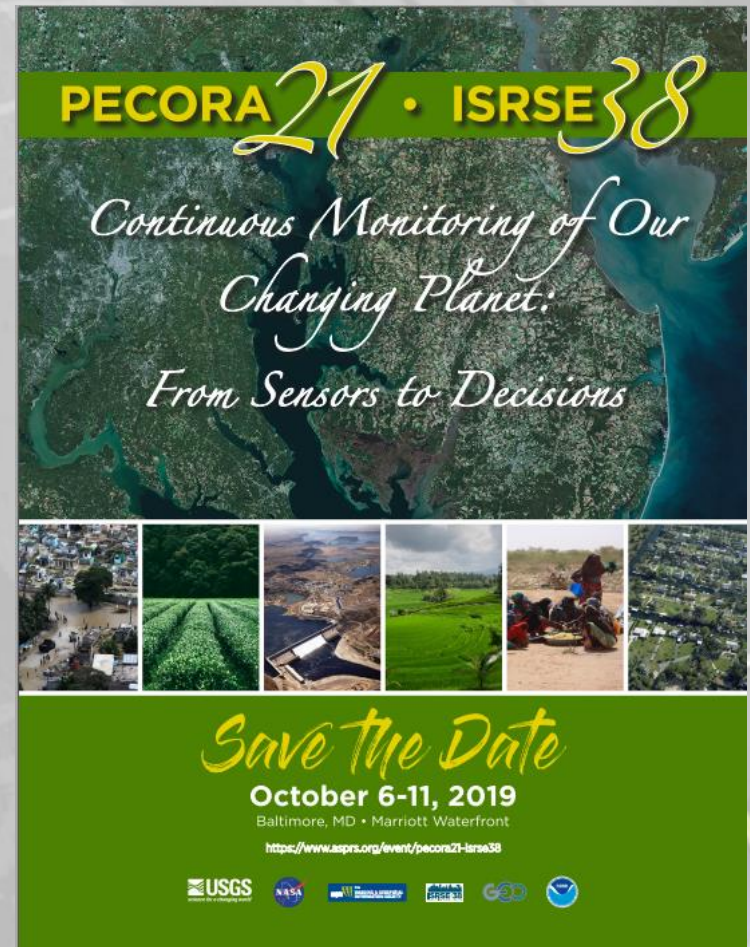
- Set of viable architecture concepts (~3) that will provide NASA/USGS a basis for formulating future acquisition strategies/approaches

Pecora 21/ ISRSE-38 Joint Meeting To be Held in 2019

A joint meeting of the **21st William T. Pecora Memorial Remote Sensing Symposium** (Pecora 21) and the 38th International Symposium on Remote Sensing of Environment (ISRSE-38) will convene in **Baltimore, Maryland, USA** from **October 6 – 11, 2019**.

The combined conference will be **hosted by NASA, NOAA and the USGS**, with an overarching theme of “**Earth Observation – Continuous Monitoring of Our Changing Planet: From Sensors to Decisions.**”

Visit <http://pecora.asprs.org/> for more information about the conference.



LCMAP Releases Project Website

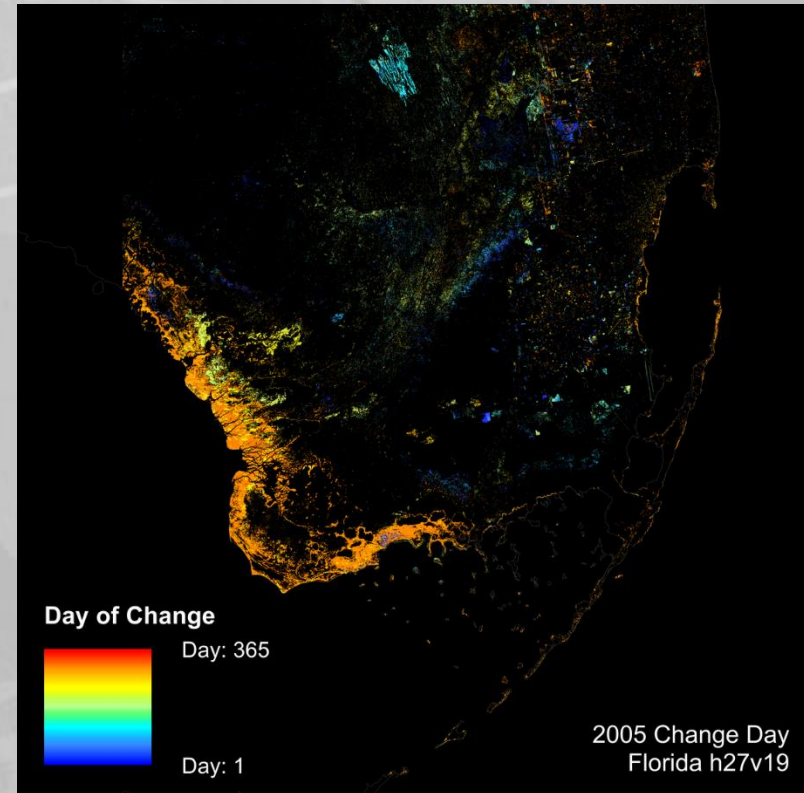
The USGS Land Change Monitoring, Assessment, and Projection (LCMAP) initiative now has an online home. The stand-alone LCMAP website is located at www.usgs.gov/lcmap.

LCMAP represents the **next generation of land cover and change mapping**. It synthesizes decades of advancements in remote sensing technology to provide timely information on how, why and where the planet is changing.

It **leverages Landsat ARD** to create independently-validated datasets and applications to enhance our understanding of natural and man-made change and help address pressing questions of land and resource management.

Anticipating **release of LCMAP sample data this spring**, followed by a full product suite over the summer. The site includes product descriptions, and explanations of the initiative and its six core areas of study.

LCMAP products for the conterminous US include primary and secondary land cover classes with confidence layers for each, annual land cover change, time of spectral change and time since last change, change magnitude, spectral stability period and model quality data.



NLI Program Priorities for 2019

- Inform Landsat 10 design and development via NASA-USGS **Architecture Study Team**
- Definition and preparation for **Global Analysis Ready Data** (ARD)
- Operational status and productivity from **Land Change Monitoring, Assessment, and Projection** (LCMAP)
- Integrating Landsat data with relevant geospatial and climate data sets to drive innovation toward **big data science and predictive capabilities**
- **IT modernization** for Landsat data leveraging commercial cloud
- Investigating **UAS and small satellite** capabilities for tip and cue applications
- Release of **new Landsat user survey**, OSTP **National Plan** for Civil Earth Observations/Earth Observation Assessment (**EOA**) **2016** results synopsis
- Increasing utilization of NCAC capabilities across the Bureau, particularly **commercial high-resolution data**; ensure future commercial data buys include **civil agency requirements and favorable licenses**
- Mature and institutionalize RCA processes to significantly **expand user need satisfaction across USGS, DOI and the Federal Civil Community**

NLI Strategic Directions

- Characterize Federal and associated **user needs** across the full range of land-imaging data sources
 - Multiple data types
 - Multiple observing platforms
- Maintain and expand public-private, interagency, and international **partnerships** to advance Federal agencies' land-imaging objectives
- Sponsor land remote sensing **science** to maximize land-imaging data utility
- Maximize available **technological efficiencies** in data access, processing, and application
- Support national-level Earth observation **policy** to advance U.S. economic and environmental security
 - Develop a national land-imaging strategy to maximize land-imaging capabilities and better serve the public interest