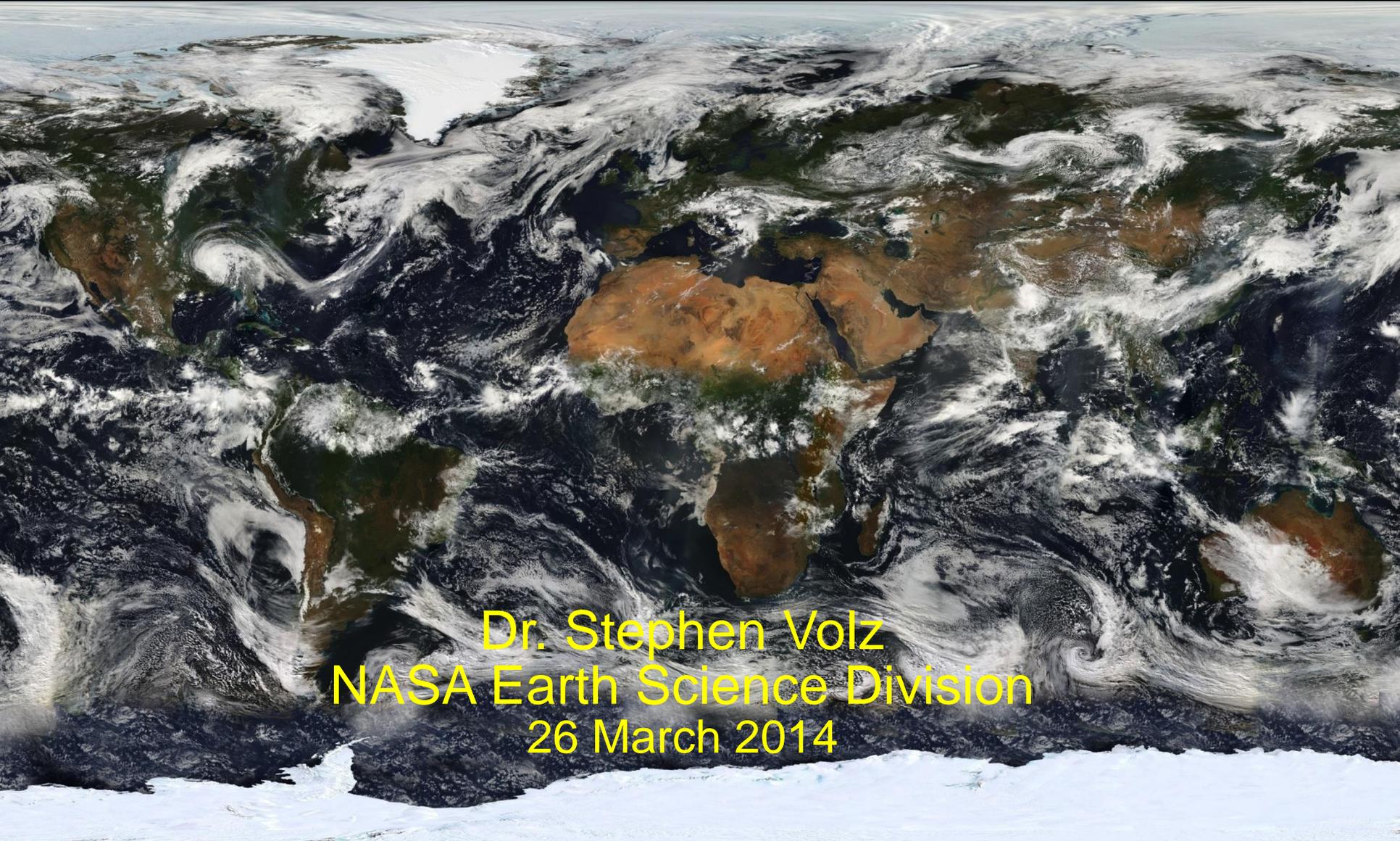




# NASA Earth Science Flight Program Overview



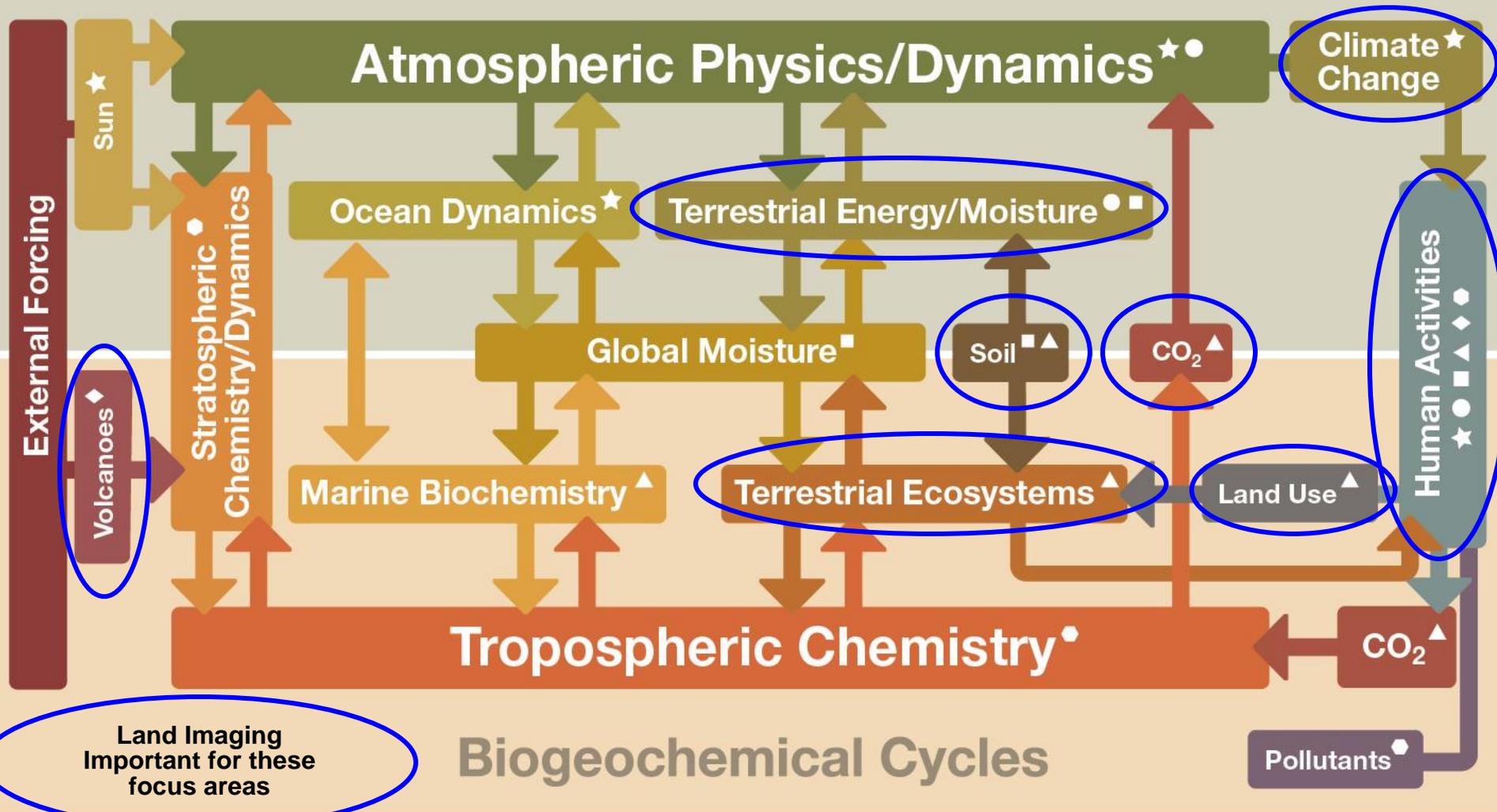
Dr. Stephen Volz  
NASA Earth Science Division  
26 March 2014

- ✦ NASA Science Objectives
- ✦ Guiding Principles for Mission Development
- ✦ Sustainable Land Imaging Program
  - Guidance
  - Implementation Approach
  - Expected Deliverables
- ✦ Plan forward

# Understanding the Earth System



## Physical Climate System ★●



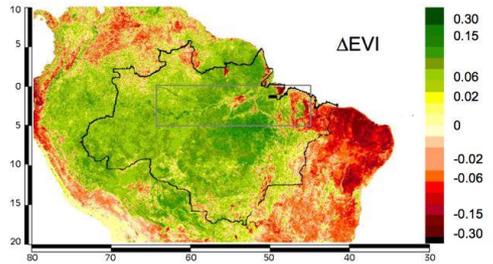
- ★ Climate Variability and Change
- Atmospheric Composition
- ▲ Carbon Cycle and Ecosystems
- Global Water and Energy Cycle
- Weather
- ◆ Earth Surface and Interior

# Earth SCIENCE Division Focus Areas



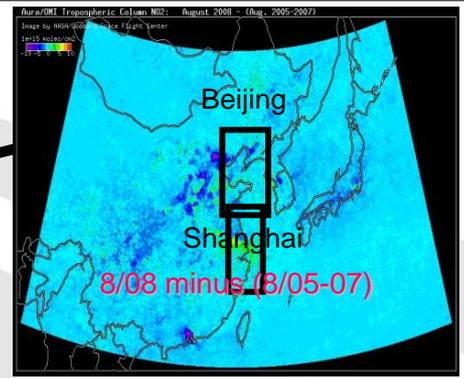
Basin-wide greening in dry season

October EVI (dry season) minus June EVI (wet season)



