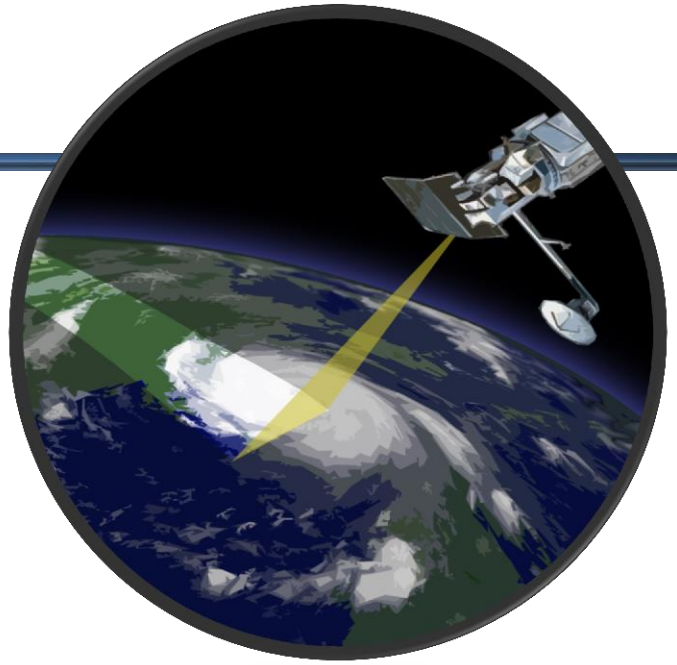
USGS
science for a changing world

USGS Perspectives on Landsat



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Challenges

- Establishing a comprehensive, integrated joint-agency **"Sustained Land Imaging Program"** with NASA, as called for by the NRC Space Studies Board in 2013, and enhancing imaging capabilities and data products via emerging technology

- Maturing and institutionalizing USGS **Requirements, Capabilities & Analysis (RCA)** processes to significantly expand user need satisfaction across USGS, DOI and the Federal Civil Community

- **Communication—** the biggest challenge

NASA/USGS Sustainable Land Imaging Program

2013 - National Research Council Space Studies Board Report: The U.S. Government should establish a "Sustained and Enhanced Land Imaging Program" with persistent funding for current and 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."

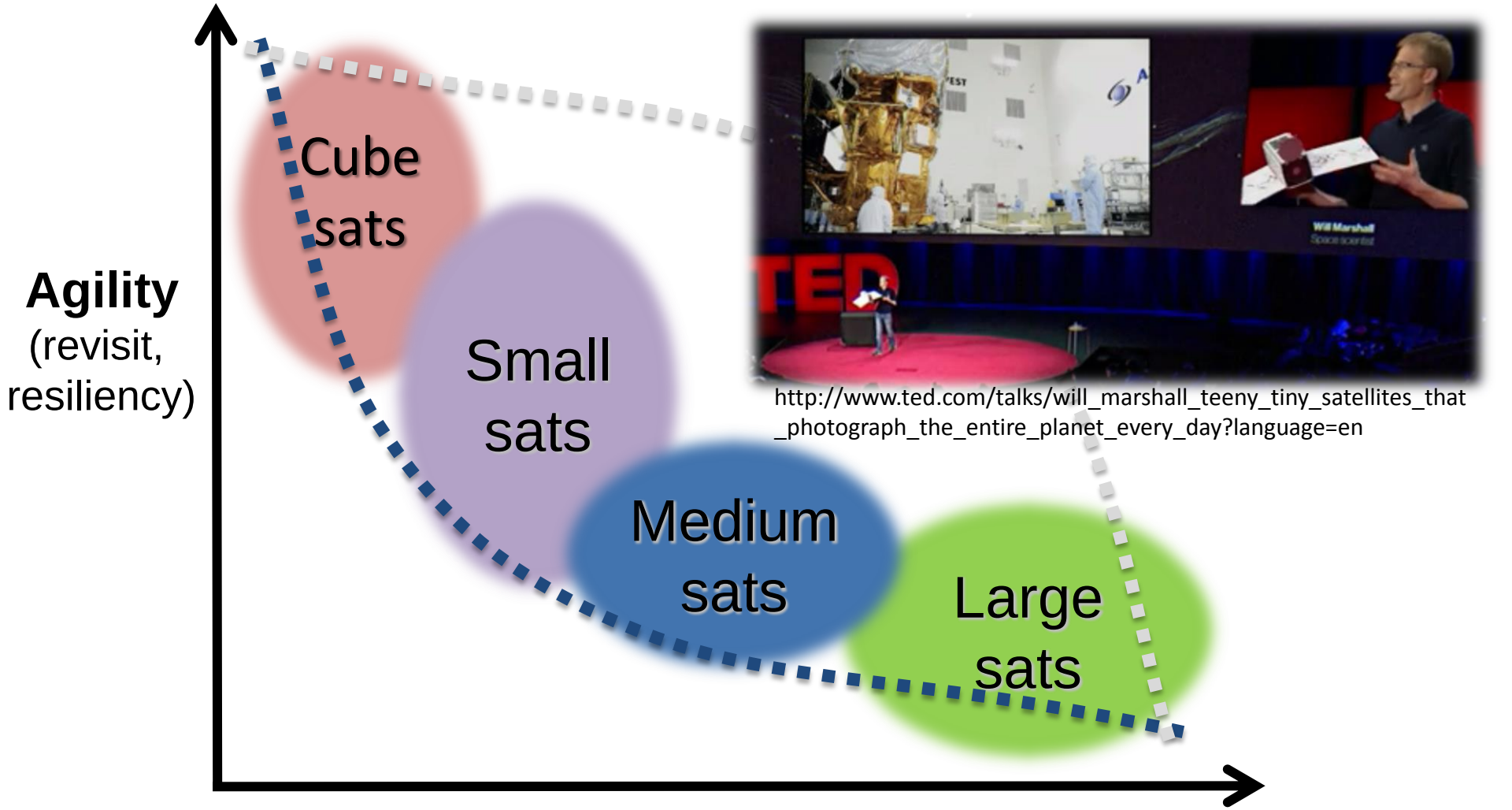
2014 - Sustainable Land Imaging Architecture Study Team Report: Established trade space via expert knowledge, RFI responses; explored hundreds of architecture alternatives via several design cycles

