National Land Imaging
Update on the USGS ~~Land Remote Sensing~~ Program

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Department of the Interior

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Outline

- DOI/USGS overview
- Sustainable Land Imaging (NASA/USGS)
- Landsat mission status
- Decadal Survey recommendations / challenges
  - User needs
  - Partnerships
- Data management
- Landsat science
  - Analysis ready data
  - Time-series analysis

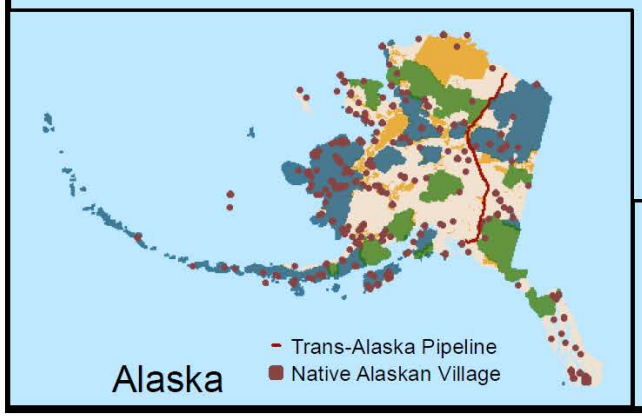
Department of the Interior (DOI)

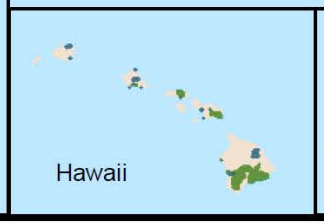
- SECRETARY
- DEPUTY SECRETARY
  - ASSISTANT SECRETARY Policy, Management and Budget
    - CHIEF INFORMATION OFFICER
  - OFFICE OF INTERGOVERNMENTAL AND EXTERNAL AFFAIRS
  - OFFICE OF CONGRESSIONAL AND LEGISLATIVE AFFAIRS
  - OFFICE OF COMMUNICATIONS
  - SOLICITOR
  - INSPECTOR GENERAL
  - SPECIAL TRUSTEE FOR AMERICAN INDIANS
  - OFFICE OF THE EXECUTIVE SECRETARIAT
  - **ASSISTANT SECRETARY Fish, Wildlife and Parks**
    - National Park Service
    - U.S. Fish and Wildlife Service
  - **ASSISTANT SECRETARY Indian Affairs**
    - Bureau of Indian Affairs
    - Bureau of Indian Education
  - **ASSISTANT SECRETARY Land and Minerals Management**
    - Bureau of Land Management
    - Office of Surface Mining, Reclamation, and Enforcement
    - Bureau of Ocean Energy Management
    - Bureau of Safety and Environmental Enforcement
  - **ASSISTANT SECRETARY Water and Science**
    - U.S. Geological Survey
    - Bureau of Reclamation
  - **ASSISTANT SECRETARY Insular Affairs**
    - Office of Insular Affairs

Dr. James Reilly (confirmation Hearing 3/6/18)

Department of the Interior Lands

Manages 20% of U.S. land mass





Oil & Gas Platforms
Bureau of Land Management
Bureau of Indian Affairs
Fish & Wildlife Service
National Park Service
Bureau of Reclamation

N
0 75 150 300 450 600
Miles

USGS The National Map

U.S. Geological Survey
$1.1B (FY2018 Enacted)

- ~8000 employees
- 65 science centers
- 400 field offices
- 270 buildings (owned)
- Thousands of streamgage & seismic monitoring stations


Ecosystems


Energy and Minerals, and Environmental Health


Natural Hazards


Science Quality and Integrity


Water


Land Resources


Core Science Systems

USGS

Science mission-- Non regulatory

National Land Imaging (NLI) Program

($93.1M enacted FY18)

Fundamental goal

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

National Land Imaging Appropriations

	FY16 Enacted ($M)	FY17 Enacted ($M)	FY18 Enacted ($M)	FY19 PB ($M)
Satellite Operations	57.6	71.2	78.5	73.0
Science Research & Investigations	14.6	14.6	14.6	3.0
Total	72.2	85.8	93.1	76.0

USGS NLI Program Components

Satellite Operations

- Collect, archive, process & disseminate Landsat & Landsat-like data (Landsat 1-8, Sentinel-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 2018/2019 Landsat 10 decision

Science, Research & Investigations

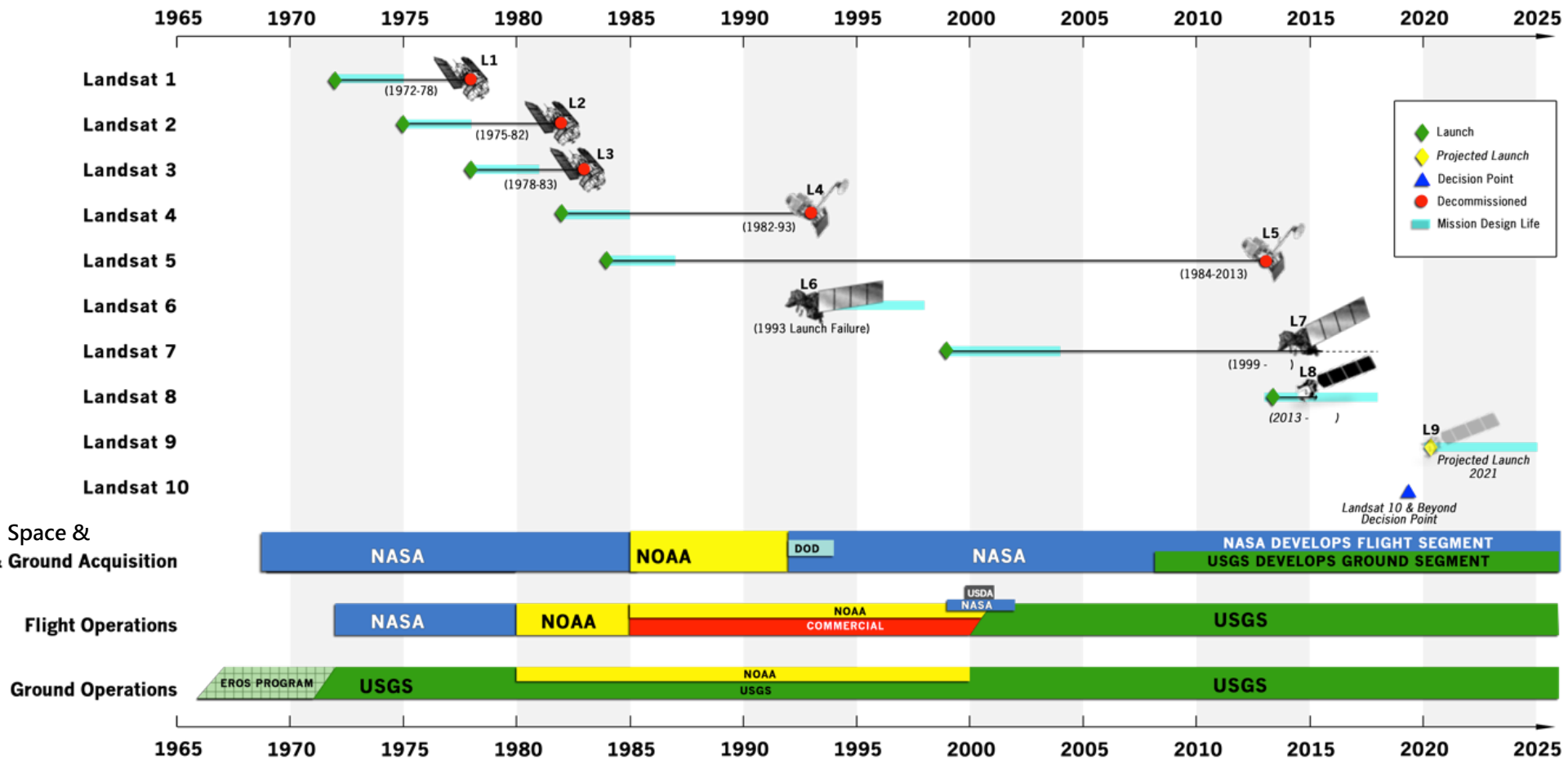
Conduct science, research and technology investigations to improve upon and develop new products and services

- Investigate potential Federal civil uses of unmanned aerial systems, hyperspectral, lidar, radar and other remote sensing technologies

Manage National Civil Applications activities

- Provide National Security Space system geospatial data from two USGS centers to support a wide range of USGS missions including hazard warning and response, natural resource management, and scientific research
- Facilitate Federal civil agency use of National Security Space Systems through management of the Civil Applications Committee

Landsat data continuity since 1972



The Landsat Program has amassed the longest and most comprehensive record of the Earth's land surface in existence

USGS

Sustainable Land Imaging (SLI)

- Collaboration (via 2016 agreement) between NASA and DOI/USGS that **enables the development of a multi-decade,** spaceborne system that will provide users worldwide with high-quality, global, land-imaging measurements compatible with the existing 45+ year record.

  - **Space systems-- NASA** will maintain responsibility for developing, launching and checking out space systems on-orbit before transferring to USGS for operations.
  - **Ground systems-- DOI/USGS** will be responsible for developing and maintaining, to include operating the on-orbit spacecraft, and collecting, archiving, processing and distributing SLI systems data to users.

Landsat operational, development, & assessment status

Landsat 7 (1999-)

- Collecting about 475 new scenes per day; latest fuel estimate projects operating into 2020/2021.

Landsat 8 (2013-)

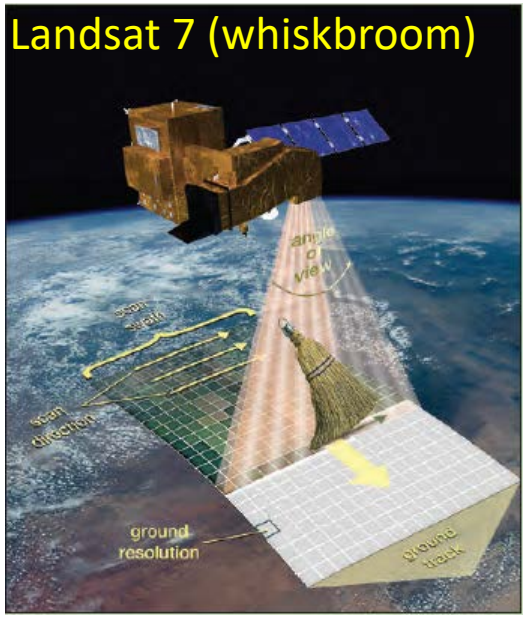
- Collecting up to 725 new scenes per day; together with Landsat 7 supports 8-day revisit.

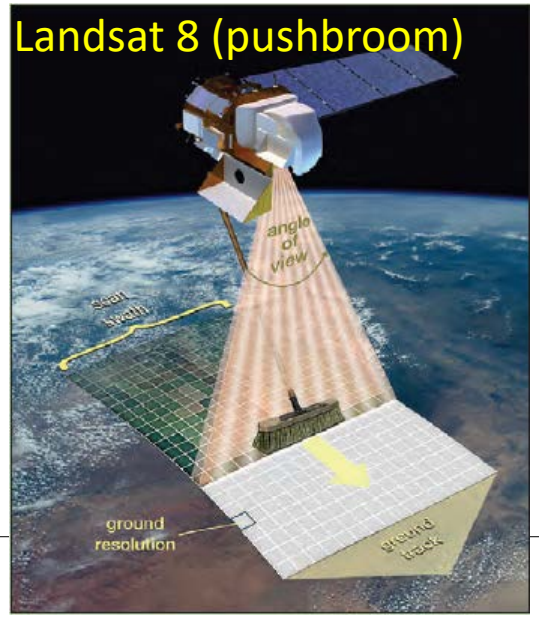
Landsat 9 (December 2020 launch)

- Essentially a copy of Landsat 8
- Upgrade to fully Class B (TIRS thermal instrument was a Class C instrument on Landsat 8)

Landsat 10 (~2025-2030 launch)

- Technology and user needs studies underway to support an architecture study to commence mid-2018.
- Everything is on the table at this point.