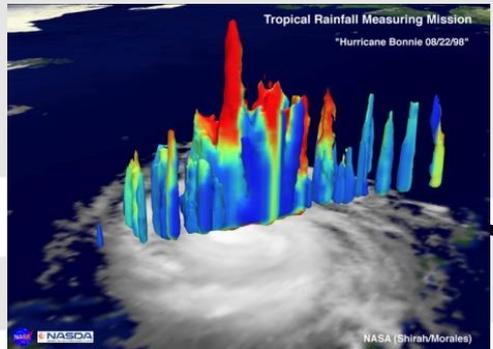
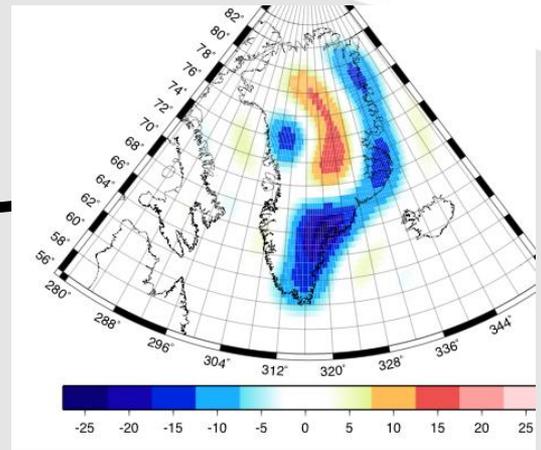
Atmospheric Composition

Carbon Cycle and Ecosystems



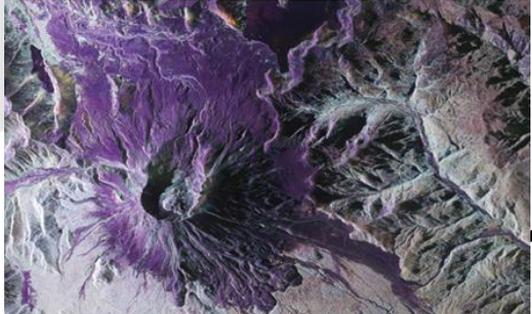
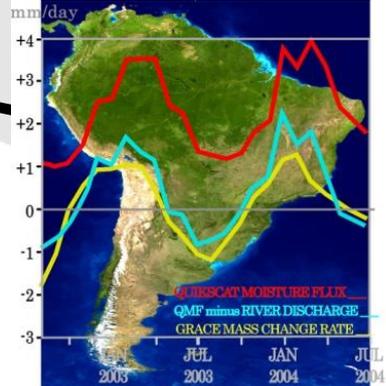
Climate Variability and Change

Weather



Water and Energy Cycle

Earth Surface and Interior

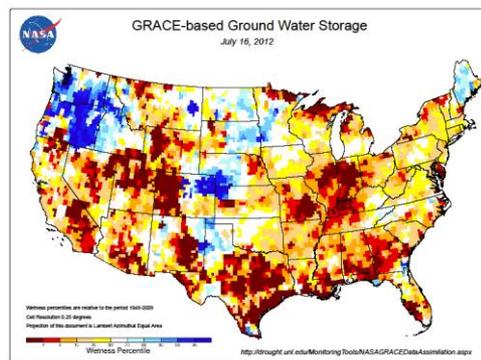


JACIE/ASPRS Joint Conference, March 2014

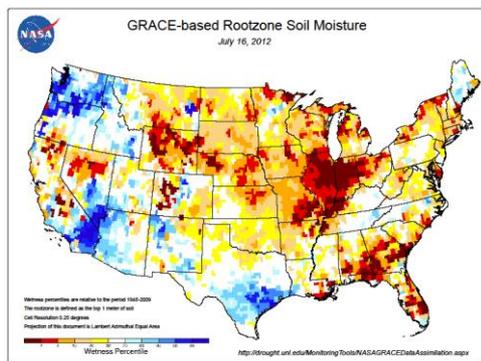
# NASA GRACE Products Actively Supporting Official U.S. Drought Assessments



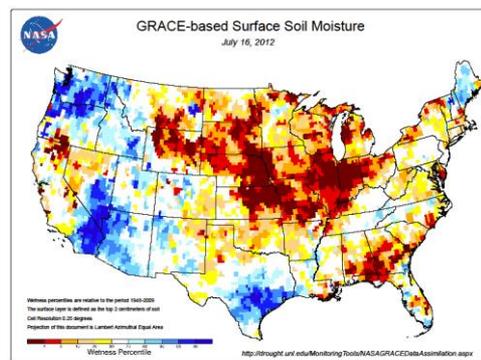
Ground Water Storage



Rootzone Soil Moisture

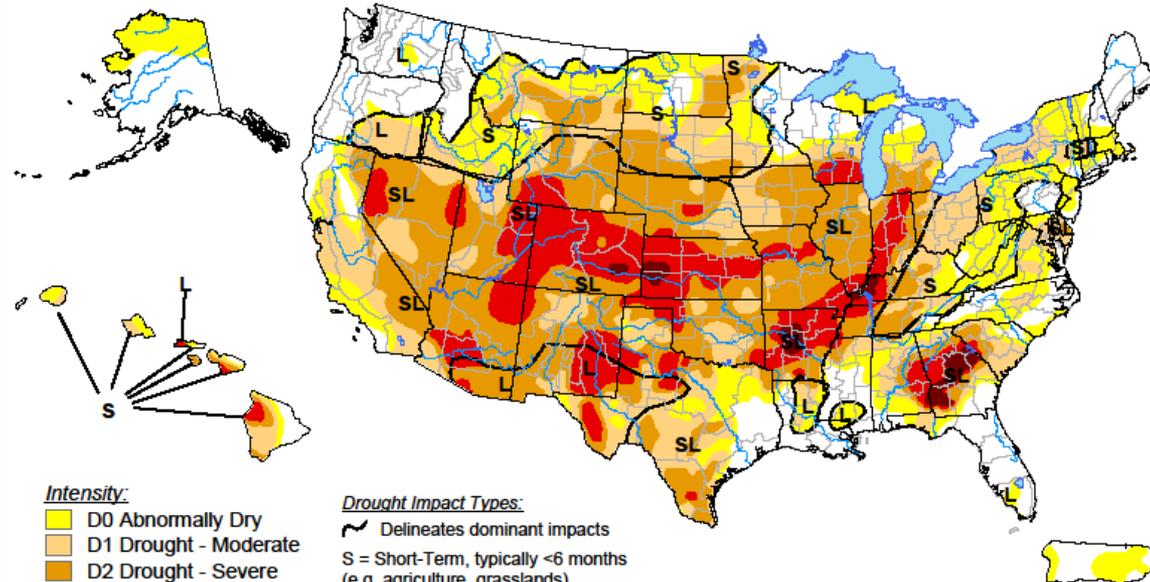


Surface Soil Moisture



## U.S. Drought Monitor

July 17, 2012  
Valid 7 a.m. EDT



### Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

### Drought Impact Types:

- Delineates dominant impacts
- S = Short-Term, typically <6 months (e.g. agriculture, grasslands)
- L = Long-Term, typically >6 months (e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://droughtmonitor.unl.edu/>



Released Thursday, July 19, 2012

Author: Richard Heim/Liz Love-Brotak, NOAA/NESDIS/NCDC

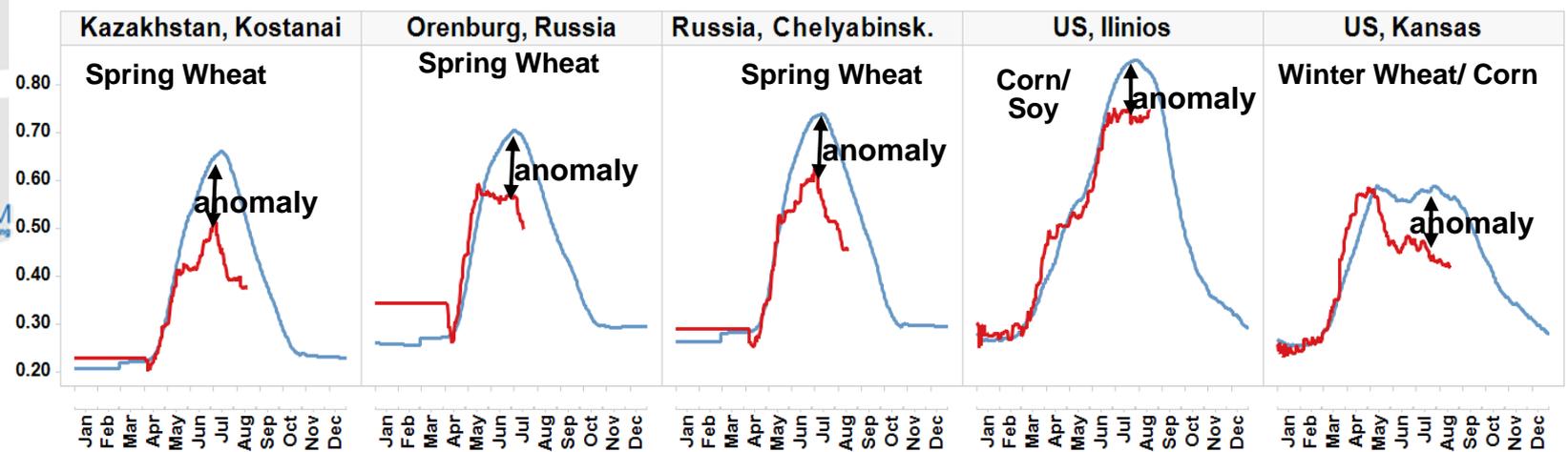
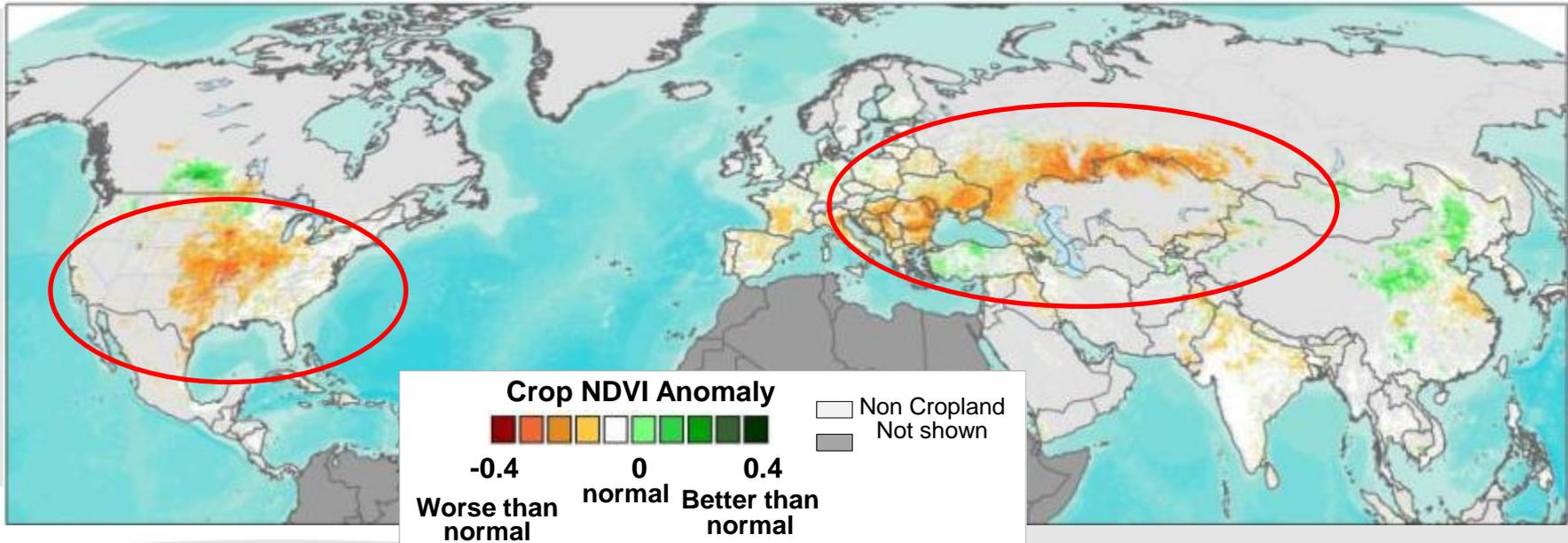
“These [GRACE] maps provide regional to national-level water resource information that was previously unavailable to policy and decision makers. The novel use of satellite-based gravity data in combination with advanced modeling techniques has given us a unique perspective on groundwater that was not resolvable through just ground-based observations.”