2015, 2016 - President's 2016, 2017 Budgets: The Sustainable Land Imaging program includes investments in technology and innovation to ensure a world class land imaging program for the next 25 years:

- Landsat 9 (fully Risk Class-B rebuild of Landsat 8) to launch in 2020/2021
  - Low programmatic risk implementation of a proven system, upgrades to bring system to Class B; intended to assure observational continuity of Landsat-Class data to the community
- Land Imaging Requirements Collection and Analysis
  - USGS is partnering with Federal agencies to document the uses of and requirements for Earth observation data, and map these requirements to a range of Earth observing systems
  - Enables the Nation's future Landsat systems to be driven by the Nation's land imaging requirements
- Land Imaging Technology and Systems Innovation
  - NASA is conducting instrument reduction studies, business model studies and other technology investigations to reduce cost and risk in next-generation Landsat missions
- **Landsat 10 (Next-generation Landsat system) to launch in mid-late 2020s**
  - Mission definition to be informed by Requirements and Technology investments in 2015 – 2018, leading to a key decision point in 2018, project initiation in 2019

Communication— messaging matters

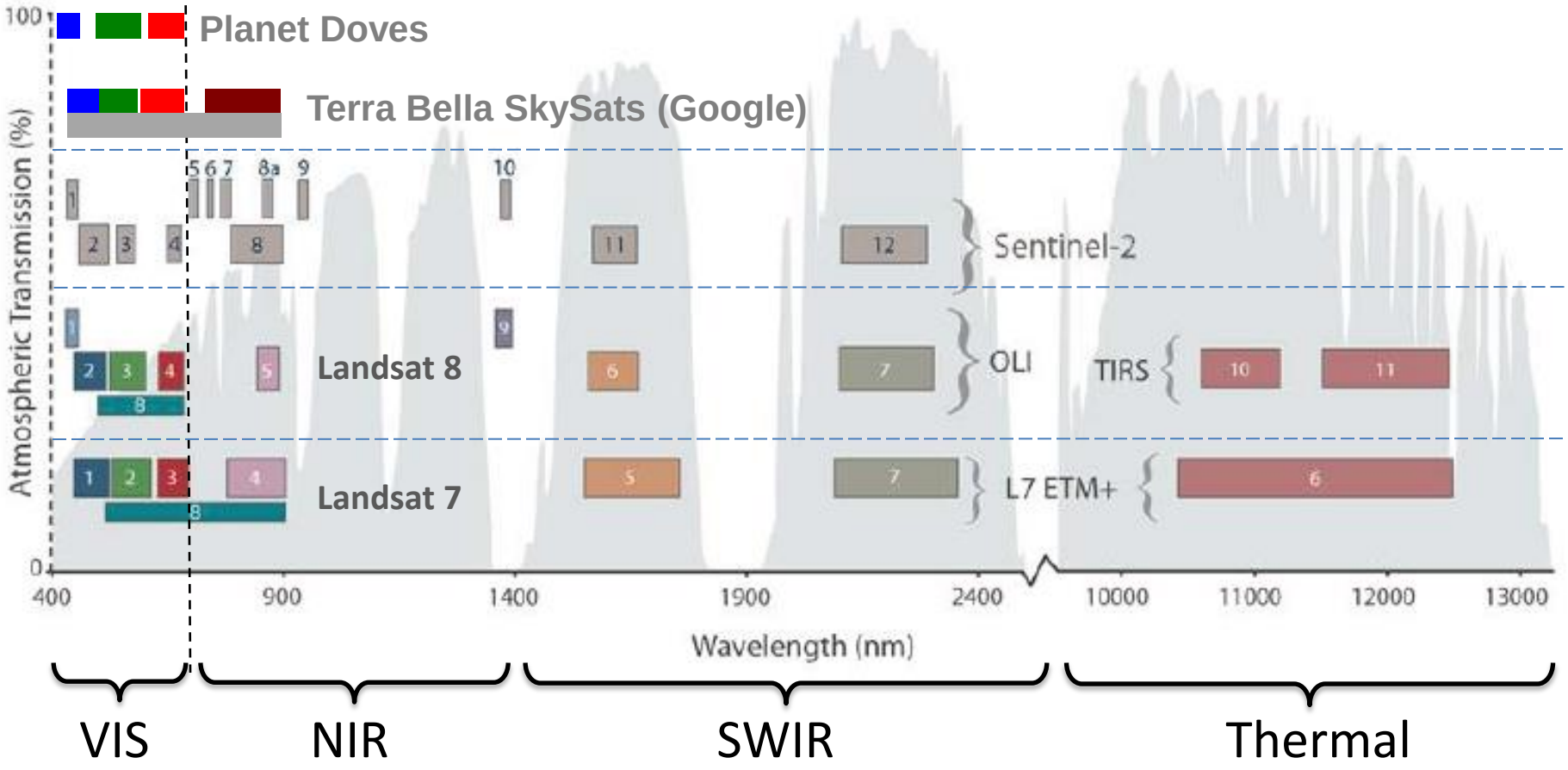
Communication— space collection architectures



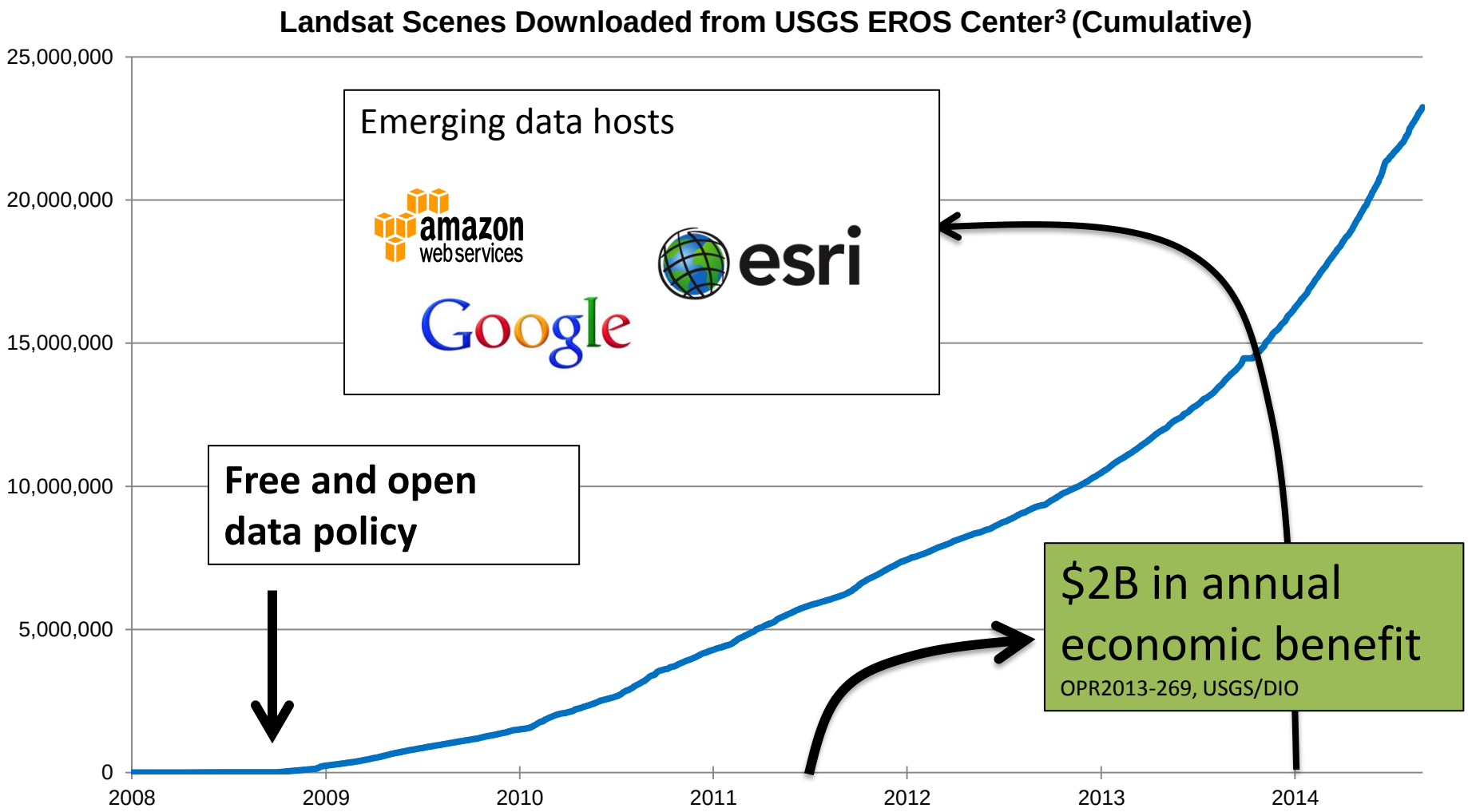
http://www.ted.com/talks/will_marshall_teeny_tiny_satellites_that_photograph_the_entire_planet_every_day?language=en