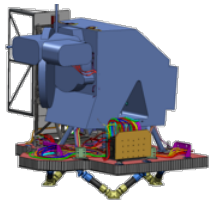


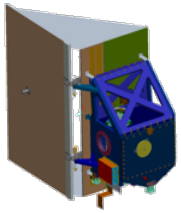
USGS

Landsat 9 mission segments

NASA

Space Segment





Operational Land Imager 2

- Multi-Spectral Imaging Instrument
- Pushbroom VIS/SWIR sensor
- Four mirror telescope
- Focal Plane consisting of 14 SCAs

Thermal Infrared Sensor 2

- 2 thermal channels
- Pushbroom design
- Quantum well detectors
- Actively cooled Focal Plane Assembly (FPA)

Spacecraft

- 3-axis stabilized
- Accommodates OLI-2 & TIRS-2

NASA

Launch Segment

Atlas V 401
Vandenberg AFB SLC-3

Launch site integration facility to be competitively selected

USGS

Ground Segment

Landsat Mission Operations Center

- Command & telemetry
- Trending & analysis
- Flight dynamics
- Science acquisition planning
- Primary and backup MOCs at GSFC
  - (NASA is responsible for basic facility and launch support room costs prior to on-orbit acceptance)

Operations

- Flight Operations Team
- NASA leads (USGS supports) mission operations readiness activities, pre-launch, launch and early orbit activities
- USGS leads operations following on-orbit acceptance

Data Processing and Archive System

- Ingest, product generation, & image assessment/ processing
- User Portal web interface for data discovery, product selection & ordering (for Cal/Val), & product distribution
- Storage and archive services

Ground Network Element

- Ground stations/antennas for X-Band image & S-Band telemetry data downlink
- Generation of S-Band command uplink

NAS 2017 Decadal Survey recommendations for USGS

- USGS should ensure that its process for understanding user needs is continued and enhanced throughout the life of the SLI program.

- SLI should ensure minimal budget growth, and ideally reduce cost from one generation to the next.

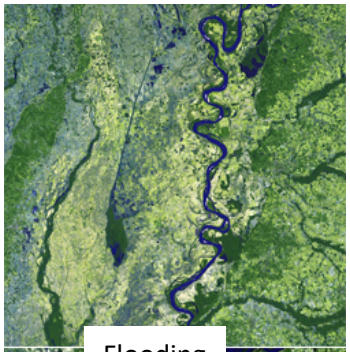
- Partnerships and user communities associated with SLI should be protected and continue to expand.

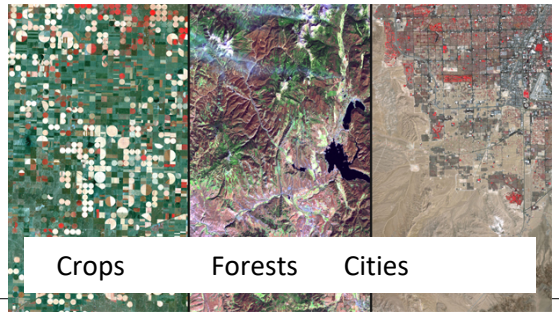
    - Leverage Cloud Service Providers
    - Leverage new imagers with higher spatial resolution than Landsat, but that still retain the capability to do global surveys to support a broader SLI mission
    - Leverage international missions

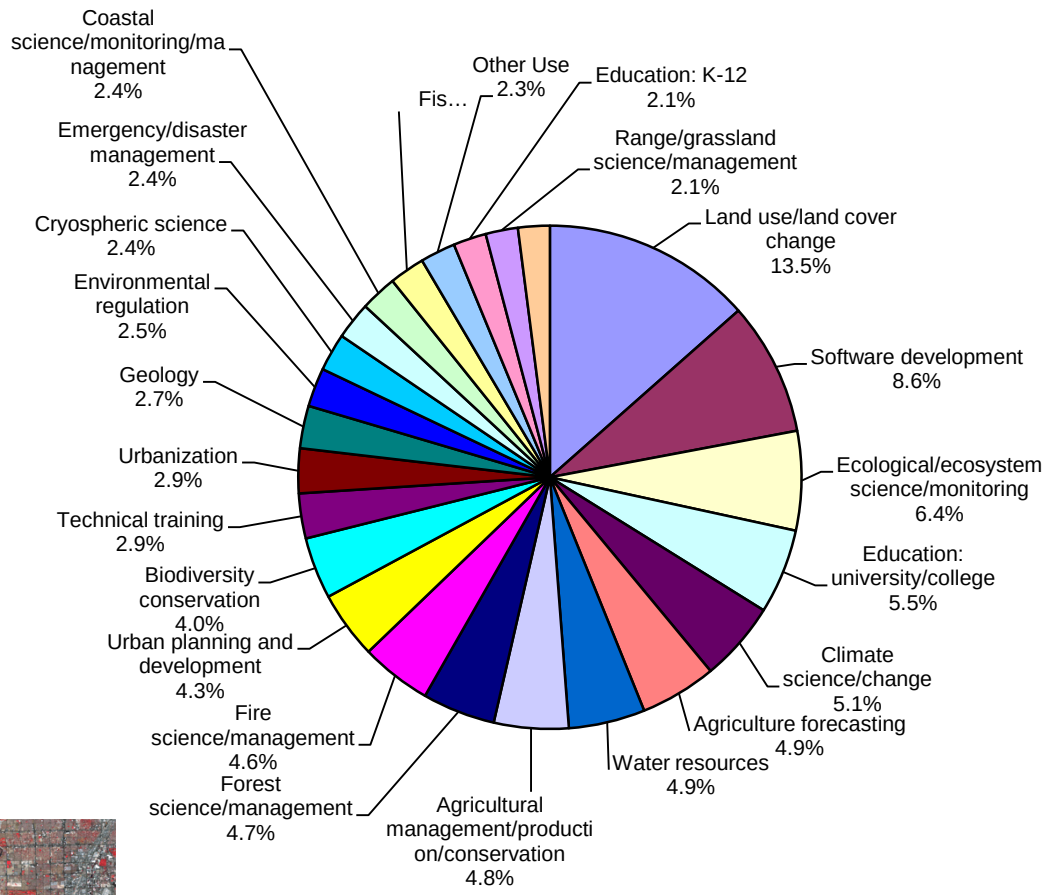
SLI user needs assessment

Demand for Landsat data

- Land Use / Land Cover Change
- Agriculture Monitoring & Forecasting
- Hazards Monitoring & Mitigation
- Disaster Response & Recovery
- Land Resource Management
- Ecosystem Monitoring
- Urban Planning & Development
- Water Resource Management







Acquired via passive survey from EE registrations

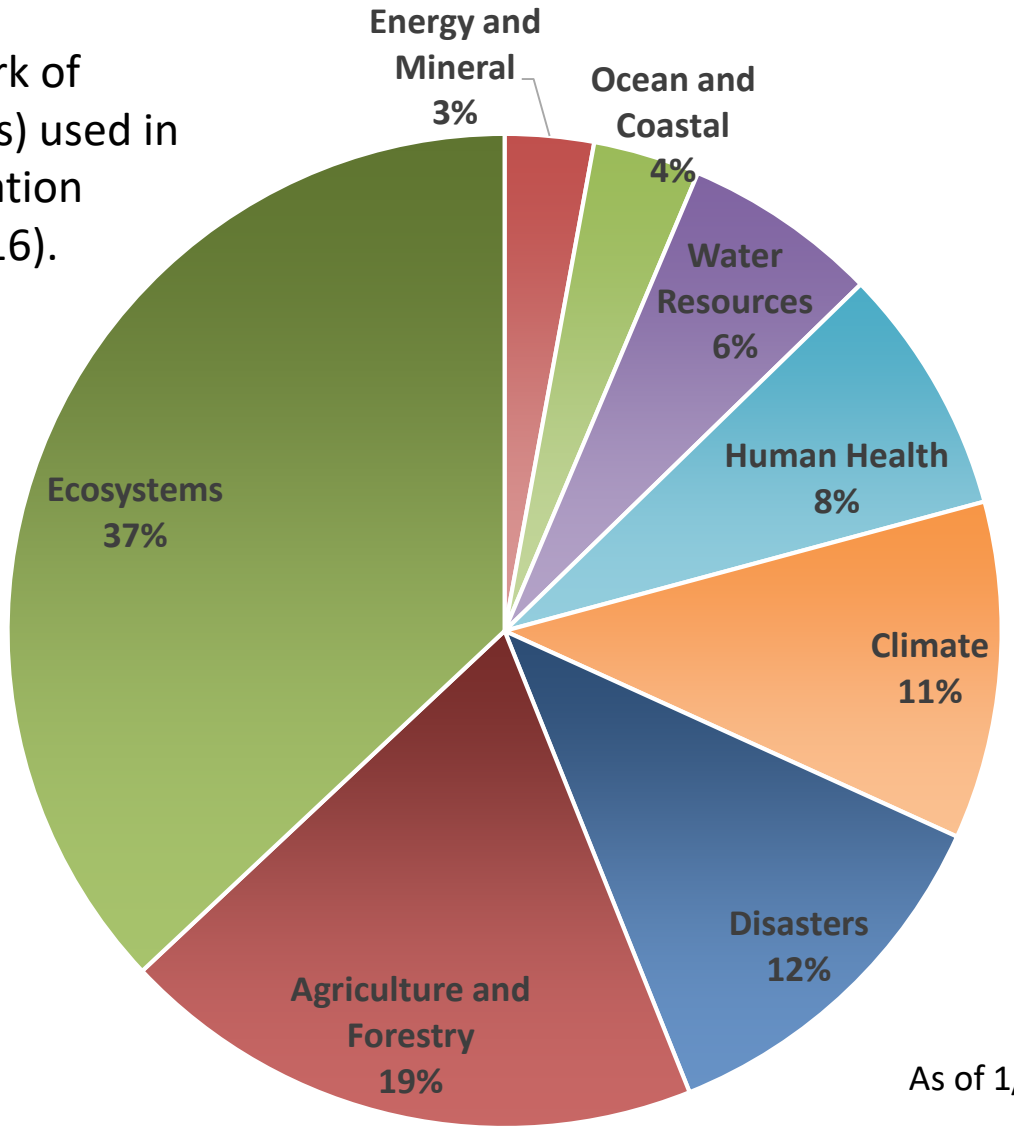
USGS

Landsat 10 user needs data collection population

- Expert elicitation of predominantly Federal civil subject matter experts (SMEs) who rely on moderate resolution land imaging across 176 applications:
  - Participants drawn from the U.S. Office of Science and Technology Policy (OSTP) Earth Observation Assessment (EOA) 2016
  - Members of the HyspIRI, MODIS, and ASTER science communities, the Landsat Science Team, and other experts from the agriculture, water quality, cryosphere, geology, and thermal remote sensing communities
  - **Users that had acquired high-volumes of Landsat and Sentinel-2** data through the USGS Earth Resources Observation and Science (EROS) Center
- Included representatives from multiple DOI and USDA agencies, EPA, NOAA, NASA, and the DOE

Distribution of applications by Societal Benefit Area (SBA)

Adopts the OSTP framework of societal benefit areas (SBAs) used in the National Earth Observation Assessment 2016 (EOA 2016).



n = 176

As of 1/8/2018

Main user needs findings

- At **minimum**, users needed **continuity** of Landsat data and derived products with **free and open** data access.

- To **better** perform their work, users need **weekly clear** observations, **10m** spatial resolution for (VNIR – SWIR) and 30-60m for thermal, and **additional red edge bands** and **narrower bands in VNIR and SWIR** regions.

- **Ideally**, users want clear imagery every **3 days** at **5-10m** spatial resolution, and **contiguous 10nm-wide VNIR – SWIR** band and **more** (5-8) **thermal** bands.

- Federal and non-Federal needs were similar.