Brian Wardlaw, National Drought Mitigation Center<sup>5</sup>

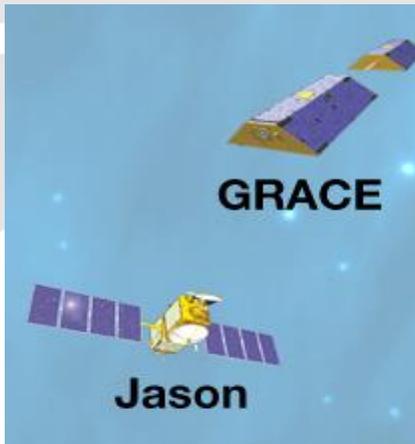
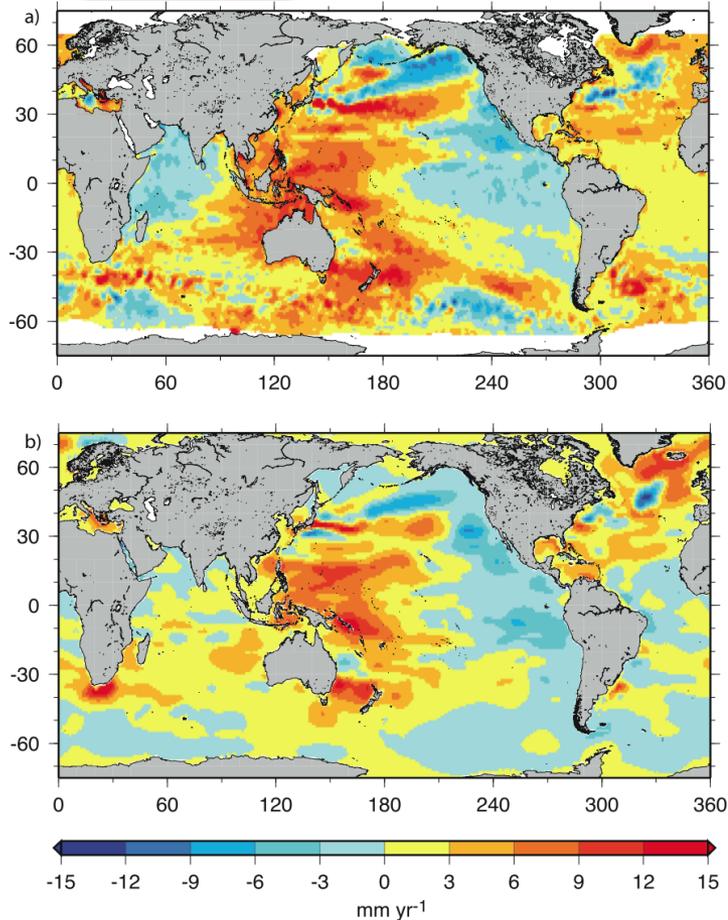
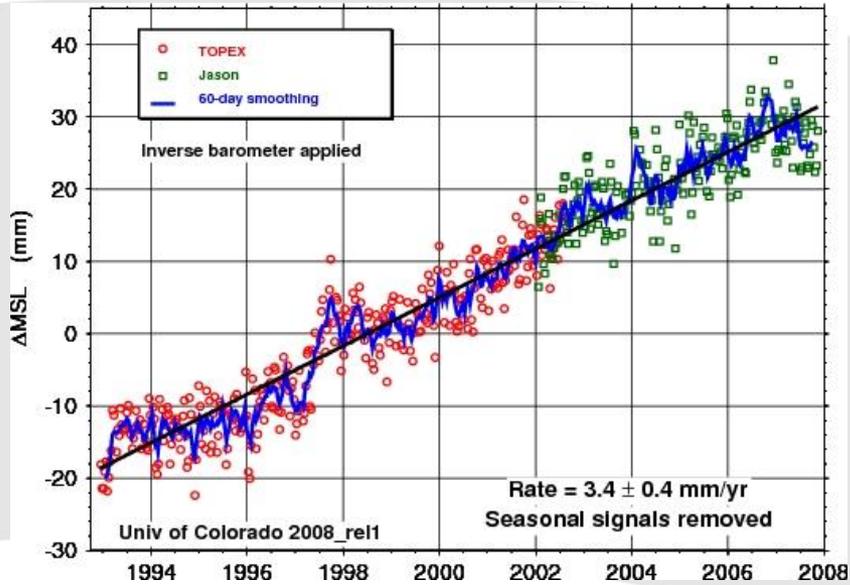
# Crop Condition: Global Outlooks



Northern Hemisphere Crop NDVI Anomalies, Aug 13th, 2012



# Sea Level Rise from Multiple Measurements: Altimetry and Gravimetry



Steric Contribution

IPCC WG1 FAR (2007)

## In Development

- Formulation
- Implementation
- Primary Ops
- Extended Ops

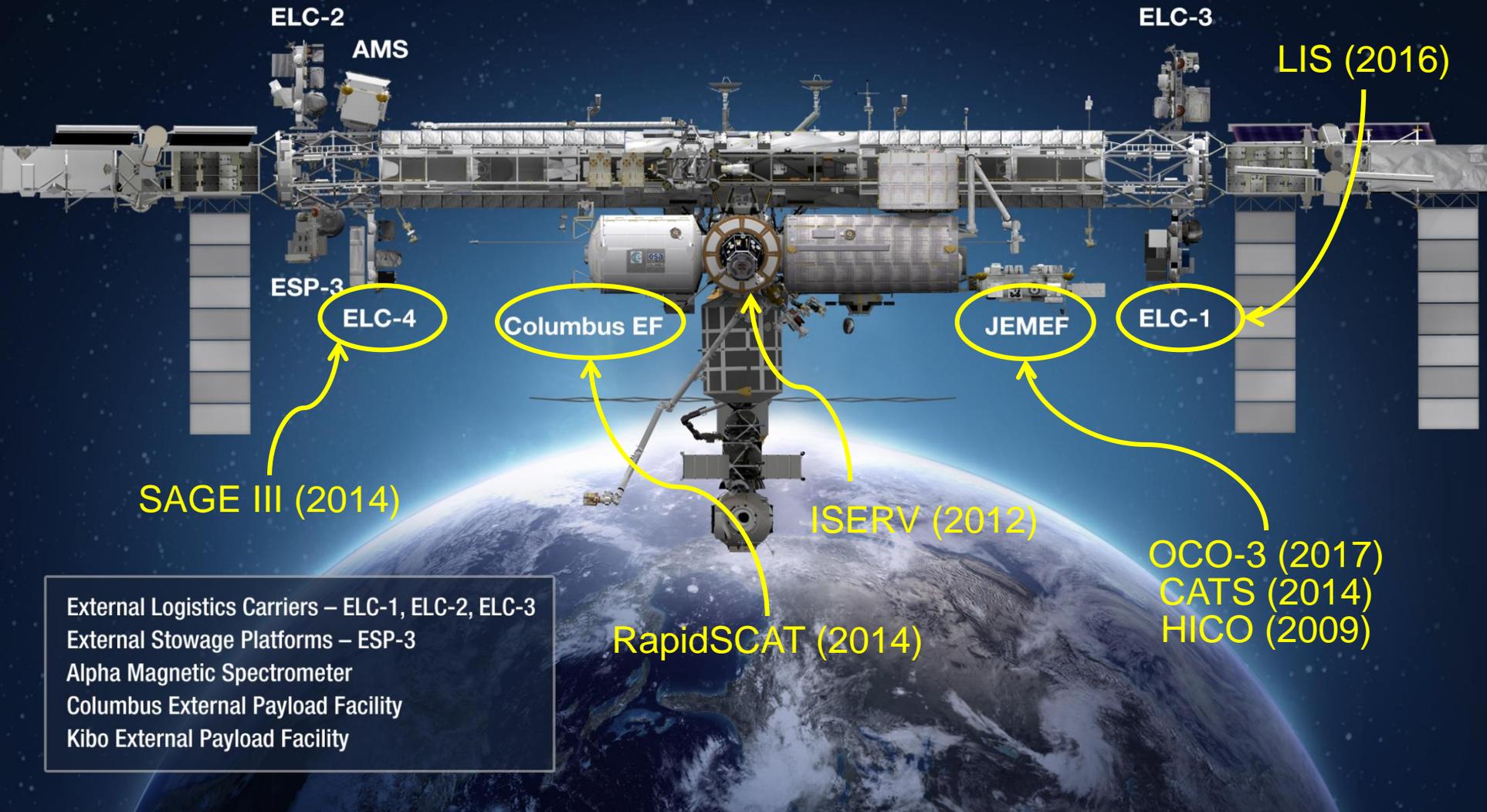


## In Operation



# International Space Station

## Earth Science Instruments



External Logistics Carriers – ELC-1, ELC-2, ELC-3  
External Stowage Platforms – ESP-3  
Alpha Magnetic Spectrometer  
Columbus External Payload Facility  
Kibo External Payload Facility

