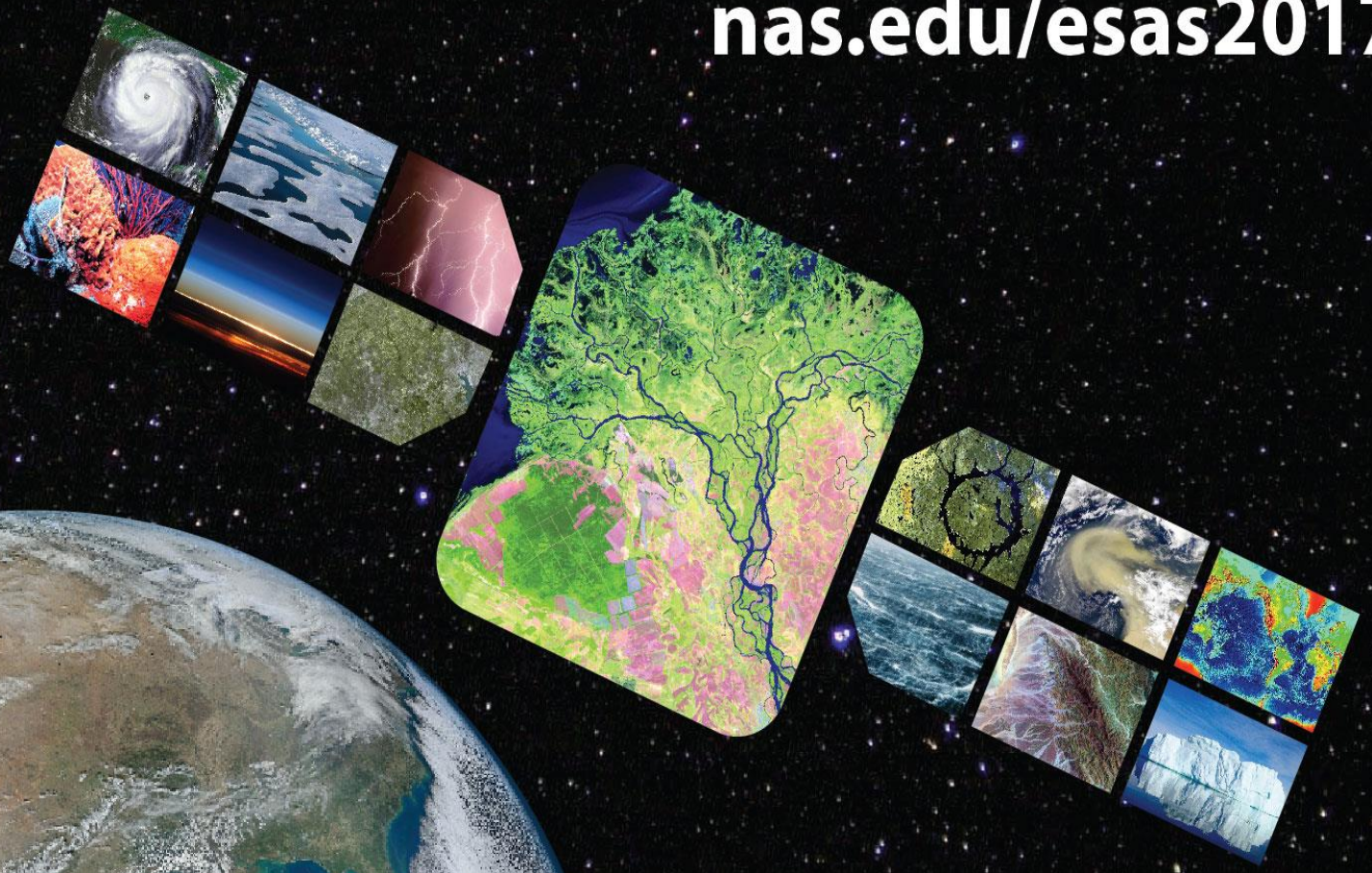
Charting the course for the next decade of Earth observations

nas.edu/esas2017



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ESAS 2017: The 2017-2027 Decadal Survey for Earth Science and Applications from Space