Communication— spectral content

OLI = Operational Land Imager
TIRS = Thermal Infrared Sensor



Communication— economic benefit



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Funding for Landsat 9 ground system dev. (USGS)

DEPARTMENT OF THE INTERIOR, ENVIRONMENT, AND RELATED AGENCIES APPROPRIATIONS BILL, 2017

House Report 114-(yet to be numbered), Interior, et al.

"The Committee supports existing Landsat operations and the accelerated launch schedule for Landsat-9 and therefore recommends $78,194,000, **$6,000,000 above the fiscal year 2016 enacted level, for the land remote sensing account.** Carryover balances from the satellite operations account should be applied to cover anticipated costs for Landsat-9 development.

Senate Report 114-281, Interior, et al.

"Program adjustments have been made to the sub-activities to provide an **increase of $15,400,000 for the Landsat system to stay on track with the NASA Landsat operation and plan**. The Committee is aware of the Survey's obligations to deliver the ground system for Landsat 9 on time while maintaining support functions for other program areas….."

If the House and Senate do not pass a budget this year…

Then a Continuing Resolution (CR) is likely, for either several months, or potentially a full year

- ❑ **The USGS requires full funding of the 2017 President's Budget—a $15.4M increase over the 2016 budget—to ensure a 2020 L9 launch.**

- ❑ **A full-year CR in Fiscal Year 2017 without new funding identified for the USGS Landsat 9 (L9) ground system will result in budget issues to USGS climate and land use science activities:**

How does USGS determine requirements?

USGS Requirements, Capabilities & Analysis (RCA) Activity

- Comprehensively understand US and International use of and needs for Earth observations
- Requirements Elicitation identifies fundamental information needed by the user (what needs to be observed or measured): Geographic Coverage, Horizontal & Vertical Resolution, Sampling Interval, Accuracy, Length of data record, Data latency, etc.

USGS Requirements Surveys

- USGS/NASA Landsat Applications Survey of 33 Landsat products (2012)
- USGS National Land Imaging Requirements Pilot Project with 12 federal agencies (2014)

Landsat Science Team (Co-chaired by USGS and NASA)

- 21 scientists & engineers from the Federal Government, academia & international organizations

National Geospatial Advisory Committee's Landsat Advisory Group

- Provides advice to the Federal Government on Landsat requirements, objectives and actions

DOI Remote Sensing Working Group

- Team of remote sensing experts from all DOI bureaus working together to share expertise

OSTP-led Activities

- National Plan for Civil Earth Observations (2014), Earth Observation Assessments (2012, 2016)

Others: NRC Reports, USGEO activities, AmericaView, Case Studies, User feedback

How does USGS meet requirements via capabilities?

NASA:

- Work with NASA on Landsat 9 and future Sustainable Land Imaging systems
- Use NASA earth observation systems like MODIS, ASTER, GRACE, Aura

International:

- Negotiate Bilateral agreements with European Union (for Sentinel-2 data)
- Leverage international agreements (for India's Resourcesat data)

National Security Space Systems:

- Use Civil Applications Committee to access National Security Space system data
- Digitize declassified imagery (Corona, Argon, KH-9) and make it publicly available

Aerial systems:

- Use USDA aerial imagery
- Operate unmanned aerial systems to collect data for many applications

Commercial systems:

- Leverage USGS Commercial Remote Sensing Data Contracts (DigitalGlobe and others)
- Use the Joint Agency Commercial Imagery Evaluation forum to assess satellite data