# NEW: Sustainable Land Imaging (SLI)



## FY13 Administration Direction

*In FY14 NASA will initiate the definition of a sustained, space-based, global land imaging capability for the nation, ensuring continuity following LDCM. Near-term activities led by NASA, in cooperation with USGS, will focus on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives. Evaluations and design activities **will include consideration of stand-alone new instruments and satellites, as well as potential international partnerships**. It is expected that NASA will support the overall system design, flight system implementation, and launch of future missions, while USGS will continue to fund ground system development, post-launch operations, and data processing, archiving, and distribution.*

*- President's FY2014 Budget release for NASA*

## FY14 Congressional Direction

*Delivery Date Aug 15, 2014*

*Land Imaging.—The Committee commends NASA and its team for the recent successful launch of Landsat 8, and provides \$30,000,000 for Land Imaging activities.... However, the Committee is concerned about the administration's approach towards the follow-on Landsat 9 mission.... The Committee is highly skeptical of either a hosted payload or international partner concept for Landsat 9. The Committee discourages NASA from spending an inordinate amount of time or funds on these alternate approaches.... At the same time, expectations that a Landsat 9 mission will cost a billion dollars due to enhanced new instrumentation or other efforts at program resiliency are equally unrealistic. For this reason, the Committee expects a plan not later than 120 days after enactment of this act detailing how Landsat 9 will ensure data continuity ... with an overall mission cap of approximately \$650,000,000, a level substantially below that required for Landsat 8.*

*-- Congressional Language incorporated into FY14 Appropriation*

*JACIE/ASPRS Joint Conference, March 2014*

*Delivery Date May 18, 2014*



# Three Basic Tenets for the Program

## ✦ Sustainability

- The SLI program should provide the data products for the long haul, without extraordinary infusions of funds, within the budget guidance provided.
- It should also ensure the technology required for the program is available and appropriate for the long haul

## ✦ Continuity

- The SLI program should continue the long term Landsat data record. This does not necessarily mean the imagery per se, but the usable products that define the utility of the data record.
- Understanding how the data are used is essential when considering potential architectures.

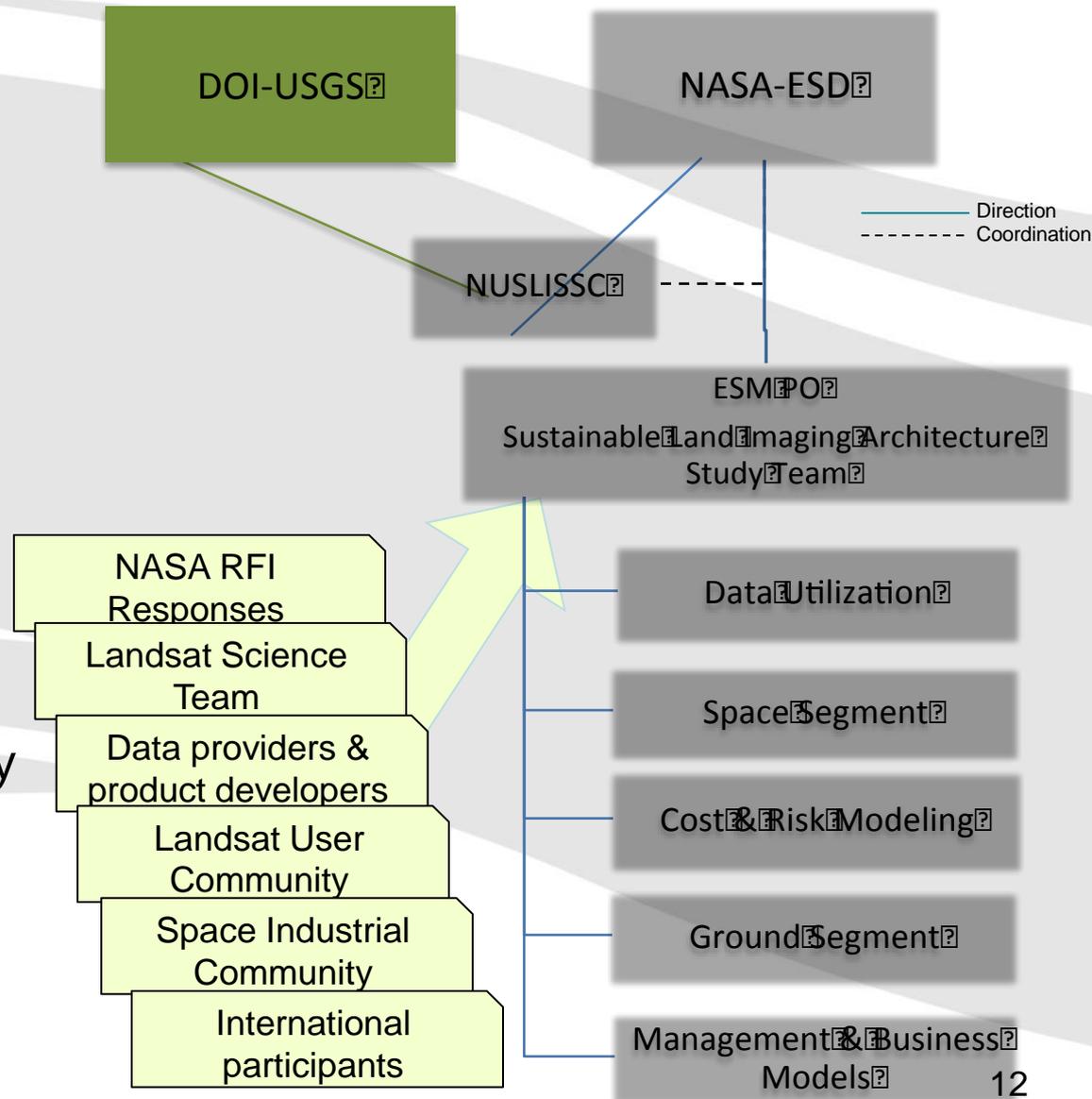
## ✦ Reliability

- The SLI program should exhibit a form of functional redundancy. The data sets should be able to draw on equivalent or near equivalent deliverables from different sources to provide the data for the highest priority land imaging data products.
- With these “near equivalent” data sources identified in advance, the loss of a single satellite or instrument on orbit should not cripple the program or significantly impact users, and the program will exhibit graceful degradation.

# Sustainable Land Imaging Study Execution



- ★ NASA leads the study, closely coordinated with USGS
- ★ Multi-disciplinary Architecture Study Team (AST) executes the study for NASA
- ★ AST is essentially governmental, including NASA, USGS, Aerospace, FFRDC
- ★ We actively seeks input from multiple sources and have taken multiple opportunities for community engagement
- ★ The AST reports to the NASA ESD and NASA reports to the OSTP in August 2014



# Established a Study Schedule in September



## FY13 Accomplishments

- ✦ Kick-off briefing to Administration August 6, 2013
- ✦ Establish Architecture Study Team (AST) Sep 2013
- ✦ Industry & Partner Day, RFI Release Sep 18, 2013
- ✦ Landsat User's Forum December 4, 2013

## FY14 Activities & Plans

- ✦ 1<sup>st</sup> Quarterly briefing to Stakeholders November 21, 2013
- ✦ 2<sup>nd</sup> Quarterly briefing to Stakeholders Jan 27, 2014

- ✦ **AST Design Cycle 2** Jan 27 – Mar 15, 2014
- ✦ SLI Community/Industry Forum 1 April 2014
- ✦ 3<sup>rd</sup> Quarterly briefing to Stakeholders early April 2014
- ✦ NASA ESD SLI interim report to Congress May 18, 2014

- ✦ AST completion of full SLI program options May 15 – Jul 15, 2014
- ✦ Completion of SLI study report Jul 2014
- ✦ NASA/USGS SLI report to Administration Aug 15, 2014

SLI  
Design  
Cycle #1

SLI  
Design  
Cycle #2

SLI  
Design  
Cycle #3

# Held Sustainable Land Imaging Architecture Industry & Partner Day, Sep 18

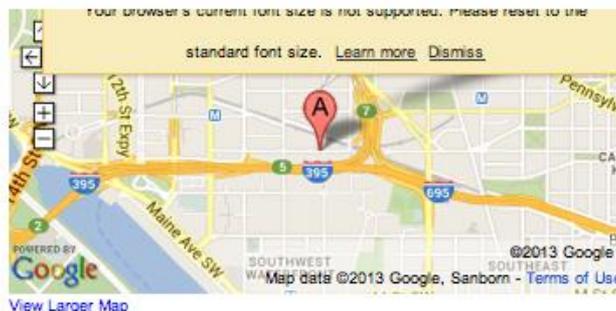


- Overview
- Watch Event (starting 1:30 p.m. EDT on September 18)
- REGISTER NOW
- Landsat @ GSFC
- Landsat @ USGS

**Time:** 1:00 - 4:30 p.m. EDT  
**Date:** Wednesday, September 18, 2013  
**Location:** NASA Headquarters James E. Webb Auditorium  
300 E Street, SW, Washington, D.C. [get directions].