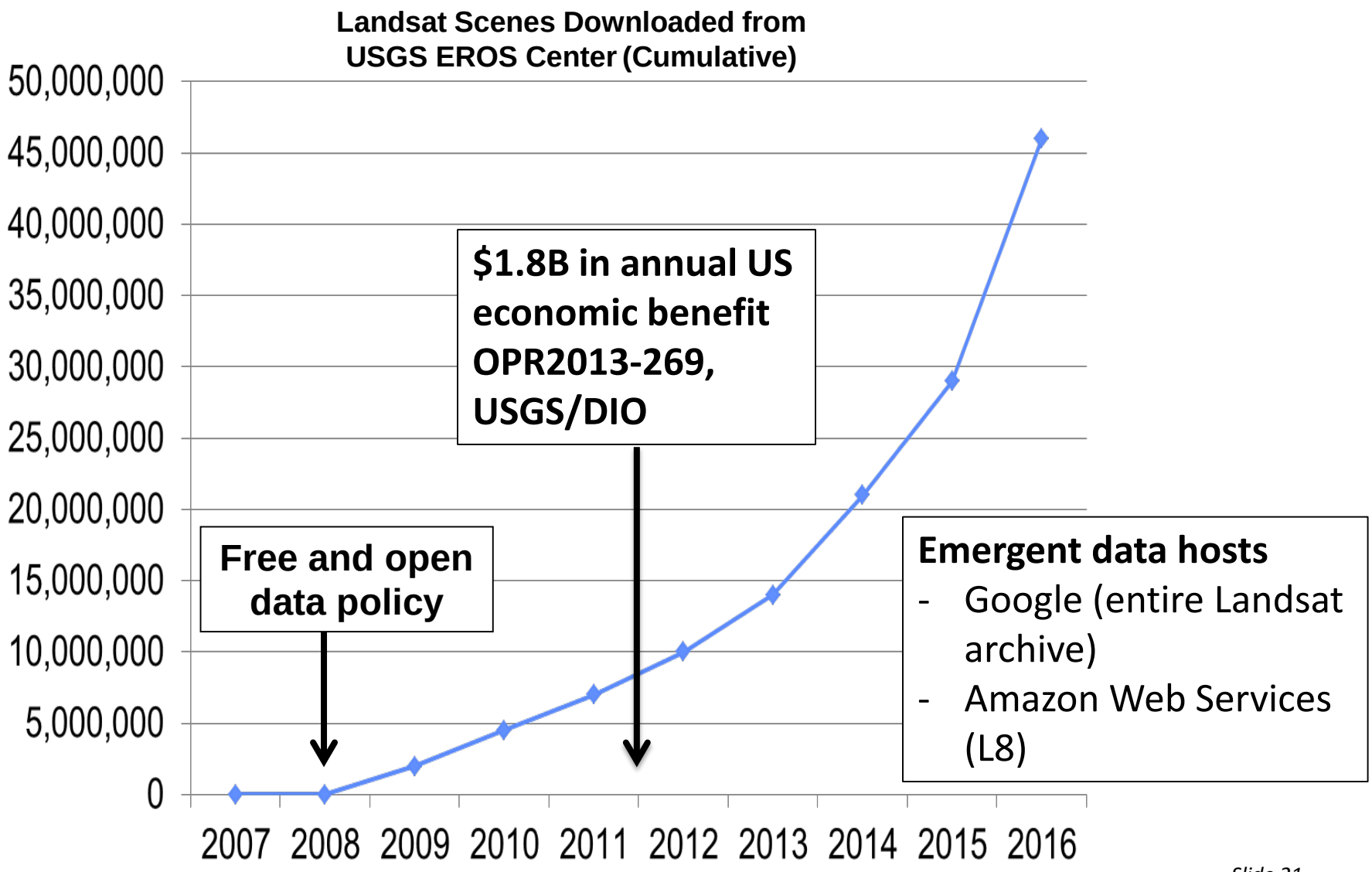
Summary of others user needs studies

- The Request for Information (all land imaging community), AmericaView (US state and local), Geoscience Australia (international), and Landsat Advisory Group (non-Fed) surveys included governmental and non-governmental, domestic and international users
  - Spatial resolution – **10m for VNIR/SWIR bands**; **30 – 60m or even 5 – 10m for thermal** data
  - Observation frequency – **Weekly to sub-weekly usable** observations
  - Spectral enhancement – **Red edge bands, several narrow bands** in the UV, VIS, SWIR, and TIR regions, and **hyperspectral** capabilities
  - **Priority** – Improvements in observation **frequency**, followed by increasing **spatial** and **spectral** resolution
- Non-Federal studies largely mirrored the user needs collected by USGS
- Will compare LST findings and results of the Value of Landsat Study

USGS

Data management and science

Free and open changed everything



USGS

Includes only downloads from the USGS EROS. (Google delivers approximately 1 billion Landsat scenes to users per month.)

USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD

- First ground system (1972)
- Manages 29.2 PB (Feb 2018) of science data (14.2 PB is Landsat)
- Last 12 months distributed 35.5 PB of science data (18.3 PB of Landsat)

Data types managed at EROS

Landsat includes:

Landsat-MSS, TM, ETM+, OLI/TIRS, OLI, TIRS, Landsatlook, ESPA, as well as Landsat Derivative Products: Image of the Week, Earth As Art, Other Image Gallery Images, MRLC, NALC, NLDC, TriDecadel, LIMA, GLS, Landsat Systematic L1G, Landsat Film, NLCD

ESPA -Landsat Surface Reflectance Climate Data Records (CDRs)

LPDAAC includes: MODIS, ASTER, SRTM, Community (GED), MEaSURES, VIIRS, and WELD

Other Satellite includes:

AVHRR, Declassified, EO-1 ALI, EO-1 Hyperion, SPOT, IKONOS, AWIFS, OrbView, QuickBird, WorldView, HCCM, Aster (EE), MODIS (EE/GloVis), eMODIS, and CEOS

Non-Satellite includes: Historical/SCAR, AHAP, NAPP, NHAP, DOQQ, DLG, DRG, SRTM, SIR-C, DEM, Image Gallery, Aircraft Scanners, and ASAS

Geospatial includes:

Orthoimagery-High Resolution Orthoimagery, DOQQ's, DRG's, NAIP, and Landsat 7 Mosaic

Land Cover-All National Land Cover Database (NLCD) versions

Other-National Atlas, BTS Roads, Afghan, Landfire, Drought, LIMA, ARMI, FEWS, IVM (Greenness), NED Bathymetry, Topo, Hydrosheds, LIDAR, NLAPS LIMA, MOPEX, and DLG2

Sentinel-2 includes: Sentinel-2A and Sentinel-2B

ISRO Resource sat includes: ISRO Resourcesat1 (AWIFS & LISS-3) and ISRO Resourcesat2 (AWIFS & LISS-3)

Analysis Ready Data (ARD) Tiles includes:

For each tile, there are six available files to download (4 .tar.gz, 1 Browse). The files are Surface Reflectance (SR), Top of Atmosphere (TA) Reflectance, Brightness Temperature (BT), Quality Assessment (QA), Full-Resolution Browse, and metadata.

IT modernization needs for Landsat data

Ability to download or utilize large volumes of Landsat data quickly

- Explore distribution partnerships via CSPs as “authorized” redistributors
- USGS maintain an authoritative copy of the data at EROS
- Redistributors will ensure open access to the data and security (i.e., read-only)
- Redistributors offer enhanced processing environments

Timely re-processing of the entire archive

- Reprocessing from Level-0 to Level-2 requires considerable compute resources
- The utilization of scalable, burst cloud-based processing resources

Enhanced access and visualization of the data

- Pre-bundled and compressed package delivery of data→ major impediment
- Region of Interest and Pixel-level access to data
- ***Disparate datasets could be searched and retrieved on a coincident basis with a Landsat query→ Tapping into MACHINE LEARNING***

USGS

Landsat processing chain

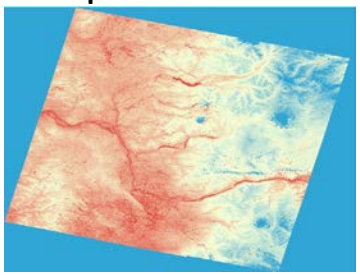
Level-0 data
Raw radiometry;

Level-1 Products
- Orthorectified L1TP
- TOA reflectance
- "Collections"

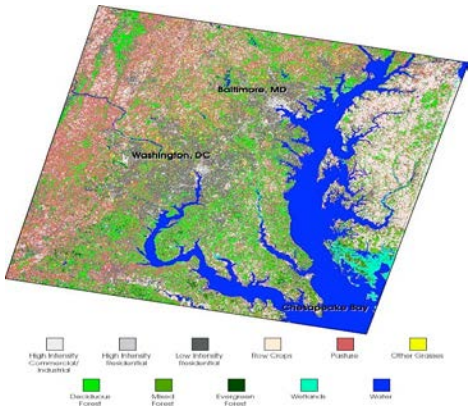
Level-2 Products
Analysis Ready Data (ARD)

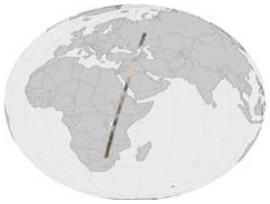
Surface reflectance

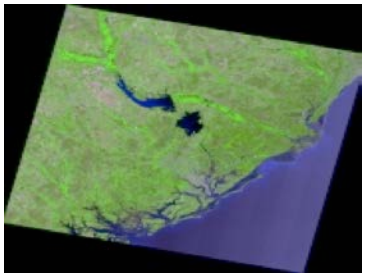
Surface temperature



Level-2/3 Products





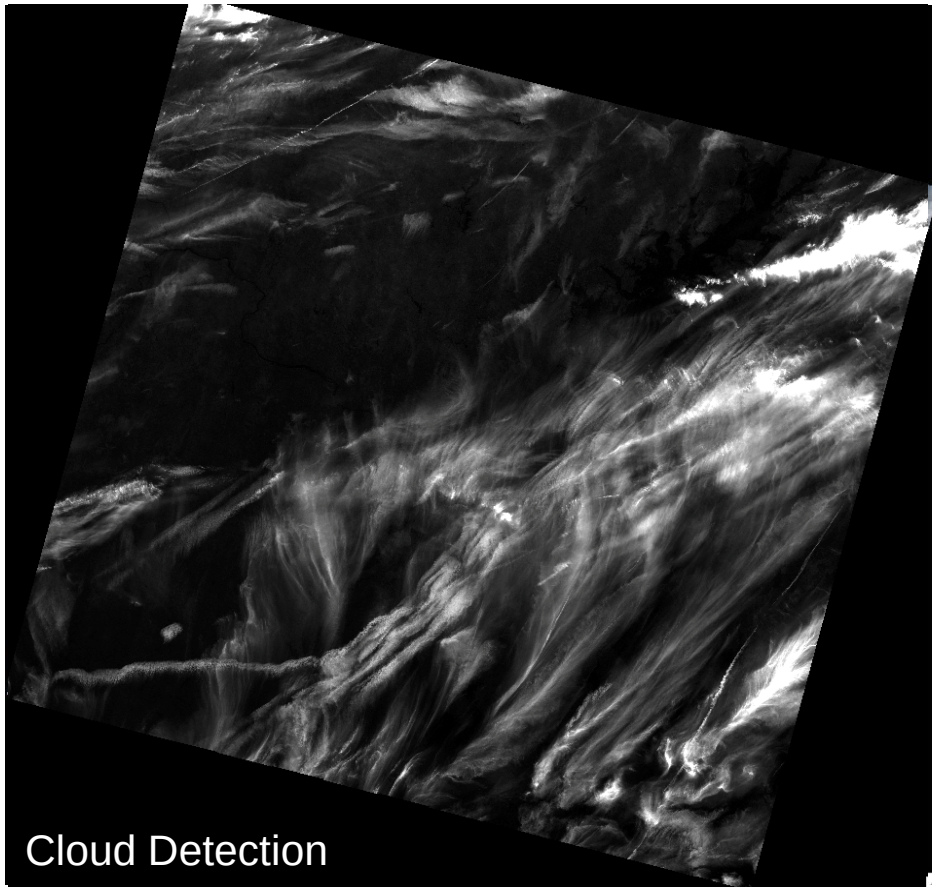


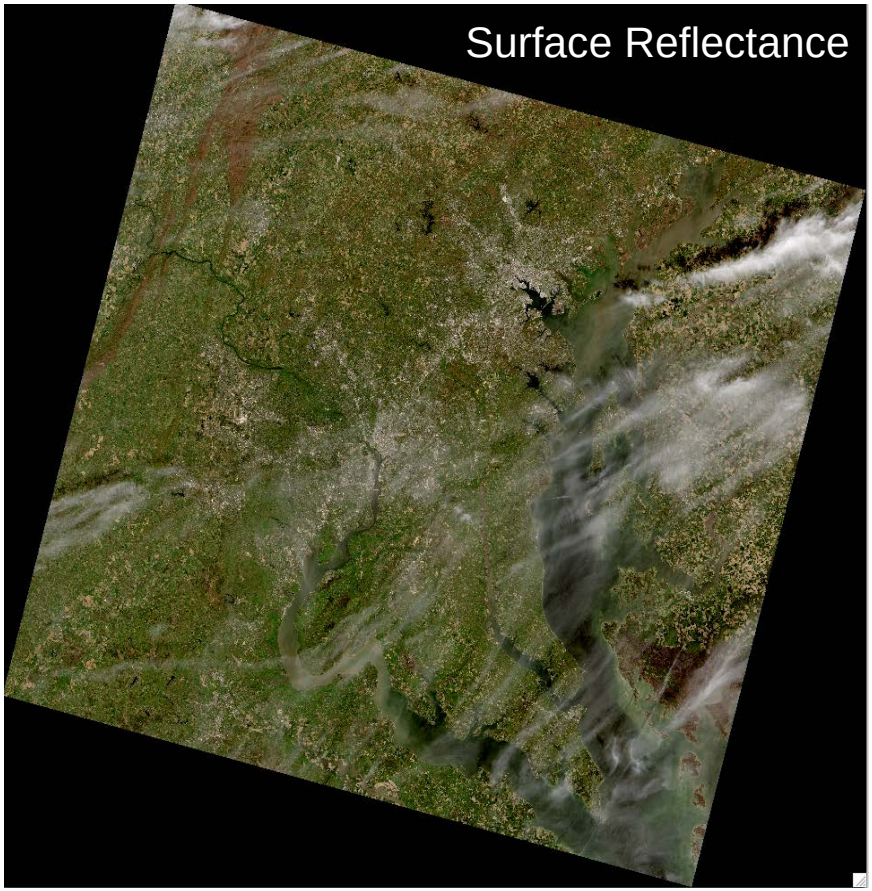
ECVs going operational
- Dynamic surface water extent
- Burned area extent
- Fraction of snow covered area