USGS:

- Make the datasets we have more accessible by enabling others to redistribute (Google, Amazon)
- Expand our menu of products based on existing datasets: create Landsat-based products like surface reflectance, surface temperature, burned area & surface water extent, biomass, Landsat JPEGs, etc.
- Conduct remote sensing research and technology investigations

Accuracy requirements from users (preliminary from RCA)

16% of the users provided information on accuracy requirements

Types of user defined accuracy

- **Geolocation accuracy**: most require less than half a pixel for vegetation index and land cover to overlay with other data sources and for change detection.
- **Radiometric accuracy**: most can't specify an exact number, but would like it to be consistent to compare spectral values over time.
- **Signal to noise ratio**: most can't specify an exact number, but stated that they are satisfied with the current level of SNR of L8 (one user specify it as 500:1).
- **Classification accuracy**: most require overall classification accuracy 80-95% for land cover, and some require particular land cover classes (crop, shrub, …,).
- **Absolute accuracy**: applies to land skin temperature (requires within a few degrees), albedo (within 0.01), LAI (within 0.3).
- **Percent accuracy**: applies to soil moisture/water content (within 5% of the water holding capacity).
- Some users ask for **"as accurate as possible"**, in lieu of specifying a requirement.

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Uncertainty propagation in remote sensing data

- Uncertainty-informed decision making may not be sufficiently supported by ***uncertainty estimates in source data***.

- Impacts of error propagation from lower to higher level products need to be understood.
  - calibration error in spectrally segmented products
  - categorical (spectral classification) error in GIS analysis ("error-aware GIS")
  - visualization of uncertainty for decision makers

- Methods
  - Analytical — probabilistic, (fuzzy, rough sets, etc.)
  - Numerical — stochastic simulation (Monte Carlo)

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Climate change and national security

Defining and communicating Landsat's role in:

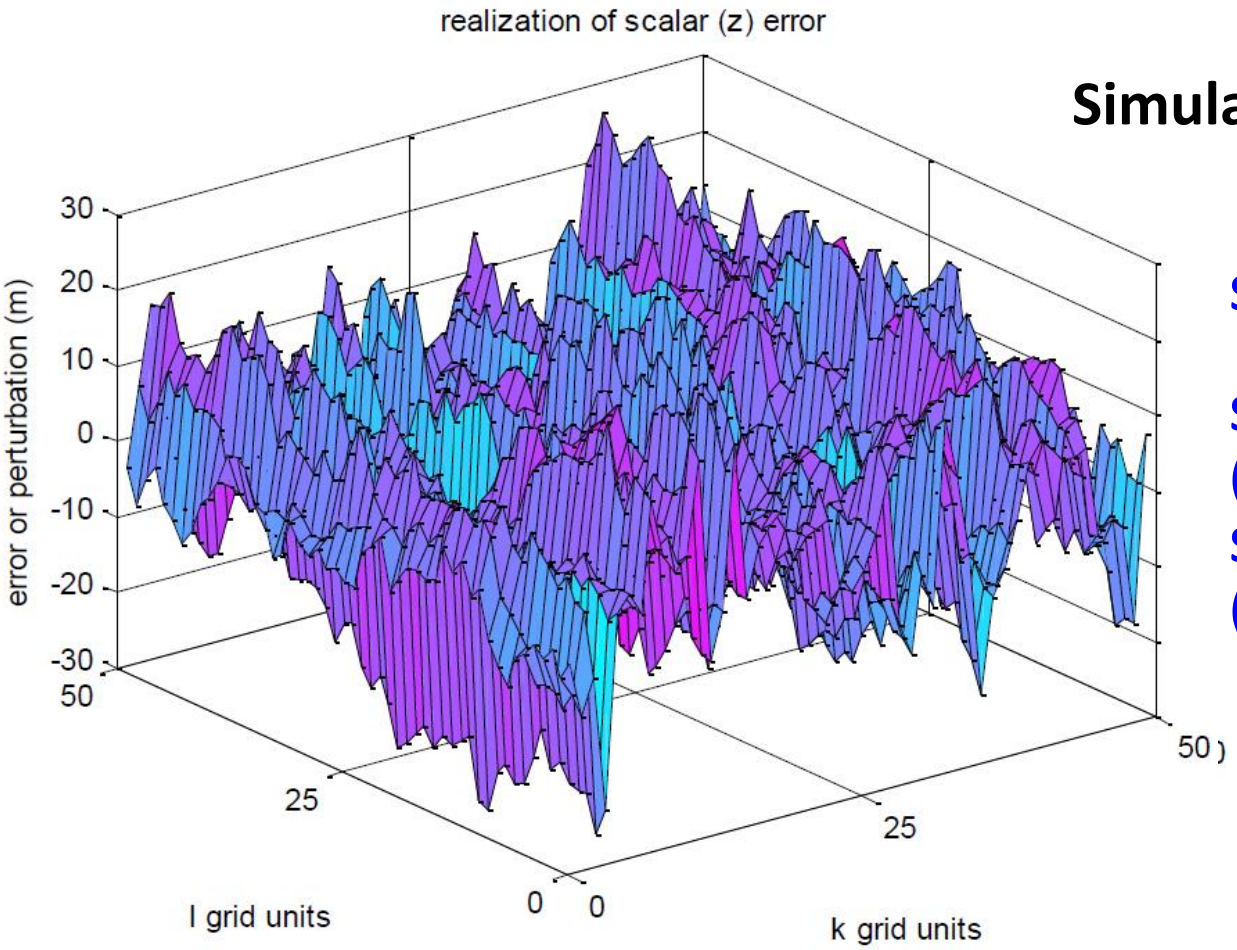
- Water– drought, flood, desertification
- Disaster early warning (e.g., famine)
- Arctic– sea ice and permafrost melt
- Sea level rise
- Carbon assessments and monitoring (COP21 Paris Agreement)
- Energy/Water/Climate nexus
- Factors driving human migration