Waleed Abdalati, Co-Chair, Survey Steering Committee
University of Colorado

Antonio J. Busalacchi, Co-Chair, Survey Steering Committee
University of Maryland

Ocean Sciences Town Hall, February 22, 2016
New Orleans, LA

ESAS 2017 Town Hall

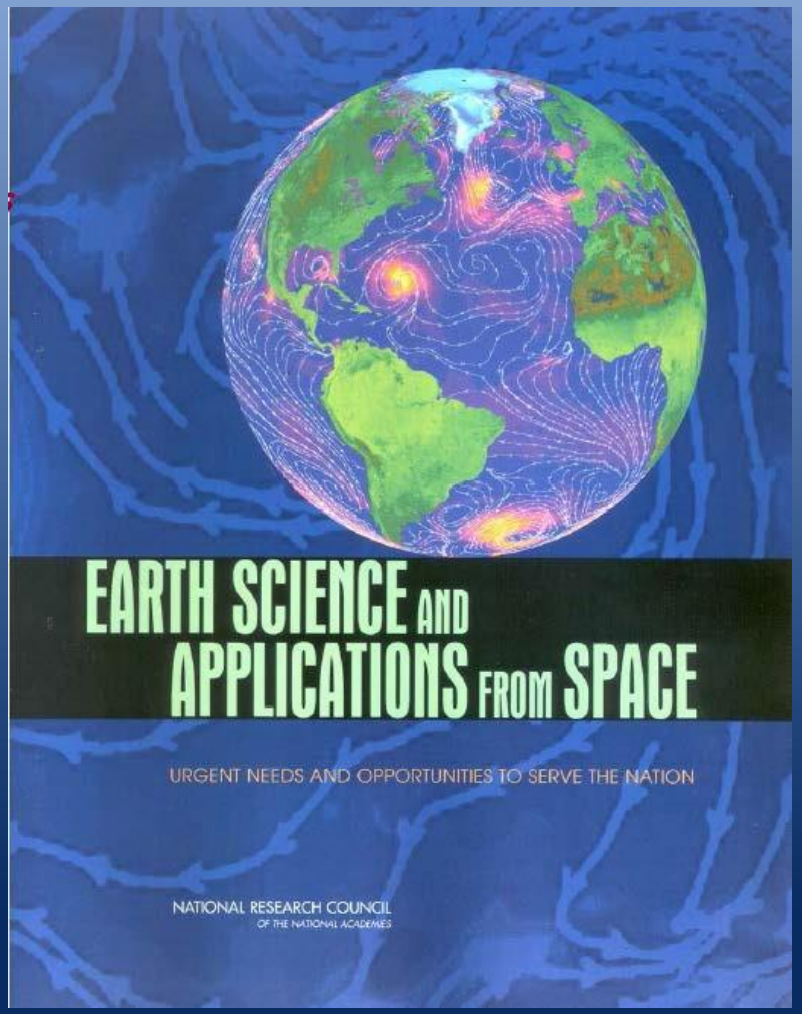
- ESAS 2007, the inaugural decadal survey
- ESAS 2017 versus ESAS 2007
- Agency Backdrop
- ESAS 2017 Statement of Task
- Study Panel Organization
- Request for Information #1 and Panel Organization
- Request for Information #2
- ESAS 2017 Timeline
- Challenges and Considerations
- Comments and Questions

Vision of the Inaugural Decadal Survey

Advancing Earth System Science to Benefit Society

"Understanding the complex, changing planet on which we live, how it supports life, & how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important for society as it seeks to achieve prosperity & sustainability."