*Capacity Note: Onsite-attendance will be limited by seating capacity.*

→ Register now



On September 18, NASA will host an event in which leadership from NASA and the United States Geological Survey (USGS) will provide details about NASA's Sustainable Land Imaging Architecture Study to design and implement a spaceborne system to provide global, continuous Landsat-quality multispectral and thermal infrared measurements for at least the next 25 years. To spur innovation and increase efficiencies, the study will identify and evaluate a range of solutions including large and small dedicated spacecraft, formation flying, hosted instruments, and integration of other land imaging data sets, as available, as well as possible international and private sector collaborations. The study will include careful consideration of the current and future planned ground system capabilities provided by the established USGS Earth Resources Observation and Science (EROS) Center. The study must recognize that lowering the system's cost to the nation is an important goal, and that implementing a system that stays within the allocated budget is an essential programmatic requirement for the U.S. government. We will describe our upcoming planning timeline and identify opportunities and processes for providing input into our planning. Following this public forum, NASA will also a Request for Information (RFI) to seek new ideas for mission elements and describe the process for submitting your ideas so that NASA/USGS teams may consider your innovative solutions.

✧ Presentations by OSTP, NASA, and USGS

✧ 159 registered participants from government, industry, academia, and potential foreign partners & collaborators

✧ NASA released its RFI on the same day



# Users Forum Dec 4, 2013

## Sustainable Land Imaging Architecture Study

### Sustainable Land Imaging Users Forum

**Time:** 1:00 - 4:15 p.m. EST  
**Date:** Wednesday, December 4, 2013  
**Location:** NASA Goddard Visitors Center Auditorium, 8800 Greenbelt Rd., Greenbelt, Md., 20771.

- > [Register for this Event](#)
- Capacity Note: Onsite-attendance will be limited by seating capacity to 124.

On December 4, the U.S. Geological Survey (USGS) and NASA will host an event in which leadership from both agencies will provide details about how user needs will be assessed to help inform NASA's Sustainable Land Imaging Program. User requirements are a critical source of information used as input to help inform the design and implementation of future spaceborne systems intended to provide global, continuous Landsat-quality visible to shortwave infrared and thermal infrared measurements for at least the next 25 years. The USGS has been developing a structured methodology for acquiring, cataloging, maintaining and evaluating user requirements for Earth observations through its Land Remote Sensing Program, which manages the USGS contributions to the joint efforts of USGS and NASA for the Landsat program. The Users Forum will feature the methodologies and approaches the USGS is utilizing to acquire and evaluate user requirements and will present some findings and evaluations that can be applied to design considerations for the development of the future architecture. The forum will include presentation of methods and preliminary findings, and will offer opportunities for feedback with regard to the approach and requirements gathered to date. The requirements component will be described in the context of our upcoming planning timeline and identify opportunities and processes for providing input into our planning. This is a notice of a meeting, not a solicitation of any kind.

### Preliminary Agenda:

| Time (EDT) | Topic                                 | Speaker   |
|------------|---------------------------------------|---|
| 12:30-1:00 | Check-in                              |   |
| 1:00-1:15  | Opening                               | Tim Newman<br>Program Coordinator USGS<br>Land Remote Sensing Program |
| 1:15-1:30  | NASA Sustainable Land Imaging Program | David Jarrett<br>Program Executive<br>NASA Earth Science Division     |
| 1:30-2:00  | Architecture Study Team Overview      | Del Jenstrom AST Manager<br>NASA Goddard Space Flight Center          |
| 2:00-2:30  | User Requirements                     | John Crowe Requirements   |

### Request for Information

- > [Get Information on RFI](#)

### FAQ

- > [Frequently Asked Questions](#)

### Reference Documents

- > [Industry & Partner Day Presentations \(9.18.2013\)](#)
- > [Landsat and Beyond: Sustaining and Enhancing the Nation's Land Imaging Program](#)

### Related Links

- > [Landsat @ GSFC](#)
- > [Landsat @ USGS](#)

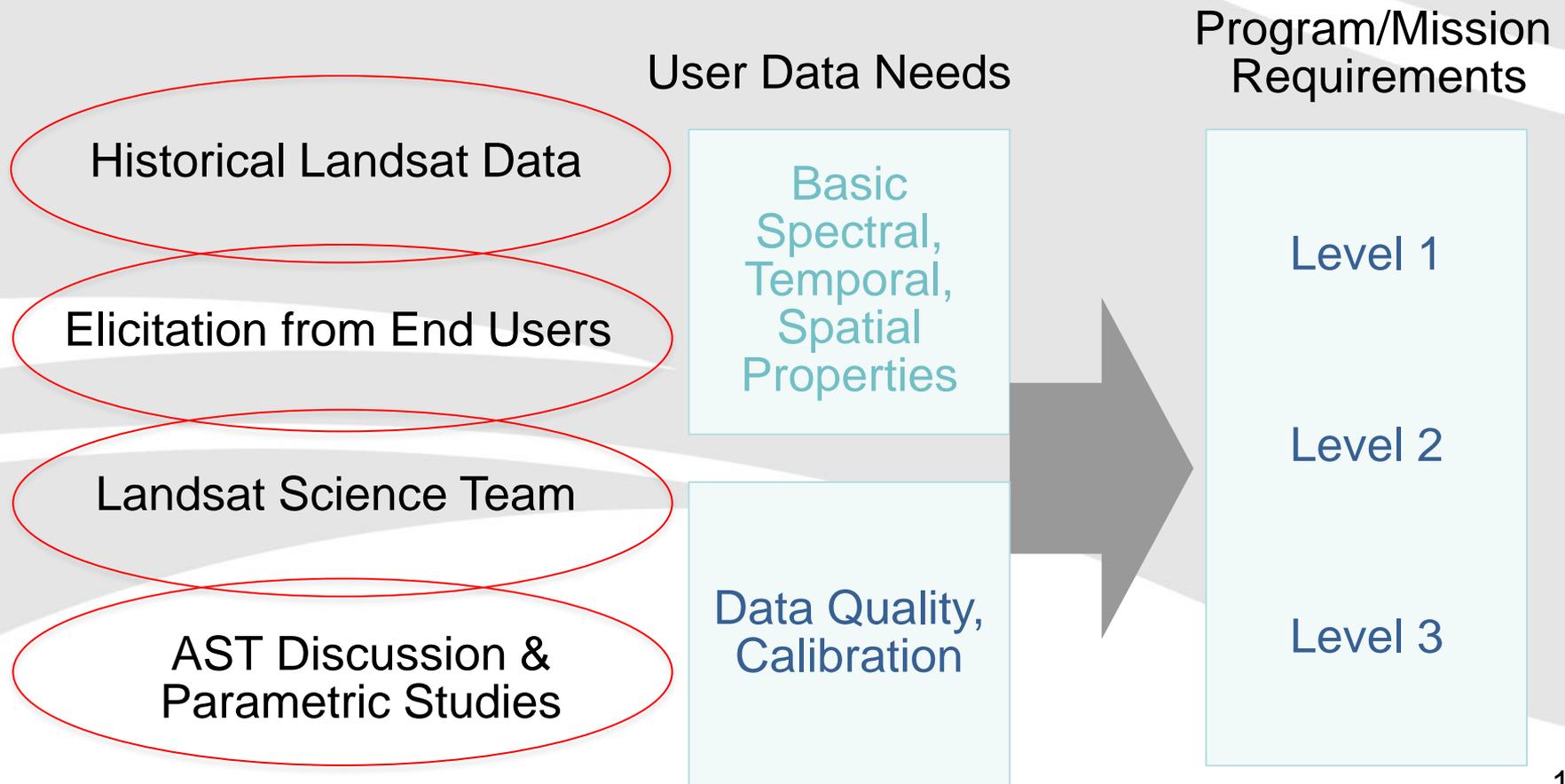
★ The Users Forum featured the methodologies and approaches the USGS is utilizing to acquire and evaluate user requirements.

★ We presented methods and preliminary findings, and offered opportunities for feedback with regard to the approach and requirements gathered to date.

# Framework for Establishing Program Performance Metrics



- ✦ Start with the 40+ year Landsat data record
  - Established the historical record and the legacy performance
  - Back compatibility with data record is an essential element of the SLI



# Historical Landsat Capabilities



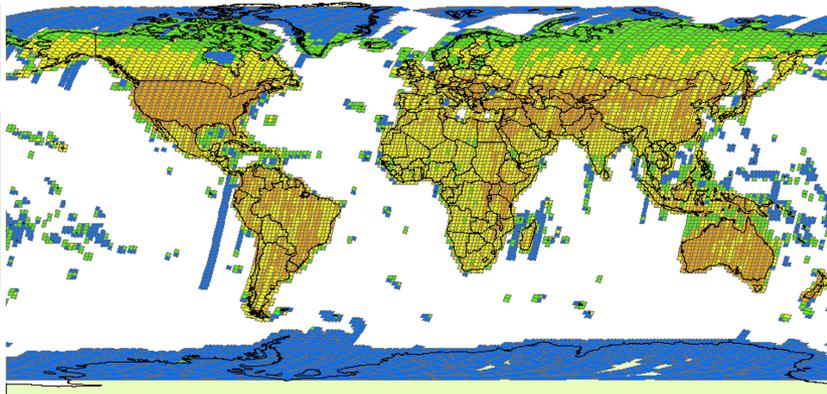
## Full Spectrum Coverage

| Satellite     | Sensor | Swath | Bits | VNIR |     |     |     | SWIR |     | TIR |                |
|---------------|--------|-------|------|------|-----|-----|-----|------|-----|-----|----------------|
| L8            | OLI    | 185km | 12   | 30   | 30m | 30m | 30m | 30m  | 30  | 30m |                |
|               | TIRS   |       |      |      |     | 15m |     |      |     |     | 100m           |
| Landsat 7     | ETM+   | 185km | 8    | 30m  | 30m | 30m | 30m | 30m  | 30m | 30m | 60m            |
| Landsat 4 & 5 | MSS    | 185km | 8    |      | 82m | 82m | 82m | 82m  | 82m |     |                |
|               | TM     | 185km | 8    | 30m  | 30m | 30m | 30m | 30m  | 30m | 30m | 120m           |
| Landsat 1-2   | RBV    | 183km |      |      | 80m | 80m | 80m |      |     |     |                |
| Landsat 3     | RBV    | 183km |      |      |     | 40m |     |      |     |     |                |
| Landsat 1-3   | MSS    | 183km | 8    |      | 79m | 79m | 79m | 79m  |     |     | 240m (L3 Only) |