Summary

- **Communication—**
  the biggest challenge
- **Sustained Land Imaging (SLI) Program—**
  between NASA and USGS
- **Requirements, Capabilities & Analysis—**
  across USGS, DOI and the Federal Civil Community
  - Future design for user needs (sensor collection, proc. serv, product types)
  - Communicate value of Landsat
  - Better understanding of accuracy needs (Uncertainty propagation)
- **Climate change and national security—**
  Defining Landsat/LCMAP role in broader arena

Backup

Stochastic simulation for uncertainty modeling

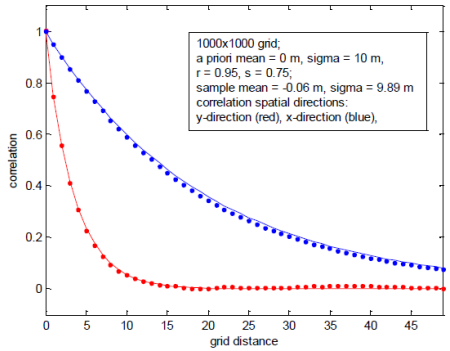


Simulating realizations

Spatially uncorrelated

Spatially auto-correlated (cor(l) = cor(k))

Spatially auto-correlated (cor(l) ≠ cor(k))



Dolloff, J., and Doucette, P. (2014). The Sequential Generation of Gaussian Random Fields for Applications in the Geospatial Sciences. *ISPRS Int. Journal of Geo-Information,* 3, pp. 817-852.