Emerging demand
- Water quality properties
- Evapotranspiration
- Active fire detection

USGS

Top of Atmosphere (TOA), cloud detection, and Surface Reflectance (SR)



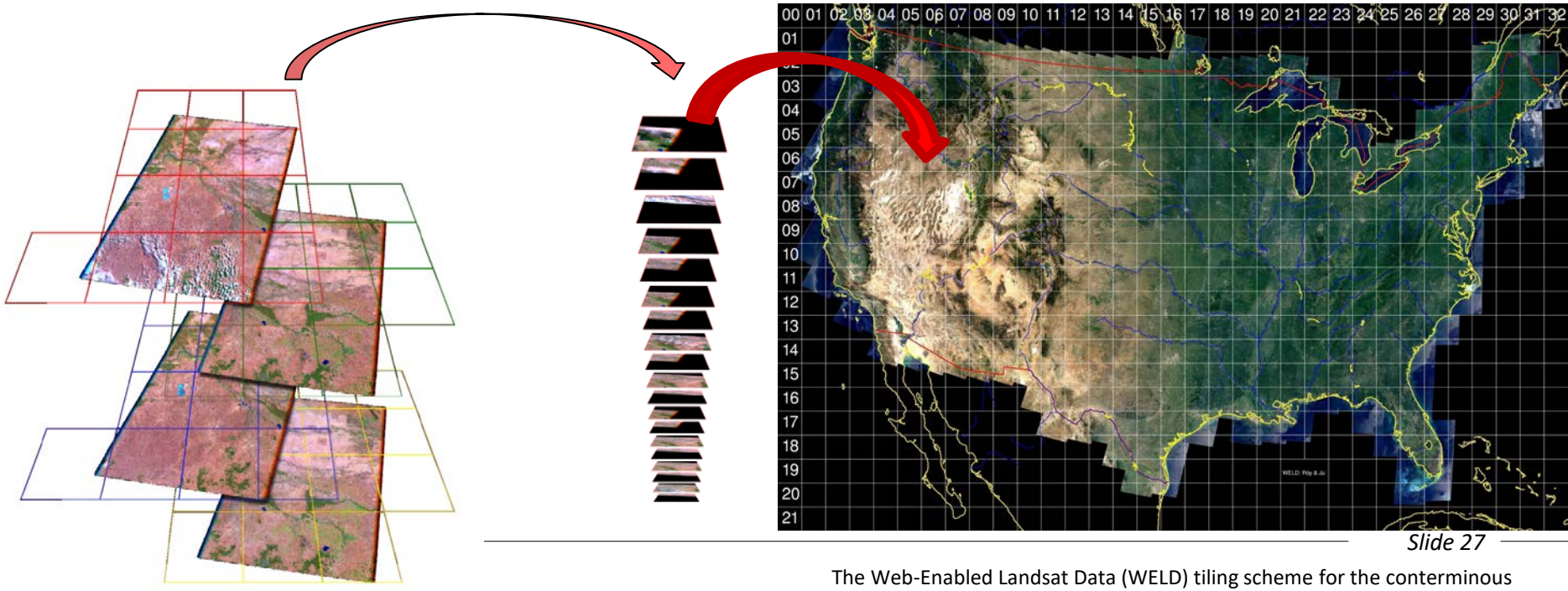


Landsat 8, path 15, row 33

Analysis Ready Data (ARD)

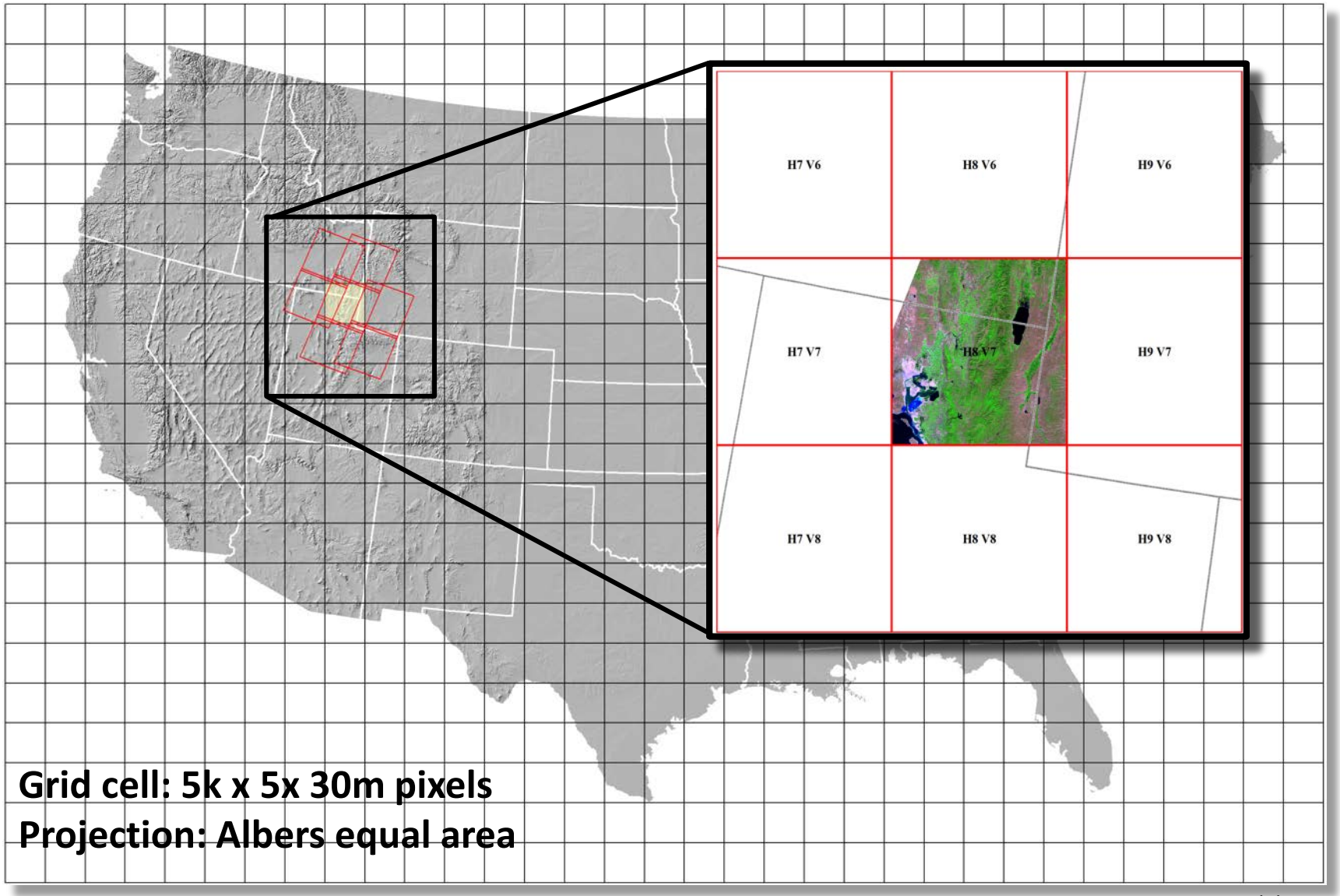
Data processed to a level that enables direct use in applications

- Allows geospatial, multi-spectral, and multi-temporal manipulations for the purposes of data reduction, analysis, and interpretation
- Consistent radiometric processing scaled to **TOA and surface reflectance**
- Consistent geometry including spatial coverage and cartographic projection – e.g., **pixels align through time**
- Metadata of sufficient detail on data provenance, geographic extent, scaling coefficients, and data type



The Web-Enabled Landsat Data (WELD) tiling scheme for the conterminous U.S. being adapted for the LCMAP ARD (graphic courtesy of David Roy, SDSU).

ARD grid system



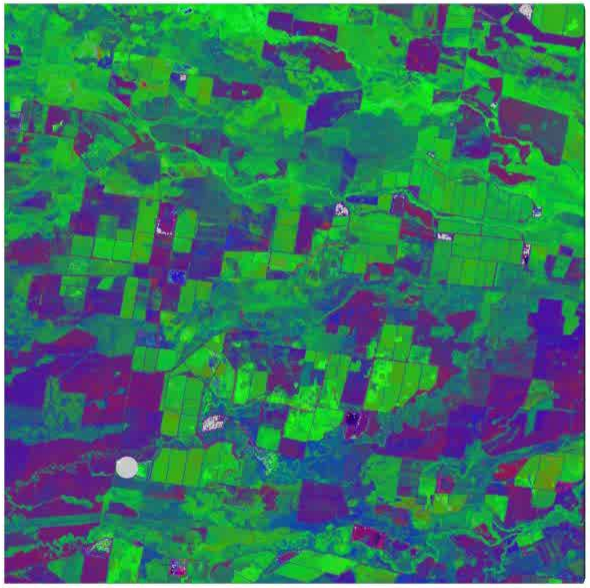
Grid cell: 5k x 5x 30m pixels

Projection: Albers equal area

USGS

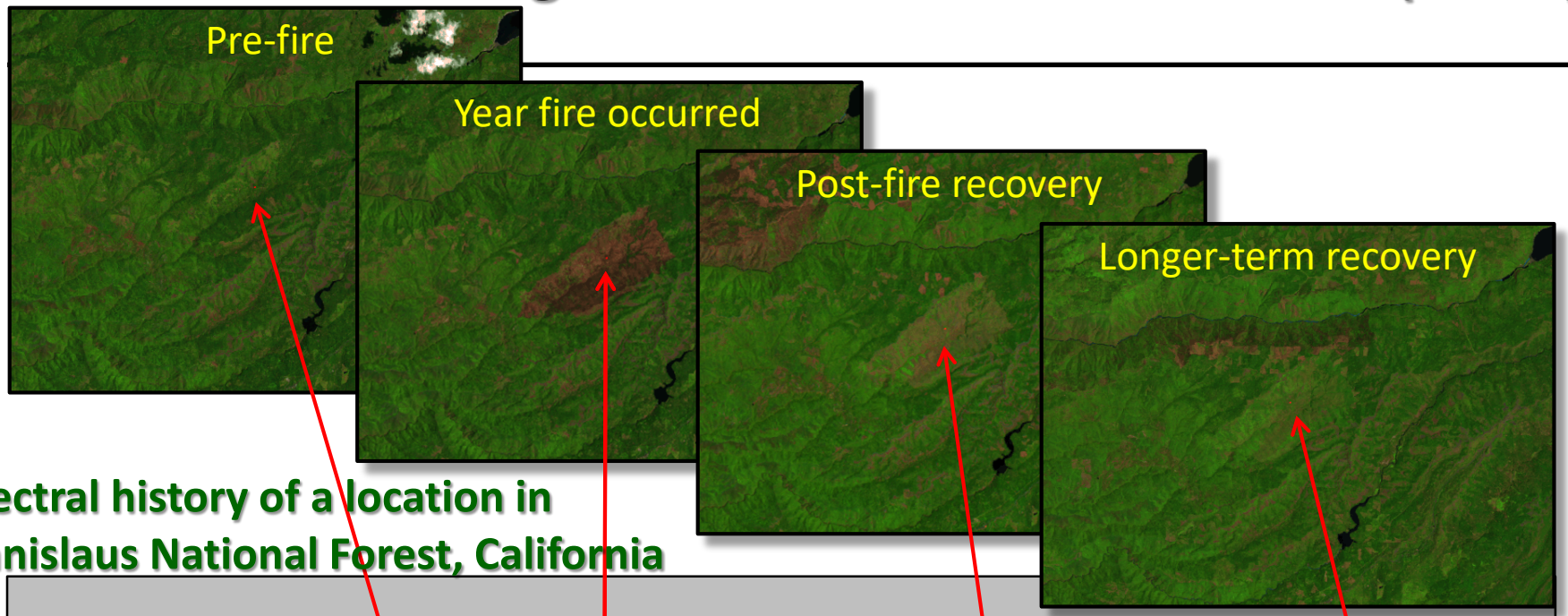
Data cube time-series analysis

Land Management – Keytah Station. ‘Fractional cover’