## Global Acquisition

## Global Distribution

FY13/FY14 L8 OLI & TIRS / L7 ETM+ Acquisitions

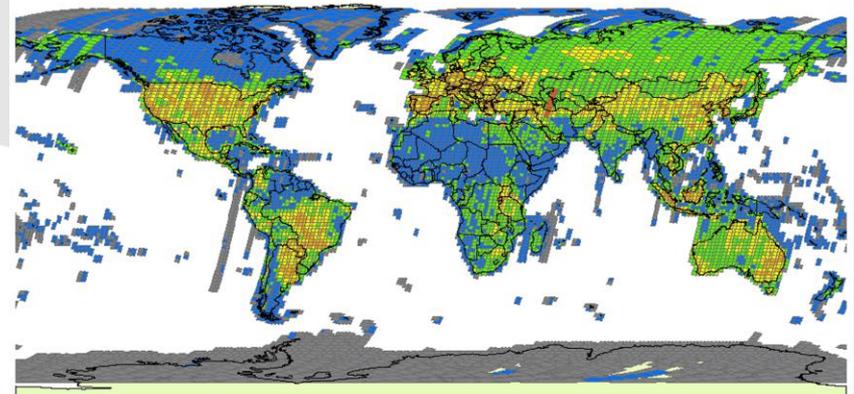


L8 OLI & TIRS / L7 ETM+ Acquired Scenes  
 June 01, 2013 through January 31, 2014  
 220,216 Total Scenes  
 13,443 Unique Locations

1 - 9 10 - 18 19 - 27 28 - 37 38 - 46

15 = 16 day coverage  
 30 = 8 day coverage

FY13/FY14 L8 OLI & TIRS / L7 ETM+ Downloads



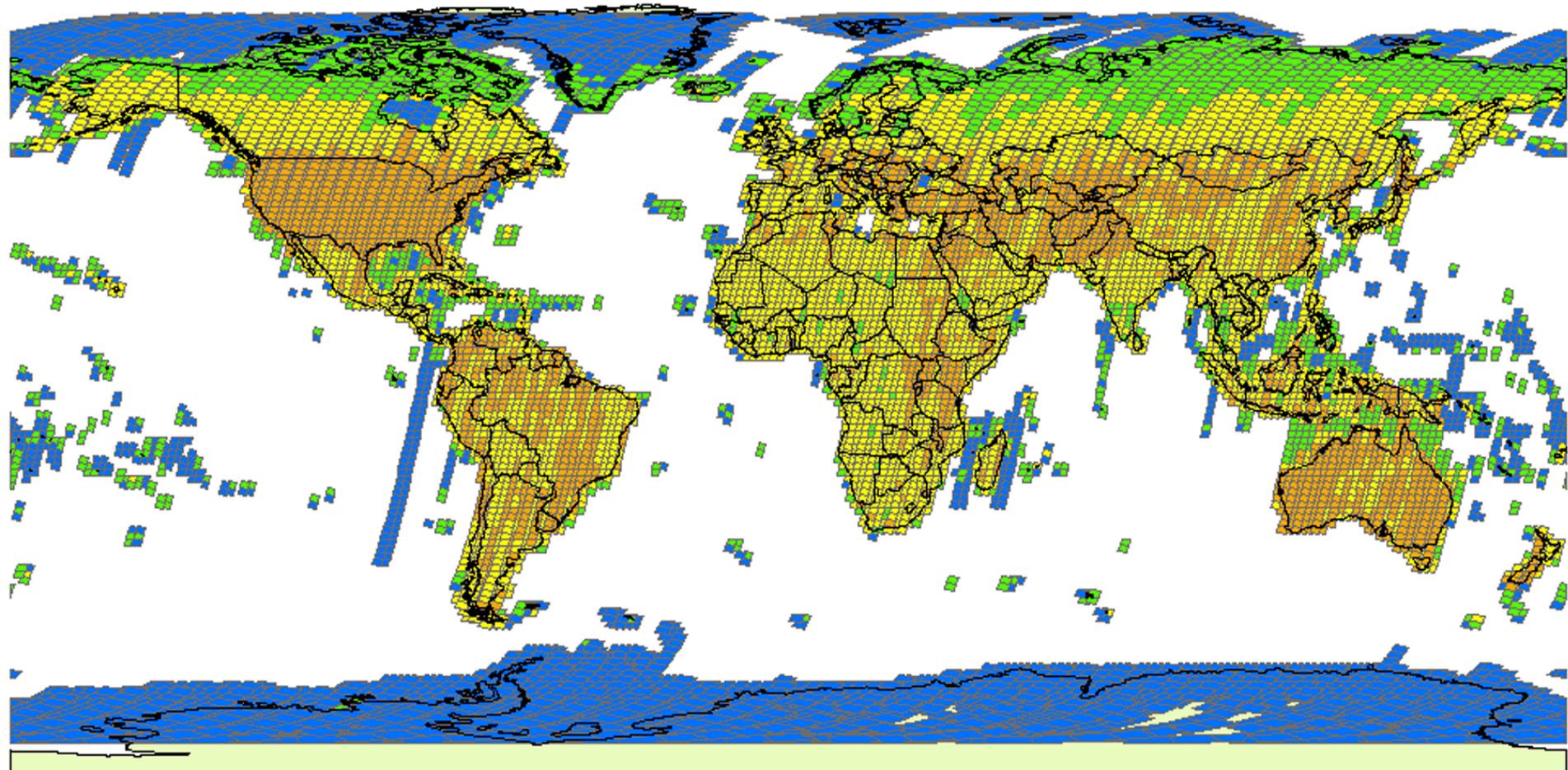
L8 OLI & TIRS / L7 ETM+ Downloaded Scenes  
 June 01, 2013 through January 31, 2014  
 245,503 Total Scenes  
 13,443 Unique Locations

No Downloads 1 - 13 14 - 37 38 - 74 75 - 305 307 - 595

# Historical Landsat Capabilities



## FY13/FY14 L8 OLI & TIRS / L7 ETM+ Acquisitions



L8 OLI & TIRS / L7 ETM+ Acquired Scenes  
June 01, 2013 through January 31, 2014  
220,216 Total Scenes  
13,443 Unique Locations

15 = 16 day coverage  
30 = 8 day coverage

1 - 9   10 - 18   19 - 27   28 - 37   38 - 46

# Architecture Trade Space



| Aerial Systems | Space-based Systems      |                                     |            |                |                                  |                  |                      |
|----------------|--------------------------|-------------------------------------|------------|----------------|----------------------------------|------------------|----------------------|
| Platforms      | Instrument Configuration | Spacecraft Platform                 | Risk Class | Launch Vehicle | Potential Technology Infusion    | Partnerships     | Business Models      |
| UAVs           | 3+ Separate Instruments  | Dedicated Spacecraft                | Class B    | Dedicated      | Hyperspectral                    | International    | Separate Contracts   |
| Airplane       | Two Separate Instruments | Hosted Payload                      | Class C    | Shared         | Micro-bolometer                  | Commercial       | Observatory Contract |
|                | Combined Instrument      | Minisat/<br>Microsat Constellations | Class D+   |                | Enabling Instrument Technologies | Federal Agencies | Prime Payload        |
|                |                          | CubeSat Constellations              |            |                |                                  |                  | Commercial Turn-Key  |
|                |                          | International Space Station         |            |                |                                  |                  | Block Buys           |
|                |                          |                                     |            |                |                                  |                  | Data Buy             |
|                |                          |                                     |            |                |                                  |                  | Sole Source          |
|                |                          |                                     |            |                |                                  |                  | 100 Space            |

- The AST started with a comprehensive taxonomy of possible contributing elements to a sustainable Land Imaging satellite solution space.
- It includes traditional approaches such as Landsat 7 and 8, but also a variety of other options