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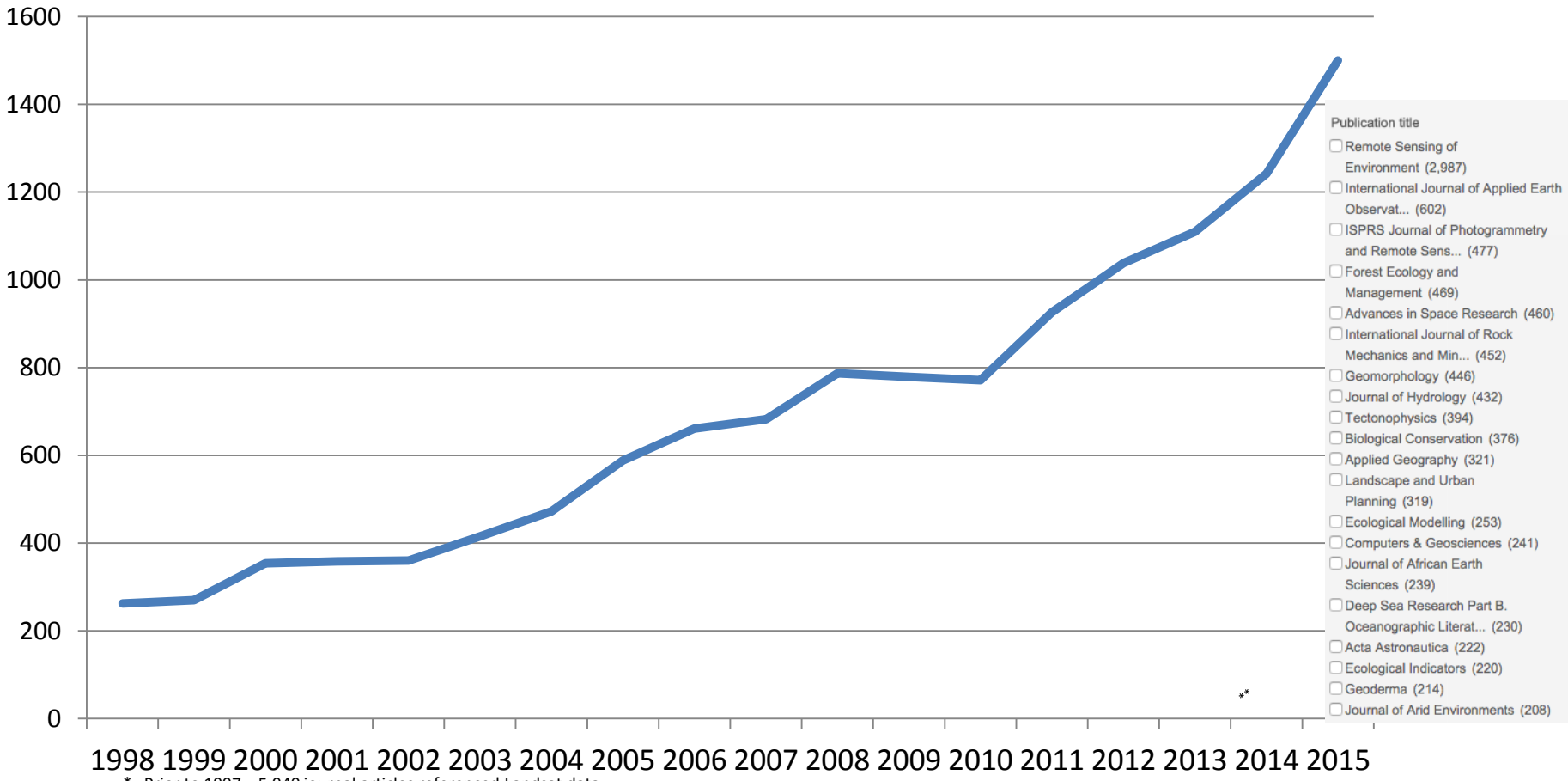
Landsat science publication

Number of Publish Science Journal Articles Referencing Landsat Data *(per year)*



* Prior to 1997 - 5,940 journal articles referenced Landsat data

** 2016 – Current Results 1,216 journal articles referenced Landsat data

Source: Search Results of the Science Direct Database (using keyword "Landsat") - cumulative results total 19,736

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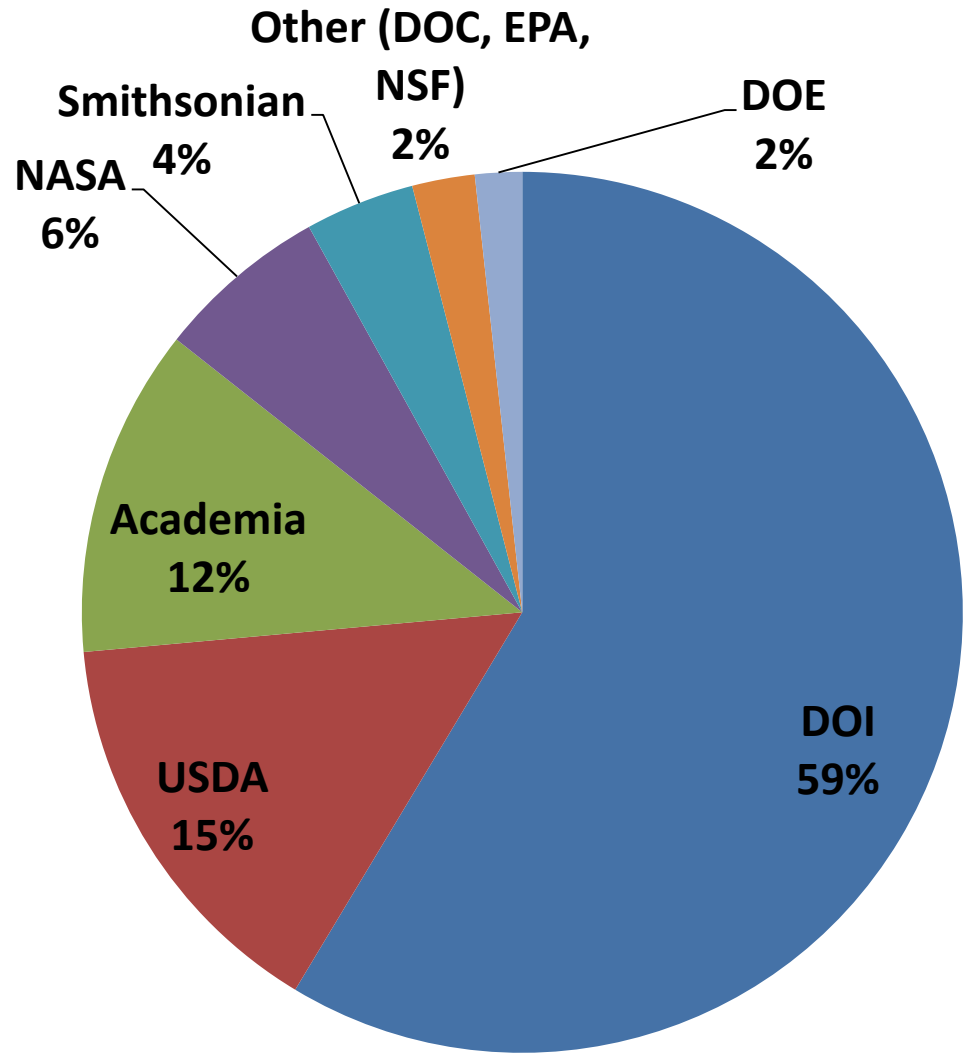
Landsat use