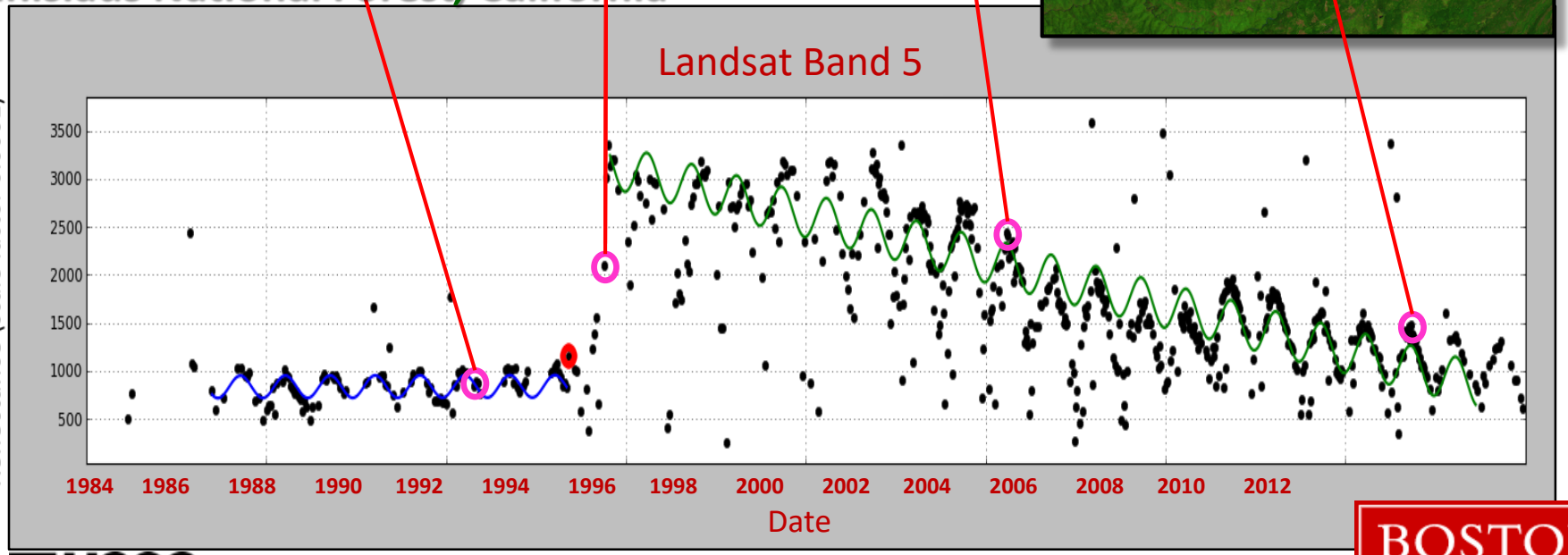


Used with permission by Dr. Stuart Minchin, Geoscience Australia

Continuous Change Detection and Classification (CCDC)



Spectral history of a location in Stanislaus National Forest, California

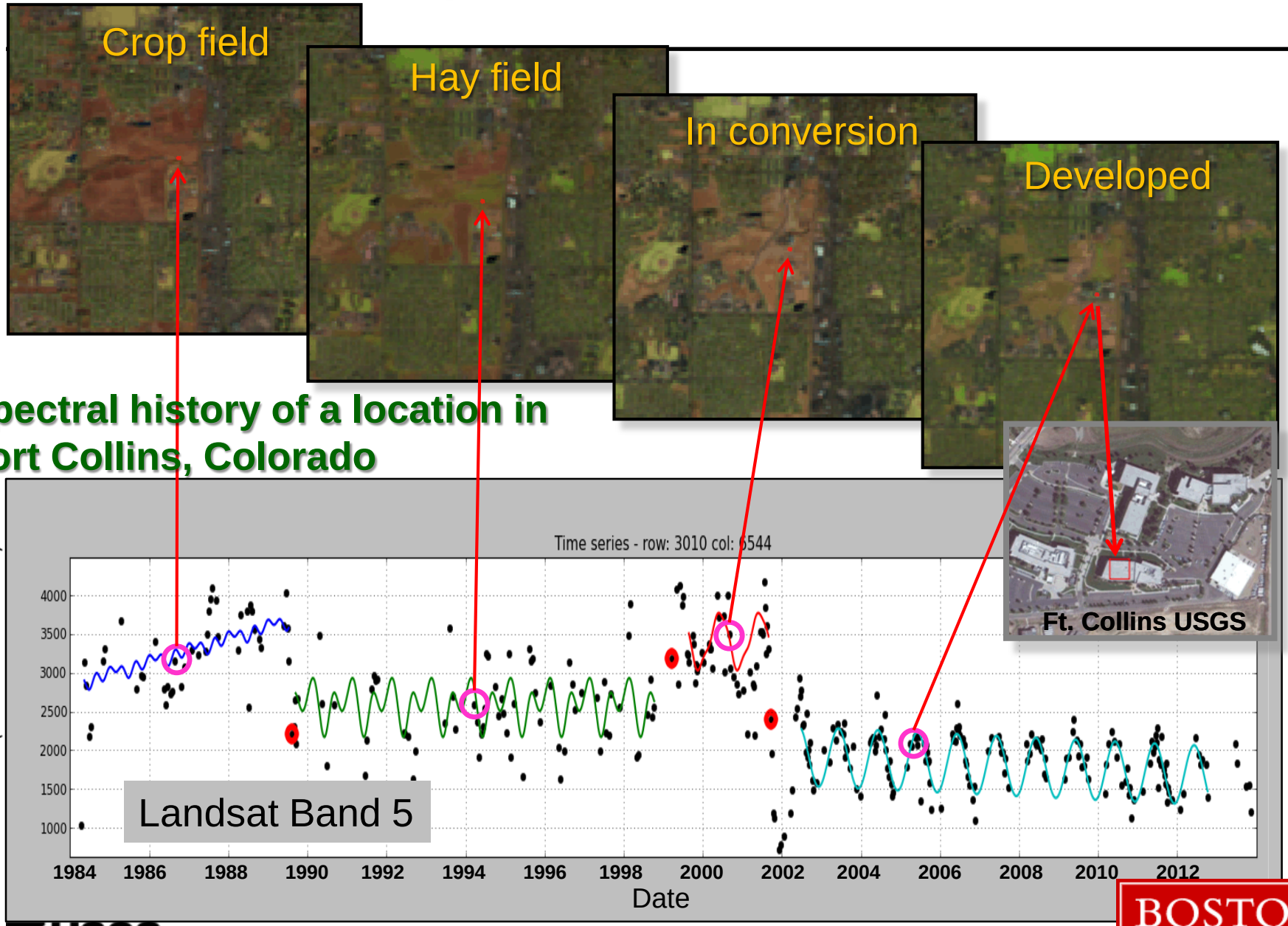


USGS

Zhu, Z. and C.E. Woodcock. 2014. Continuous change detection and classification of land cover using all available Landsat data. Remote Sensing of Environment 144:152–171.

BOSTON UNIVERSITY

Continuous Change Detection and Classification (CCDC)



Zhu, Z. and C.E. Woodcock. 2014. Continuous change detection and classification of land cover using all available Landsat data. Remote Sensing of Environment 144:152–171.

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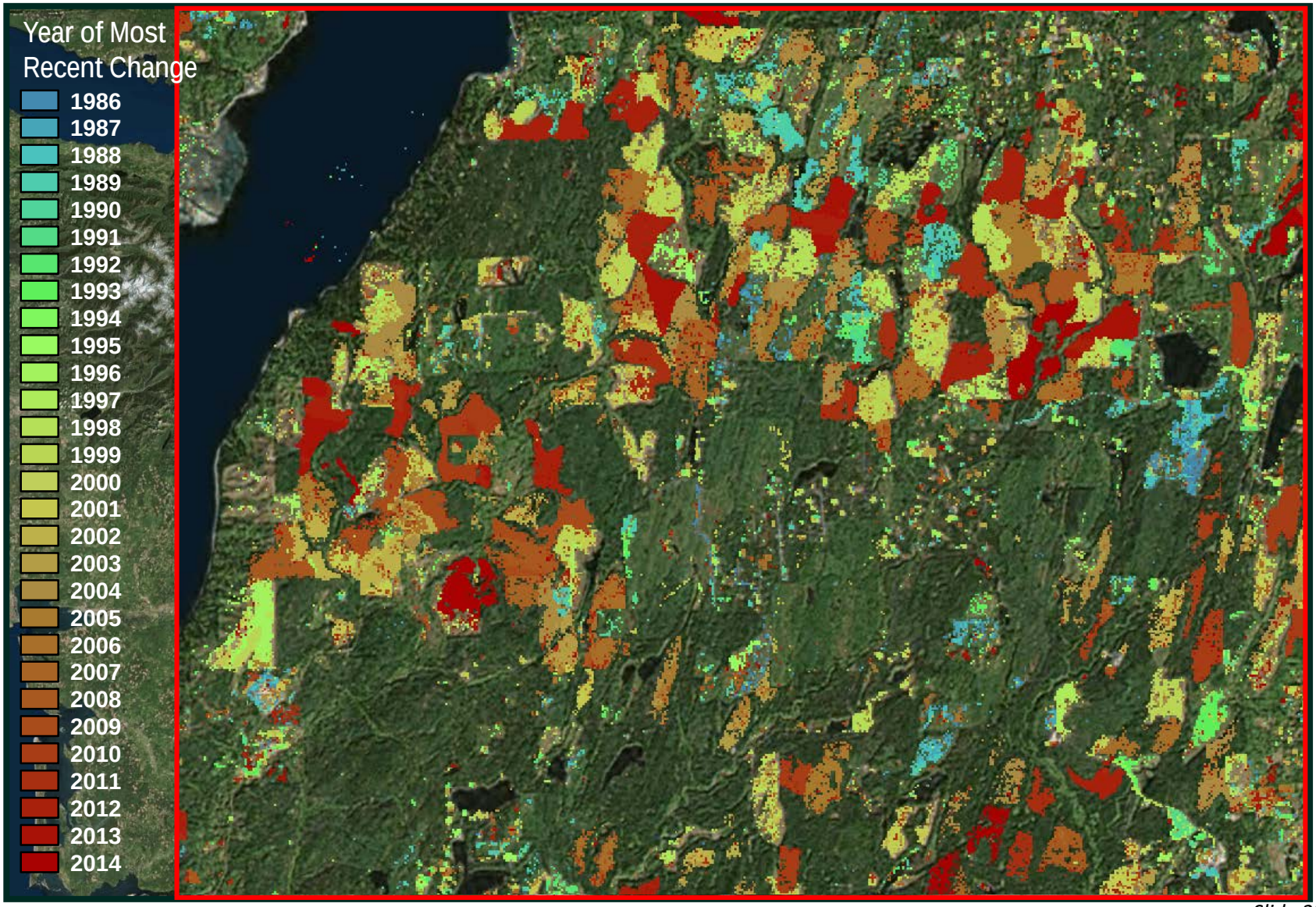
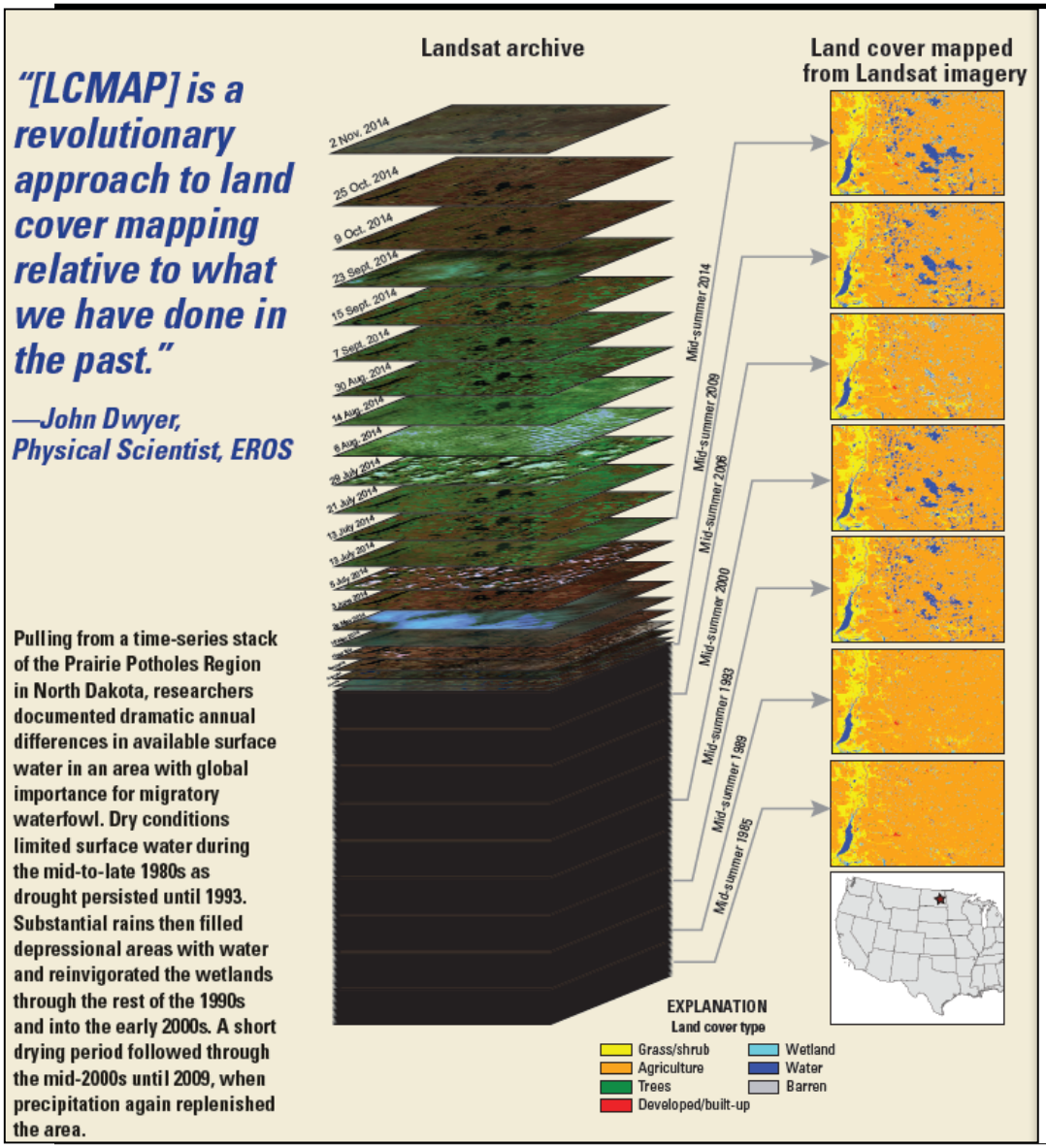
Pacific Northwest study area (timing of change)