# Architecture Building Blocks



## Arch. #1 Full Capability Observatories

## Arch. #2 Disaggregated System

## Arch. #3 International Participation

## Arch. #4 Commercial Approach

### Class B Multi

DL = 5 years  
OLI-2012-B  
TIR-mini-B  
Class B bus

### Class B Combined

DL = 5 years  
ACMS  
Class B bus

### Class C Multi

DL = 3 years  
OLI-2012-C  
TIR-mini-C  
Class C bus

### Class C Combined

DL = 3 years  
ACMS  
Class B bus

### Class D+ Multi

DL = 2 years  
OLI-2012-D  
TIR-mini-D  
Class D bus

### Class D Combined

DL = 2 years  
ACMS  
Class B bus

### Bridges

DL = 2-5 years  
OLI and/or TIR  
Class B/C/D bus

### Class D Demo

DL = 3 years  
HSI concept

### Class B TIR

DL = 5 years  
TIR-mini-B  
Class B bus

### Class C TIR

DL = 3 years  
TIR-mini-C  
Class C bus

### Class D+ TIR

DL = 2 years  
TIR-mini-D  
Class D bus

### String of Pearls

DL = 2 years  
Micro-sats  
Class D

### Class D Demo

DL = 3 years  
HSI concept

### Class B Refl.

DL = 5 years  
OLI-2012-B  
Class B bus

### Class C Refl.

DL = 3 years  
OLI-2012-C  
Class C bus

### Class D+ Refl.

DL = 2 years  
OLI-2012-D  
Class D bus

### Mini-sats

DL = 2 years  
Class D

Alternating or simultaneous  
thermal & reflective missions

## US Only Thermal

### Class B TIR

DL = 5 years  
TIR-mini-B  
Class B bus

### Class C TIR

DL = 3 years  
TIR-mini-C  
Class C bus

### Class D+ TIR

DL = 2 years  
TIR-mini-D  
Class D bus

## Joint Program

### Class B MSI

DL = 7 years  
ESA MSI  
TIR-mini-B  
Class B bus

### Class C MSI

DL = 5 years  
ESA MSI  
TIR-mini-C  
Class C bus

### Class D+ MSI

DL = 3 years  
ESA MSI  
TIR-mini-D  
Class D bus

**Data Buy**  
"Pay Once"  
Data only

**Class B Hosted**  
OLI-2012-B

**Class B Hosted**  
TIR-mini-B

**Class C Hosted**  
OLI-2012-C

**Class C Hosted**  
TIR-mini-C

**Class D+ Hosted**  
OLI-2012-D

**Class D+ Hosted**  
TIR-mini-D

### Class D Demo

DL = 3 years  
HSI concept

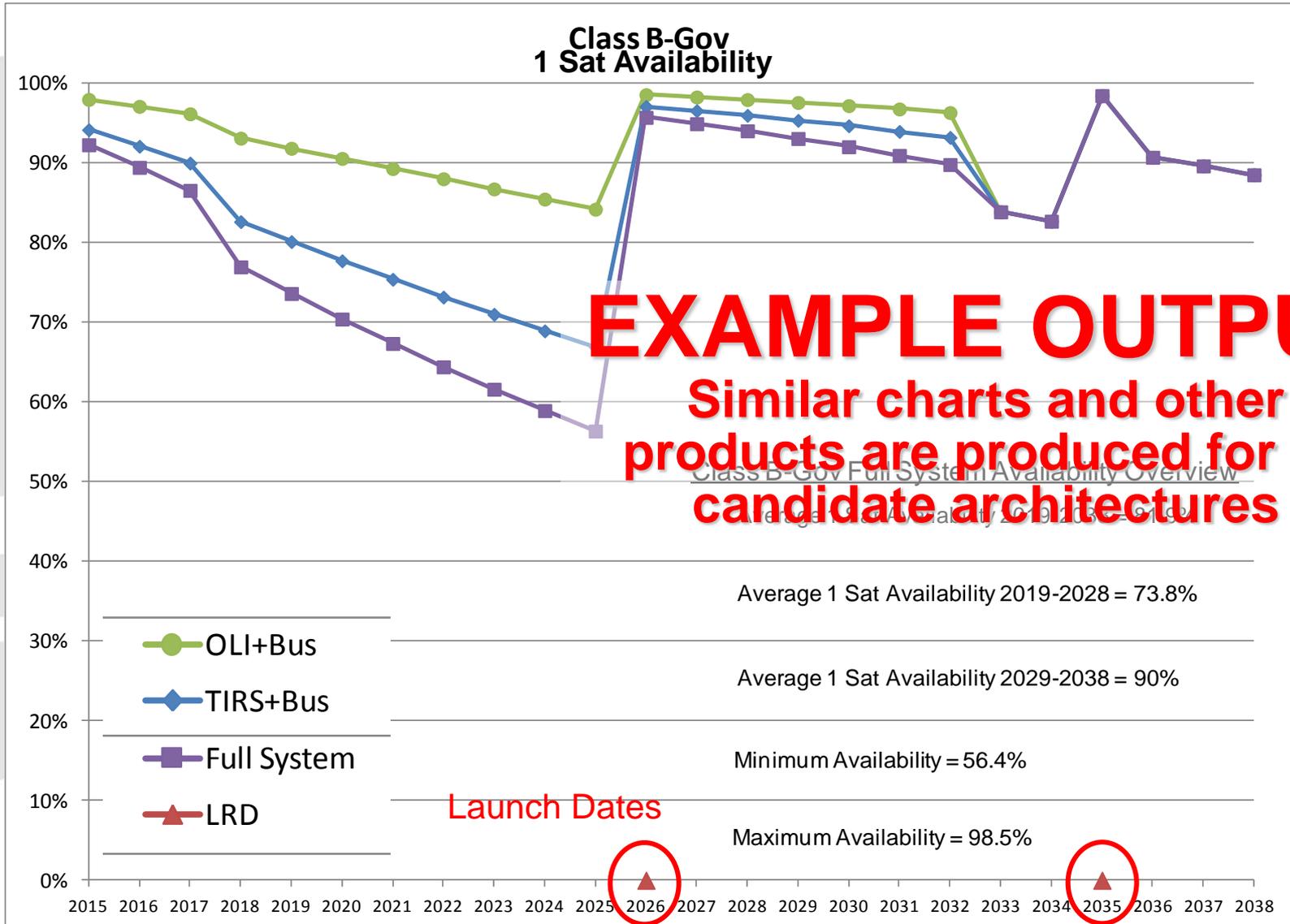
### Class D Demo

DL = 3 years  
HSI concept

# Landsat "Legacy" Class B Satellite System Availability Fitted to Allocated Budget



1 Satellite Availability



# Activities Remaining For the SLI Study



## FY13 Accomplishments

- Kick-off briefing to Administration August 6, 2013
- Establish Architecture Study Team (AST) Sep 2013
- Industry & Partner Day, RFI Release Sep 18, 2013
- Landsat User's Forum December 4, 2013

## FY14 Activities & Plans

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SLI  
Design  
Cycle #1

SLI  
Design  
Cycle #2

SLI  
Design  
Cycle #3

# Sustainable Land Imaging Architecture Study Interim Status Briefing



- ★ Architecture Study Team will present the current study status, including:
  - Science and user needs assessments
  - Metrics used to compare architectures
  - The range of architectures under consideration
  - Status of preliminary findings
  - Plans for the remainder of the study

Sustainable Land Imaging Architecture Study

Home Request for Information Reference Documents Frequently Asked Questions Event Archive

Sustainable Land Imaging Architecture Study Interim Status Briefing  
**Time:** 9:00 a.m. - 12:00 p.m. EDT  
**Date:** Tuesday, April 1, 2014  
**Location:** NASA Headquarters James E. Webb Auditorium, 300 E Street, SW, Washington, D.C.

Related Links  
> Landsat @ GSFC  
> Landsat @ USGS

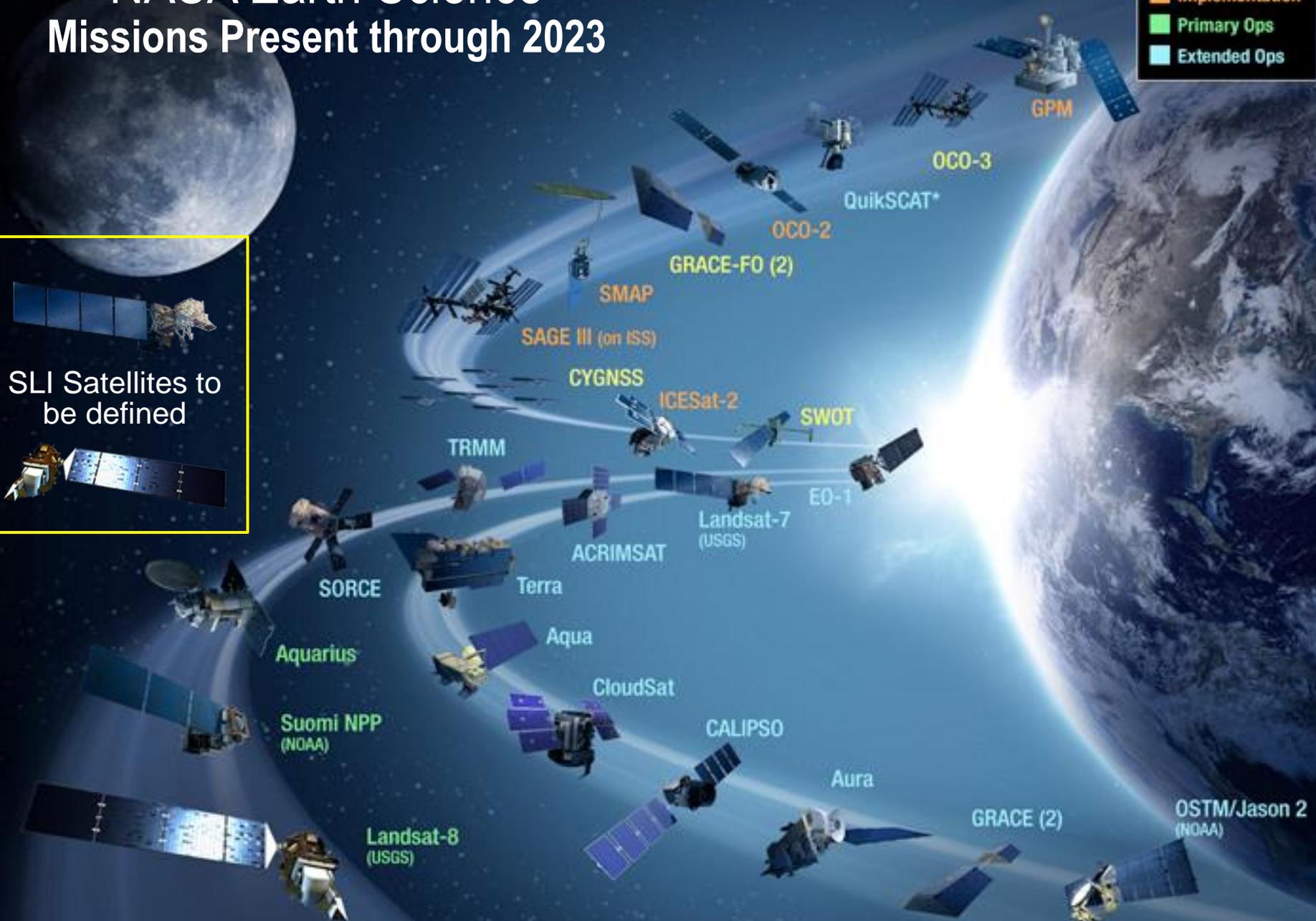
[Register for this Event](#) <http://espd.gsfc.nasa.gov/landimagingstudy/>