Surveyed Applications Using Landsat (USGS and EOA) ~174/1750



Funding for Landsat 9 Space System Dev. (NASA)

Senate Report 114-239, NASA, et al.

"Earth Science.—The recommendation includes $1,984,000,000 for Earth Science, **including $130,900,000 to continue formulation and development of Landsat-9** with a **target launch** date for Landsat- 9 during calendar year **2020**. "

Sustainable Land Imaging Architecture Study Team (AST) Evaluating Future Alternatives for SLI (2014)

Land Imaging AST Charge

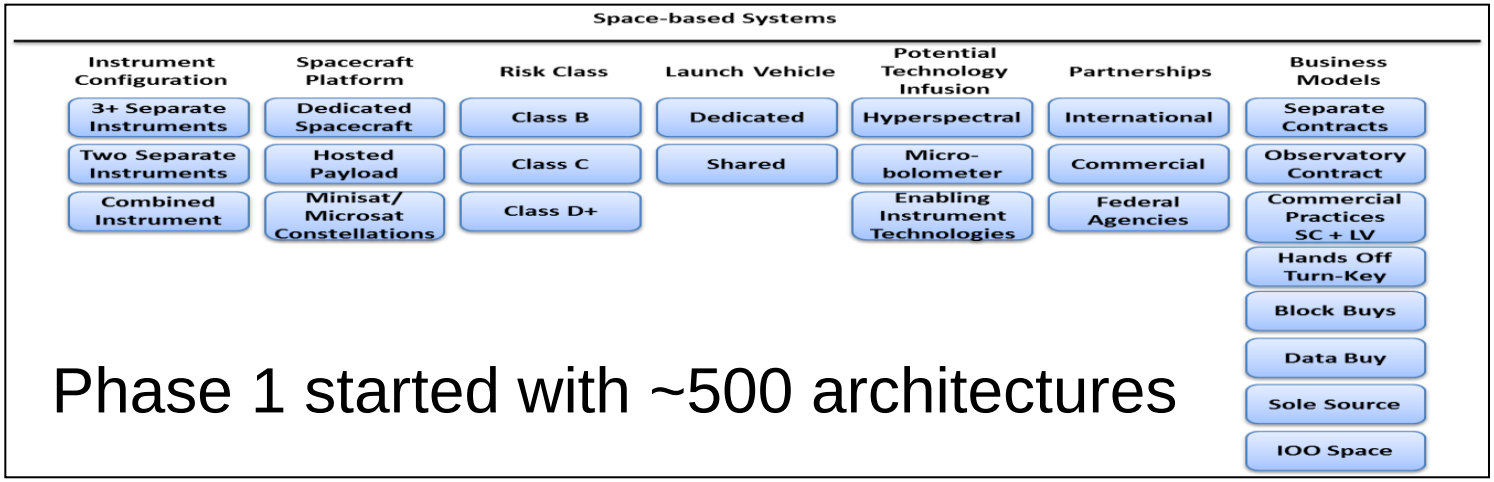
- Define **a global, Sustainable Land Imaging (SLI) system for a 20-year period** starting in 2018
- Provide cost effective options for near-term capabilities, continuity risk mitigations, and technology infusion
- Consider refined capabilities requested by the user communities
- **Include new measurement approaches & potential international and private sector partnerships**

AST Study Process

- Established study trade space via expert knowledge, intensive AST discussions, and RFI responses
- Explored alternatives via several design cycles

Key AST Findings → Landsat 8 rebuild for Landsat 9 had the lowest technical risk

- Consistent with Senate and Landsat community desires
- Avoids competitive process delays for first SLI mission
- Enables several years for SLI to prepare for efficient implementation of future architecture
- Direct data continuity with Landsat 8



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