USGS

LCMAP – Land Change Monitoring, Assessment, and Projection



- Based on Analysis Ready Data (ARD)
- Continuous change detection and classification (CCDC)
- Initial CONUS, AK, HI, 1985-2015 validated capability in Nov. 2017
- Enables:
  - Characterize historical land change at any point across the full Landsat record (1972-present)
  - Detect land change as it occurs
  - Provide near-real time alerts to land managers and other stakeholders on change events within their areas of interest
  - Provide annual summaries of US land change rates and causes

USGS

Free and open ARD & LCMAP algorithms on GitHub

- https://github.com/USGS-EROS (organization account)
  - /lcmap-pyccd
    - python continuous change detection
  - /lcmap-pyclass
    - python classification implementation
  - /espa-surface-reflectance
    - / lasrc (Landsat Surface Reflectance Code)
      - Fortran and C versions for Landsat 8
    - / ledaps (Landsat Ecosystem Disturbance Adaptive Processing System)
      - Scripts for Landsat 4-7

USGS

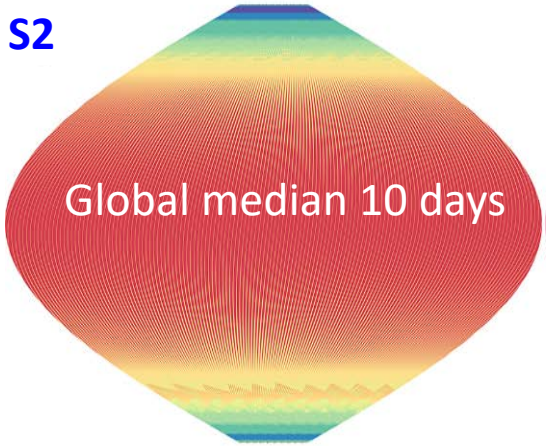
Installation of Landsat Science Team 2018-2023

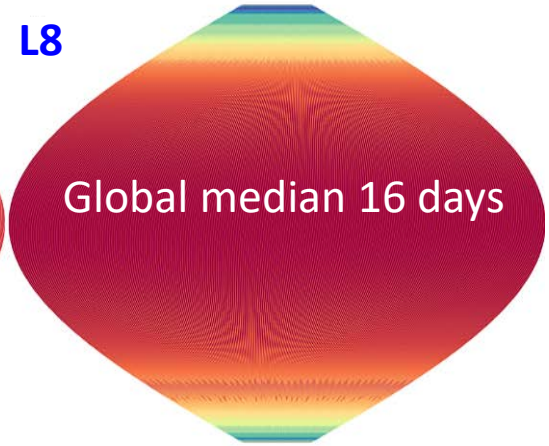
21 members: Academia (7), U.S. Gov (6), International (5), Industry (3)

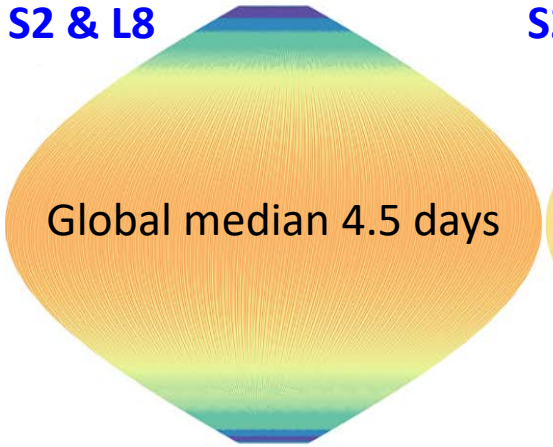
Directives

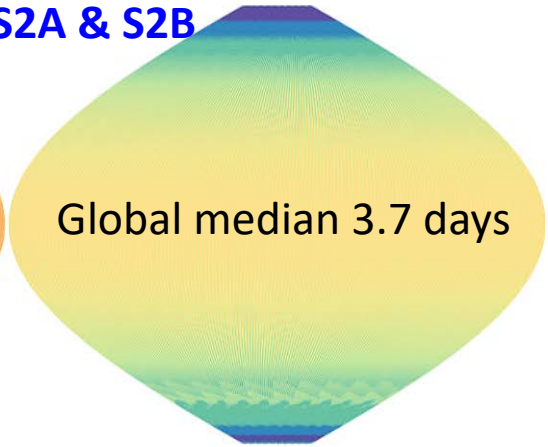
- Inform Landsat 10 design and development via NASA-USGS **Architecture Study Team (AST)**
- Inform definition and preparation for **Global Analysis Ready Data** (ARD)
- Inform continued development of **Land Change Monitoring, Assessment, and Projection** (LCMAP) initiative
- **Landsat harmonization with comparable and complementary data** (Sentinel 2 and small sats)

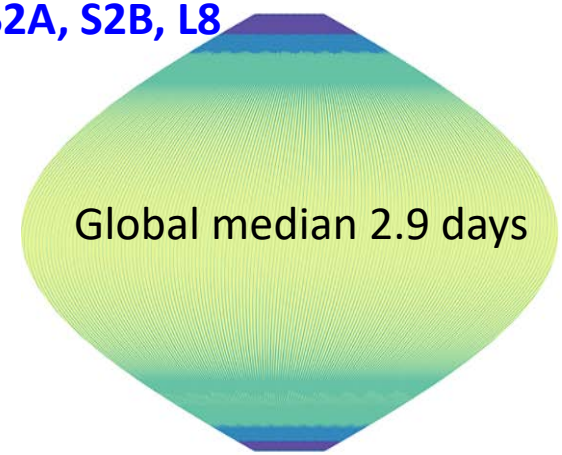
Increase in revisit intervals combining Landsat 8 and Sentinel 2

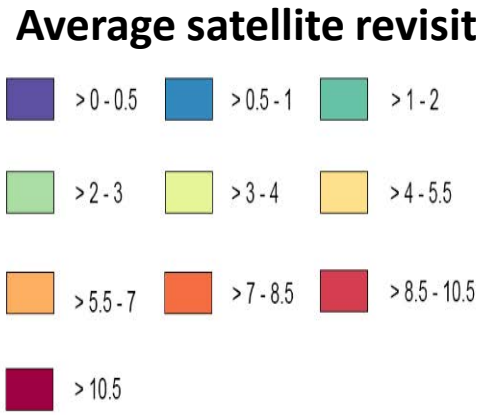








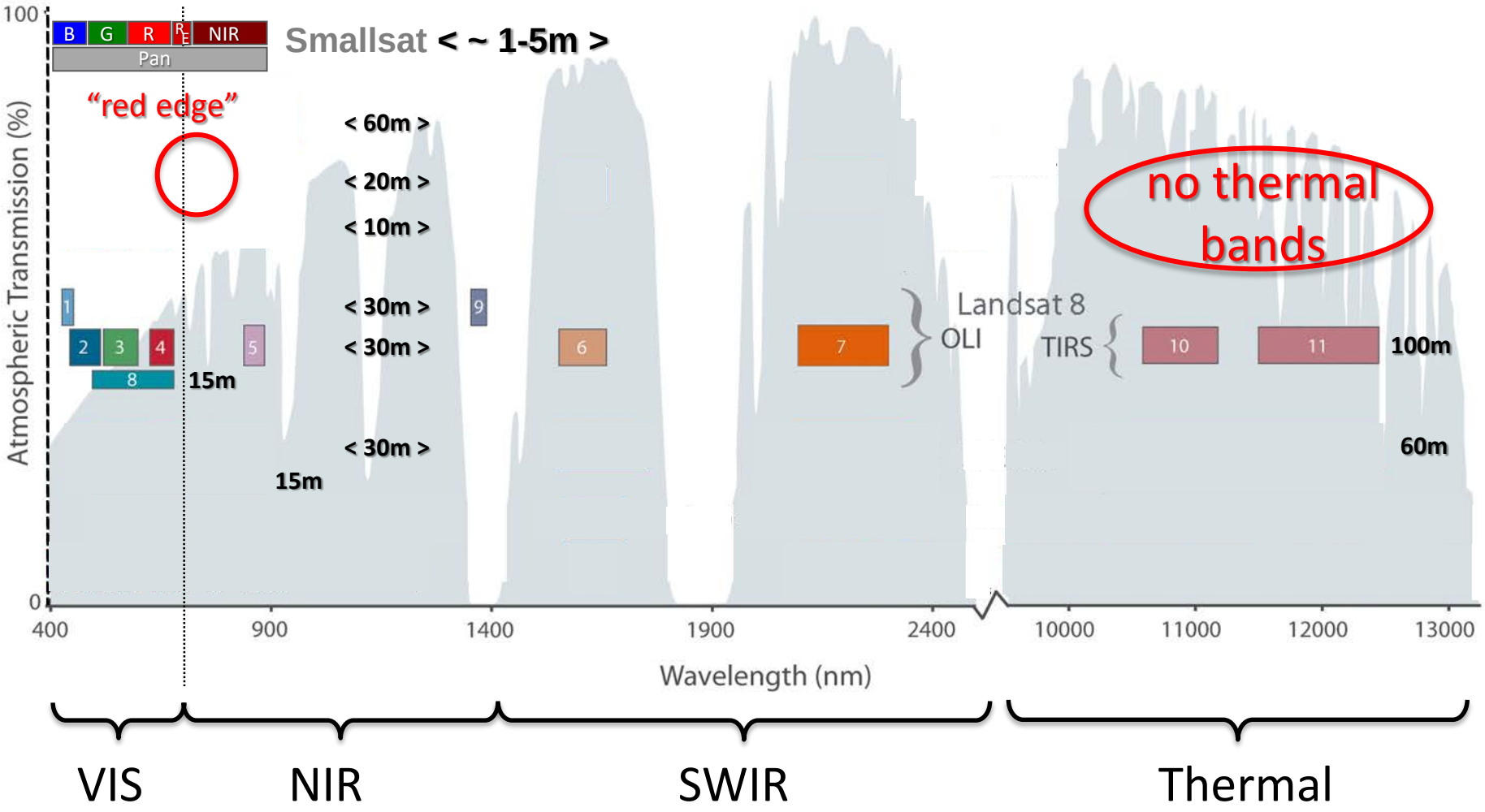




Li, J and Roy, D.P. 2017
A global analysis of Sentinel-2A, Sentinel-2B and Landsat-8 data revisit intervals and implications for terrestrial monitoring, *Remote Sensing*, 9, 902.