- ★ Community Opportunities
  - AST will be soliciting community input and feedback, including offering the opportunity for individual face-to-face discussions with the AST
  - ESD planning for future study activities

# NASA Earth Science Missions Present through 2023

|   |                |
|---|----------------|
| ■ | Formulation    |
| ■ | Implementation |
| ■ | Primary Ops    |
| ■ | Extended Ops   |

SLI Satellites to be defined



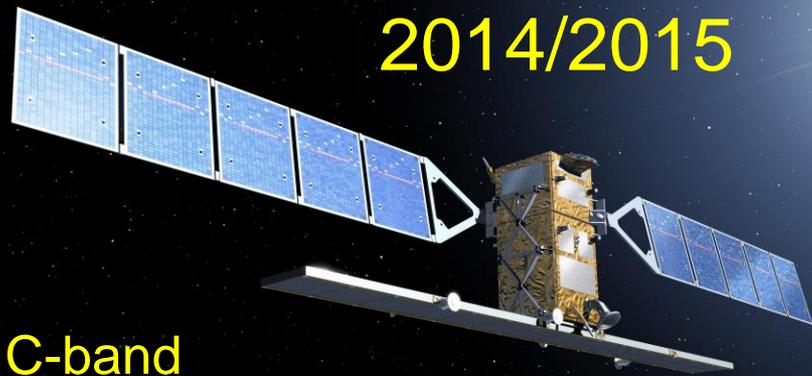
# Challenges to Prepare for 2020



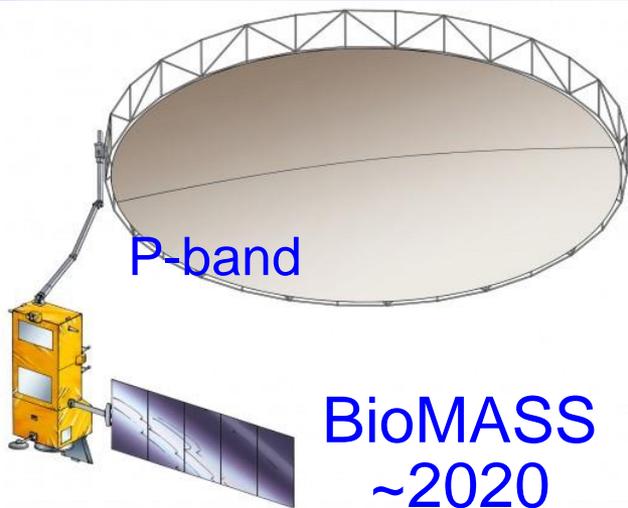
- ✦ How do we best prepare for a mixed data set?
  - Can we produce consistent products while integrating data from multiple satellites, multiple instrument types, multiple nations, across decades
  - We have Sentinel 2 along with Landsat, plus commercial and other national assets available
  
- ✦ Vicarious vs. on board cal/val
  - How can we or should we approach calibration and validation with these mixed assets?
  - Can we make vicarious calibration work for land imaging?
  
- ✦ What is the role of radar vis-à-vis visible land imaging
  - We will have free access to a wealth of global SAR data by ~2021, how can these data streams be integrated into our land imaging products?

# Upcoming SAR missions with Free & Open Data

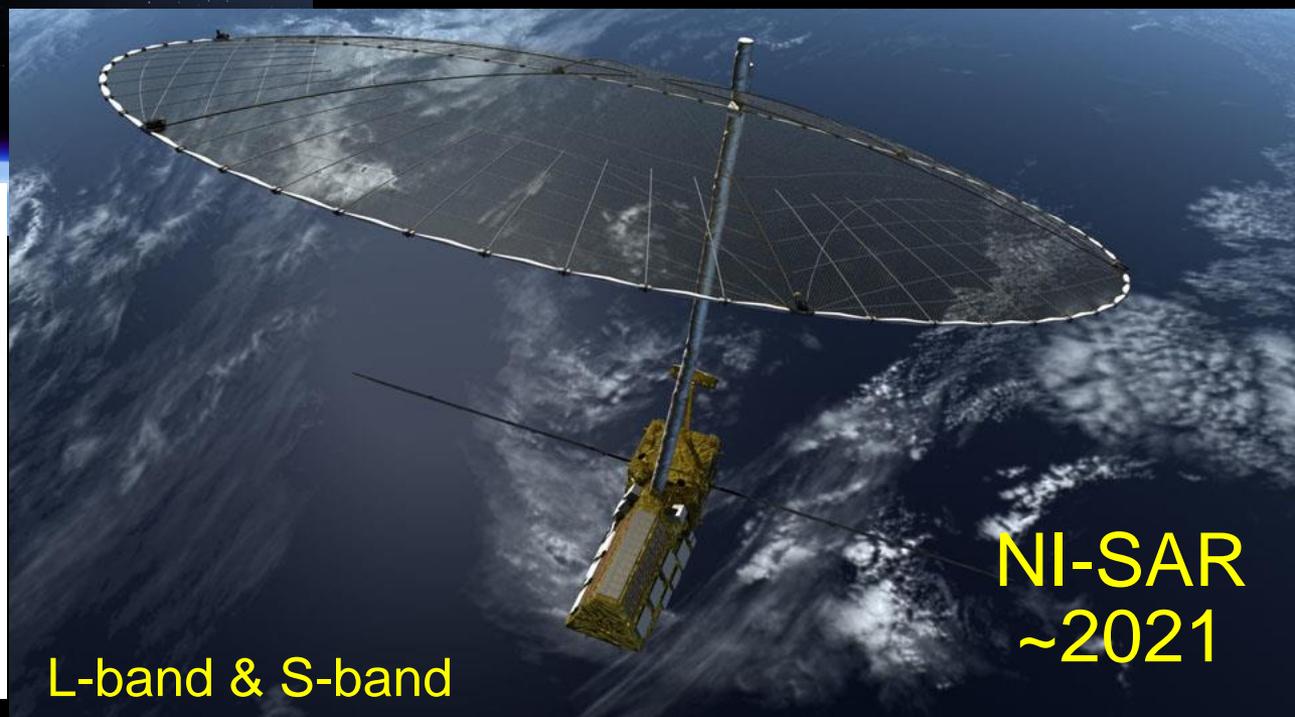
**Sentinel 1A & B**  
**2014/2015**



**C-band**



**BioMASS**  
**~2020**



**L-band & S-band**

**NI-SAR**  
**~2021**

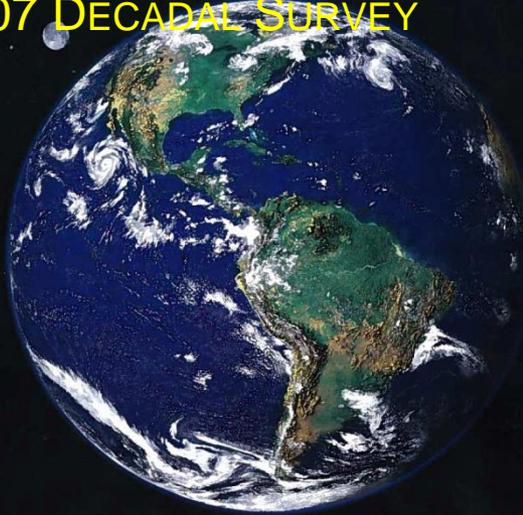


BACK-UP

# Guiding Recommendation Documents



2007 DECADAL SURVEY



## EARTH SCIENCE AND APPLICATIONS FROM SPACE

NATIONAL IMPERATIVES FOR THE NEXT DECADE AND BEYOND

NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES

- Research/Applications priorities
- No realistic budget constraint
- Shopping list of missions & activities
- Assumed Legacy missions completed

National Aeronautics and Space Administration

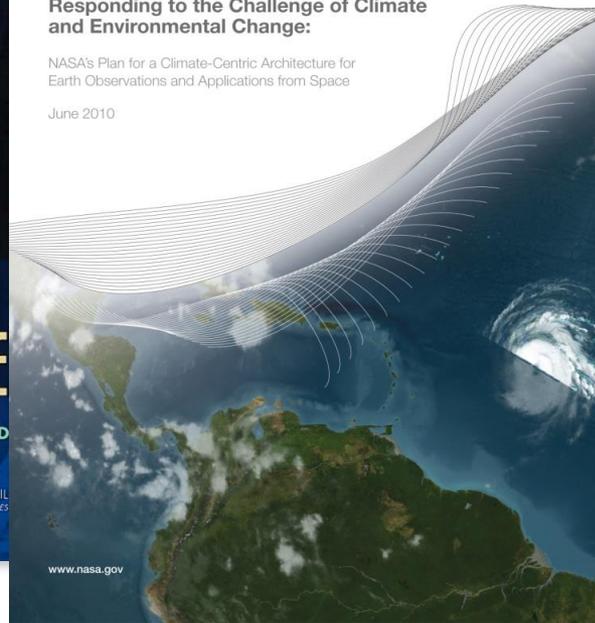


## 2010 NASA RESPONSE TO CLIMATE PLAN

Responding to the Challenge of Climate and Environmental Change:

NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space

June 2010



www.nasa.gov

- Identified new Climate Measurements
- Matched against President's budget
- Vetted w/OSTP, OMB & Admin

2012 NRC MIDTERM REPORT



## EARTH SCIENCE AND APPLICATIONS FROM SPACE

A Midterm Assessment of NASA's Implementation of the Decadal Survey

NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES

- Endorsed NASA's implementation
- "Encouraged" more rigorous cost control
- Endorsed additional Venture calls

**In addition to these documents we are of course responsive to Executive and Congressional direction.**

*JACIE/ASPRS Joint Conference, March 2014*