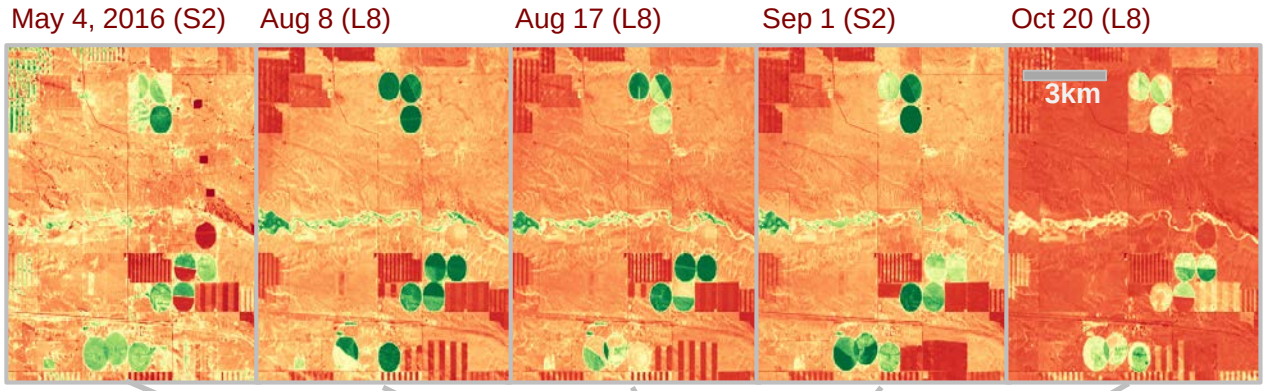
Spectral considerations

		Landsat	Sentinel-2
inclination	(deg)	98.22	98.56
orb height	(km)	705	786
period	(min)	98.8	100.65
swath	(km)	185	290
revisit	(day)	16	10

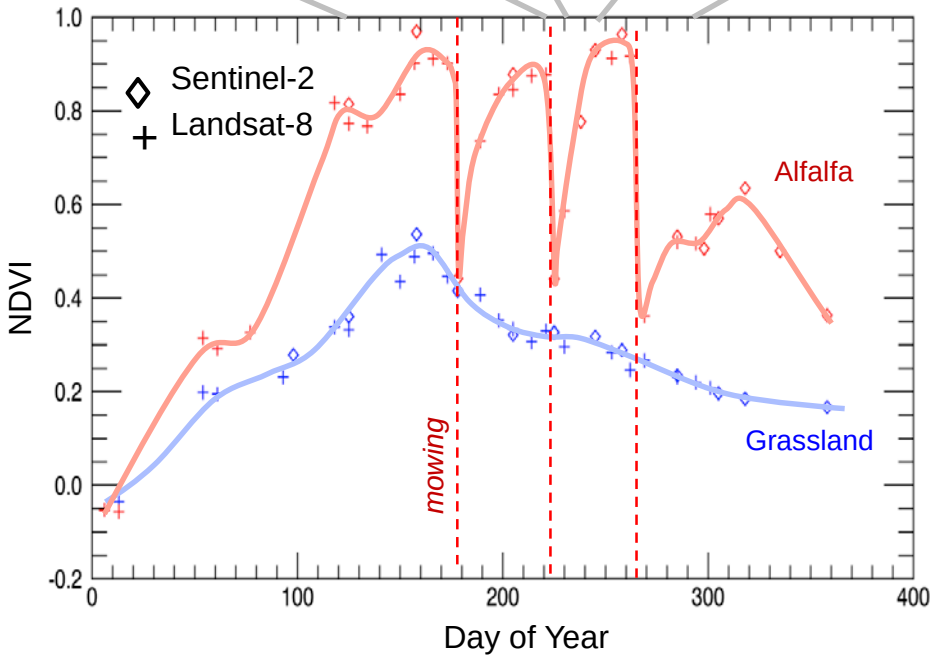


Harmonized Landsat / Sentinel-2 Products

Laramie County, WY

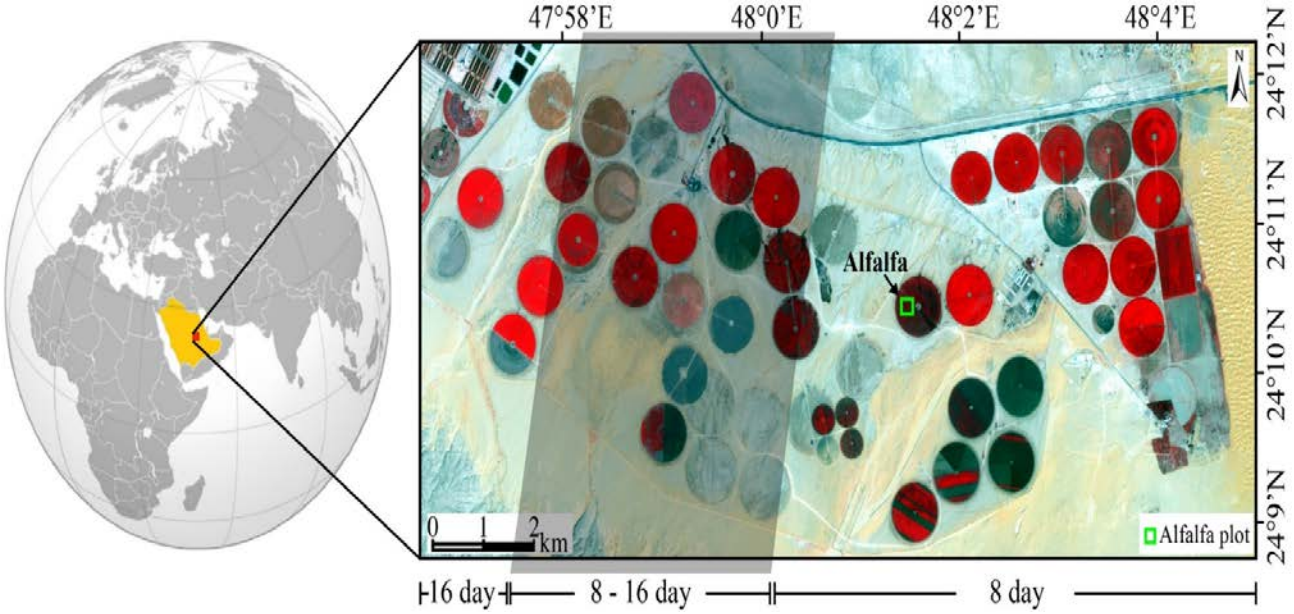


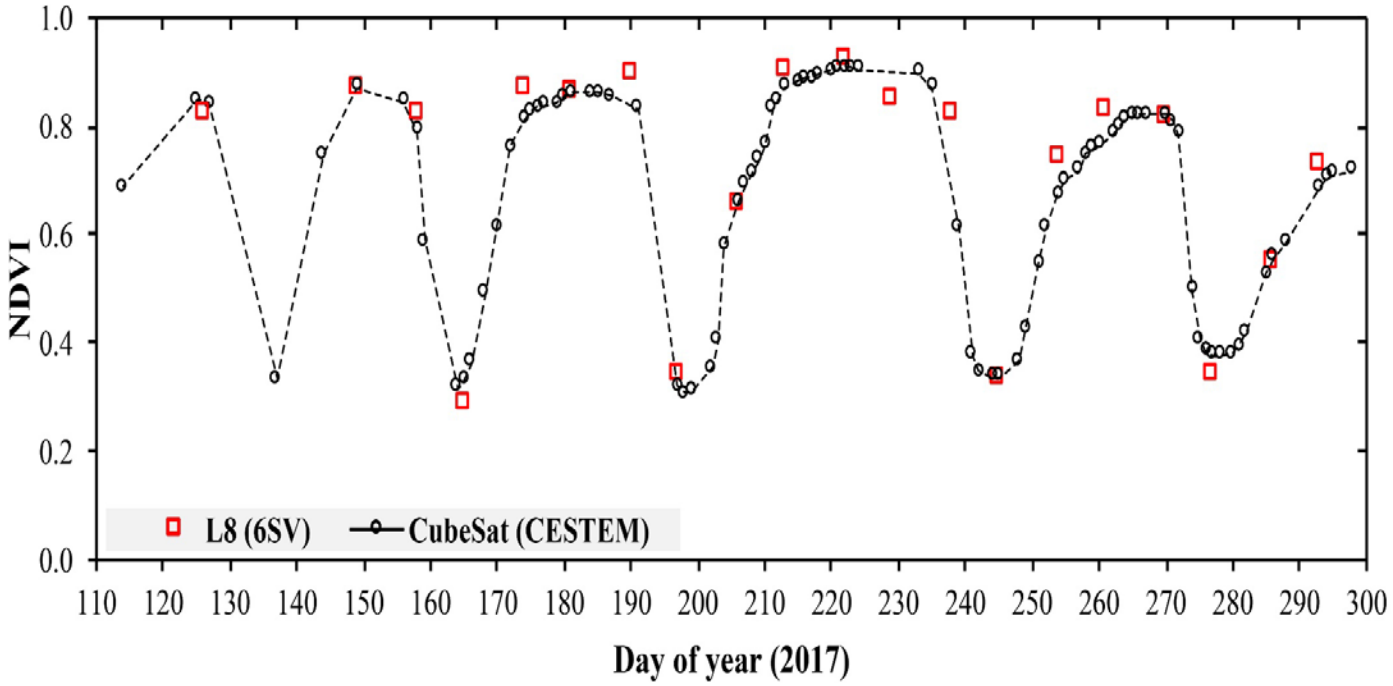
Borrowed from Jeff Masek, NASA



Seasonal phenology (greening) for natural grassland (blue line) and irrigated alfalfa fields (red line) near Cheyenne Wyoming observed from Harmonized Landsat/Sentinel-2 data products. The high temporal density of observations allows individual mowing events to be detected within alfalfa fields. HLS Products available from https://hls.gsfc.nasa.gov

Leveraging Cubesat data with Landsat 8 and MODIS





Houborg, R. and McCabe, M., 2018. *Remote Sensing of Environment, 209; 211-226.*
"A Cubesat Enabled Spatio-Temporal Enhancement Method (CESTEM) utilizing Planet, Landsat and MODIS data."

Summary

- **Sustainable Land Imaging (NASA/USGS)**
  - Landsat 9 on target for Dec 2020 launch
  - Landsat 10 mid-2018 architecture study init

- **Landsat science**
  - Science team 2018-2023 in place
  - Analysis Ready Data roll out Nov. 2017
  - LCMAP/time-series analysis moving ahead
  - Harmonization of Landsat and Sentinel 2 (HLS)

- **Decadal Survey recommendations / challenges**
  - User Needs
  - Private partnerships and international interactions
  - IT modernization / use of cloud
  - Leveraging new imaging technology

Backup

Landsat Observer Link

Data storage scaling

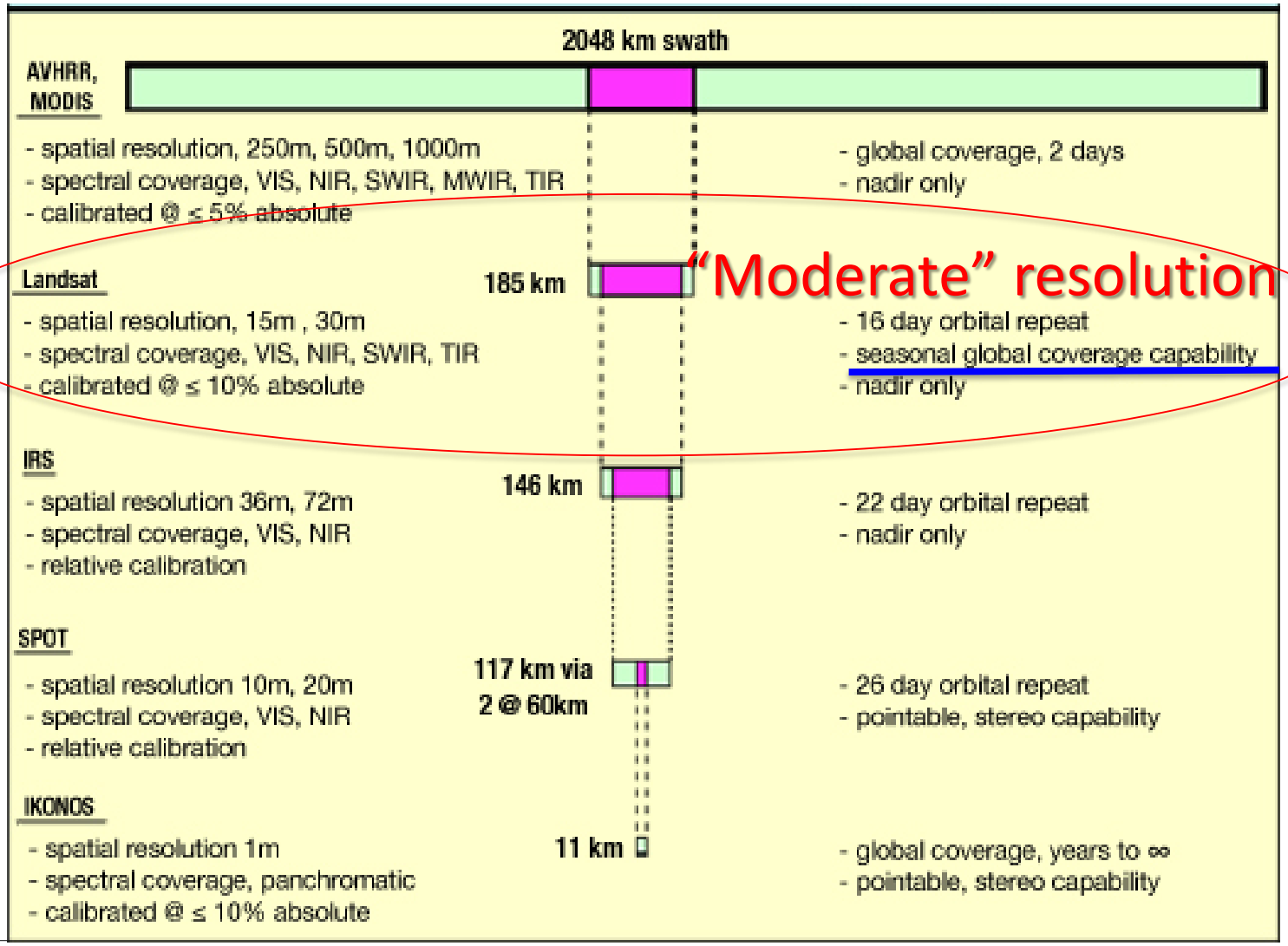
Mission	Landsat 8/9	Landsat 10	
System Attributes	Multispectral (30m, 11 bands, 8 day)	SuperSpectral (10m, 26 bands, 3 day)	HyperSpectral (30m, 150 bands, 3 day)
Image Size	1.27 GB	28.9 GB	18.5 GB
Daily Images Ingested	1365	3639	3639
Daily Ingest Volume	1.7 TB	105.0 TB	67.3 TB
Number of Images/yr.	498,068	1,328,181	1,328,181
Ingest Size/yr.	**631.6 TB**	**38.3 PB**	**24.6 PB**

- L10 estimates are not based upon any particular space architectures to achieve attributes.

- Instrument cost increase going from super to hyper spectral are speculated to be much less significant than ground segment cost increases (downlink, processing, storage, and distribution).

USGS

Global coverage: everywhere vs. anywhere



Spatial Resolution

Global Refresh Rate

USGS

Fig : Landsat 7 Science Data Users Handbook (2010), NASA

USGS Requirements, Capabilities & Analysis (RCA)

- **National Land Imaging's RCA activity uses many sources for requirements**
  - Broad range of traditional and emerging application areas within DOI, USDA, EPA, NOAA, NASA, other civil agencies, state and academic users, and some international and industry needs
  - Users identified from OSTP EOA (2016) engagement, referrals from the Landsat Science Team, USGEO Satellite Needs Working Group, partner agencies, other working groups, AmericaView, an RFI, and registered Landsat/Sentinel users
- **RCA captures information about:**
  - Spectral, Spatial and Temporal Resolution – primary attributes
  - Other attribute information including accuracy, data latency, data services and formats and other conditions for sampling (e.g., data/night collection), and geographic coverage
- **RCA uses expert elicitation, ensuring robust and mature requirements**
  - Expert elicitation techniques employed (probing questions to decouple requirements from specific technologies and explore application and experiences)
  - Iterative discussion helps to refine and solidify needs (SMEs asked to justify stated requirements in terms of the spatial scale of what they're trying to observe or discern, the rate of change of what is being observed, specific vegetation phenology, etc.)

USGS

LRS: National Civil Applications Center (NCAC)

Mission One - Saving lives

- **Natural Hazards / Disasters**

Detection, Assessment, Response, Mitigation

Volcanoes	Earthquakes
Wildfires	Landslides
Floods	Hurricanes

- **Scientific Research**

Land, Water, and Resource Management
Environmental Change Detection

- **Mapping, Charting, and Geodesy**
- **Exploitation of National Technical Means (NTM) and Commercial Imagery**

USGS

Landsat Science Team Members (2018-2023)

- **Drs. Martha Anderson and Feng Gao**, USDA Agricultural Research Service: Characterizing crop water use, phenology and yield at field scales using multi-sensor data fusion.
- **Mr. Noel Gorelick**, Google: Driving cloud-based usage of Landsat with Google Earth Engine
- **Dr. Matthew Hansen**, University of Maryland: Generating time-series maps that accurately reflect land change area: a strategy for global land monitoring
- **Dr. Sean Healey**, US Forest Service: Landsat science and applications in the US Forest Service
- **Dr. Patrick Hostert**, Humboldt University of Berlin: Synergies between future Landsat and European satellite missions, from land cover to land use
- **Dr. Justin Huntington**, Desert Research Institute: Towards the development and integration of Landsat evapotranspiration ensembles and climate data for enhanced water and land management decision support
- **Mr. David Johnson**, USDA National Agricultural Statistics Service: Leveraging analysis ready Landsat products for use in crop production estimation
- **Dr. Leo Lymburner**, Geoscience Australia: Digital Earth Australia
- **Dr. Alexei Lyapustin**, NASA GSFC: Advanced atmospheric correction of Landsat 8/Sentinel 2 data using algorithm MAIAC
- **Dr. Nima Pahlevan**, Science Systems and Applications, Inc.: Landsat-Sentinel-2 constellation for monitoring aquatic systems across the United States
- **Mr. Jean-Francois Pekel and Dr. Peter Strobl**, European Commission Joint Research Centre: Copernicus Landsat convergence, architecture and applications
- **Dr. Volker Radeloff**, University of Wisconsin: Landsat data for biodiversity science and conservation
- **Dr. David Roy**, South Dakota State University: Pathfinding near real time moderate resolution land surface monitoring, looking forward to an operational Landsat 9/10 Sentinel 2A/2B era.
- **Dr. Ted Scambos**, University of Colorado: Landsat and the cryosphere: tracking interactions between ice, snow, and the Earth system
- **Dr. Crystal Schaaf**, University of Massachusetts, Boston: Global 30m snow and snow-free land surface albedo from Landsat and MODIS/VIIRS
- **Dr. Eric Vermote**, NASA Goddard Space Flight Center: Maintenance and refinement of the Land Surface Reflectance Code (LaSRC) for Landsat's and Sentinel 2's
- **Dr. Curtis Woodcock**, Boston University: New opportunities using the Landsat temporal domain: monitoring ecosystem health, condition and use
- **Dr. Michael Wulder**, Canadian Forest Service: Integrating time and space with Landsat to learn from the past, monitor the present, and prepare for the future
- **Dr. Zhe Zhu**, Texas Tech University: Toward near real-time monitoring and characterization of land surface change for the conterminous US

USGS

U.S. Government (6)
U.S. Academia(7)
International (5)
Private Industry (3)

International Charter Space & Major Disasters

The International Charter executes priority tasking of different EO missions in a rapid fashion; it is designed to address requests concerning major disasters caused by:

Natural events

- Earthquakes
- Fires
- Floods
- Ice jams
- Landslides
- Tsunamis
- Ocean storms
- Volcanic eruptions

Man-made events

- Oil spills
- Industrial accidents





Charter Activations
(disaster types)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Sub-totals	
Solid Earth																			
Earthquake		3	1	3	5	3	2	5	4	3	5	5	3	4	1	5	1	53	**105**
Landslide	1	1	2	2			1			4	2	2		1	4	2		22	
Volcano		1	1	2	2	1	1	2	3	3	2	2	1	3	2	4		30	
Technological																			
Oil spill		3	2				4	3			1	1				1		15	**23**
Others					1						3			1	2	1		8	
Weather / Atmospheric																			
Fire				5	1	2		4	2	4	1	3	2	2	3	2		31	**358**
Flood/Ocean wave*		3	8	4	9	13	16	22	23	19	25	16	25	21	22	18	3	247	
Ice/Snow hazard								1			1	1			1			4	
Storm/Hurricane**			1	2	3	6	1	8	8	7	11	2	9	6	6	5	1	76	
Total / year	**1**	**11**	**15**	**18**	**21**	**25**	**25**	**45**	**40**	**40**	**51**	**32**	**40**	**38**	**41**	**38**	**5**		
TOTAL																			**486**

*Includes solid earth related phenomenon of a tsunami.

**Includes all wind type storms (hurricane, cyclone, typhoon and tornado).

Charter Members

Landsat Collections

- Since announcing the free and open data policy, demand for the data caused a shift from on-demand delivery to immediate access
- Collections provide a consistent archive of known data quality to support time series analyses and data "stacking", while controlling continuous improvement of the archive and access to all data
- In 2017, USGS will complete the first "collection" of Level-1 data products
  - TM, ETM+, and OLI_TIRS is complete
  - MSS and some anomalous TM data will be completed by the end of the calendar year
- Through collections, the whole archive is available but is categorized into three tiers
  - Real-time – Data that doesn't have the final ancillary data yet to produce the highest quality product possible
  - Tier-1 – Data that is enabled for "stacking" (validated that it meets a 12m RMSE threshold)
  - Tier-2 – Data that doesn't meet "stacking specification" or can't be validated that it meets it
- Additional information can be found at
  https://landsat.usgs.gov/landsat-collections

Past attempts at Landsat commercialization

- **Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365)**
  - Belief that remote sensing would easily follow the path set by commercial telecommunications satellites
  - NOAA selected EOSAT Corp. to operate satellites, sell data, develop new missions
  - By 1992, the venture was deemed a failure
    - Prices rose significantly, stifling the user market
    - EOSAT ceased global collection of imagery
    - Instrument characterization and calibration were degraded, reducing the data's usefulness
    - EOSAT opportunities for commercial expansion were limited, particularly facing new competition from the French SPOT satellite
  - To ensure future continuity of Landsat data and operations, Federal development and operations were restored under the Land Remote Sensing Policy Act of 1992 (P.L. 102-555)

- **Landsat Data Continuity Mission Data Buy (2002)**
  - After the successful launch of Landsat 7, NASA attempted to outsource Landsat as a 'Data Buy' that would combine assurance of public and private data rights
  - NASA awarded two study contracts -- to Resource21 and DigitalGlobe – to examine public/private partnership approaches
  - The subsequent Source Selection was cancelled as one bidder dropped out and the other bidder did not generate sufficient capital to meet the Government's terms

Despite commercialization failures, it remains an option for the future