-- Interim Report of the Decadal Survey, April 2005



ESAS 2007: Examples of Scientific and Societal Imperatives

- *Climate change and impacts*
- *Ice sheets, sea level, and ocean circulation*
- *Shifts in precipitation and water availability*
- *Transcontinental air pollution*
- *Shifts in ecosystems response to climate change*
- *Human health and climate change*
- *Extreme events, including severe storms, heat waves, earthquakes and volcanoes*

US Missions

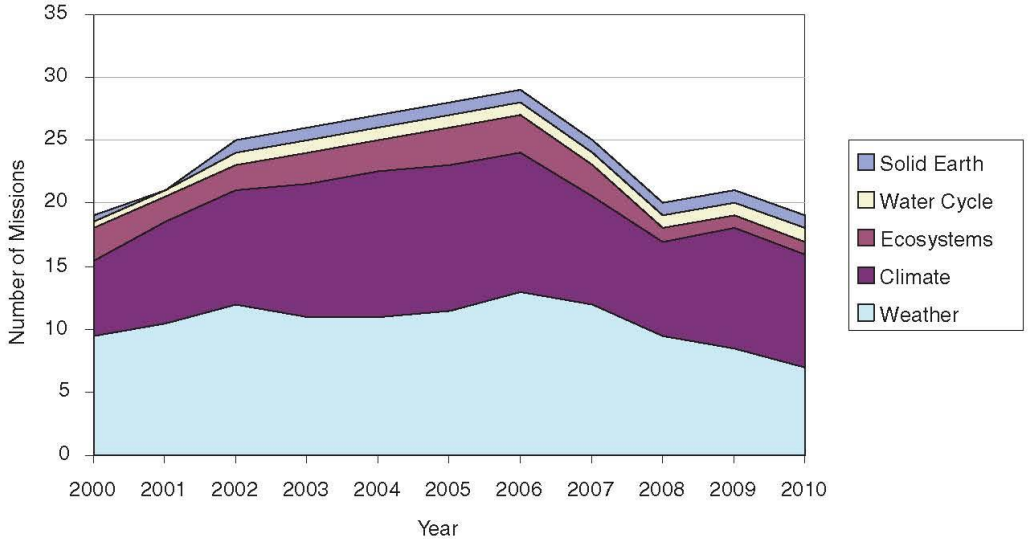


FIGURE ES.1 Number of U.S. space-based Earth observation missions in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of missions near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years past their nominal lifetimes. Most of the missions were deemed to contribute at least slightly to human health issues, and so health is not presented as a separate category. SOURCE: Information from NASA and NOAA Web sites for mission durations.

US Instruments

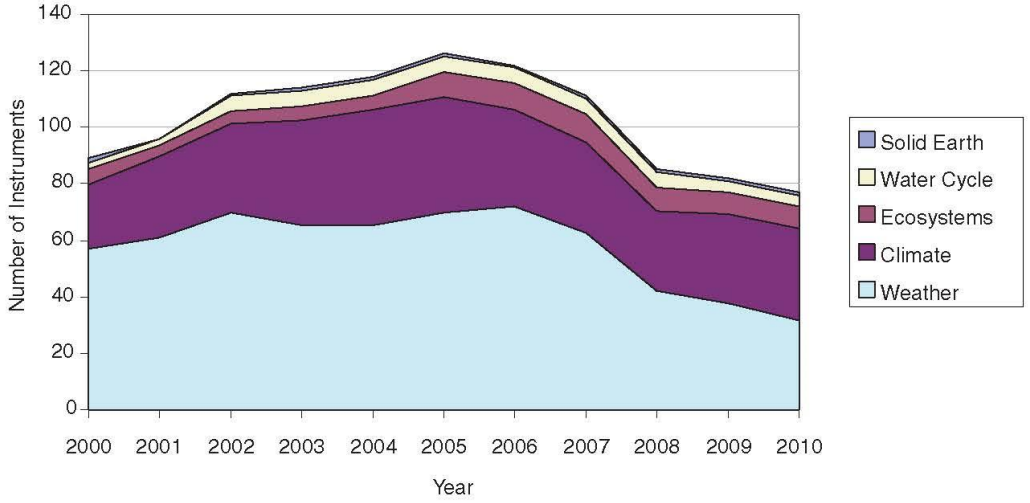
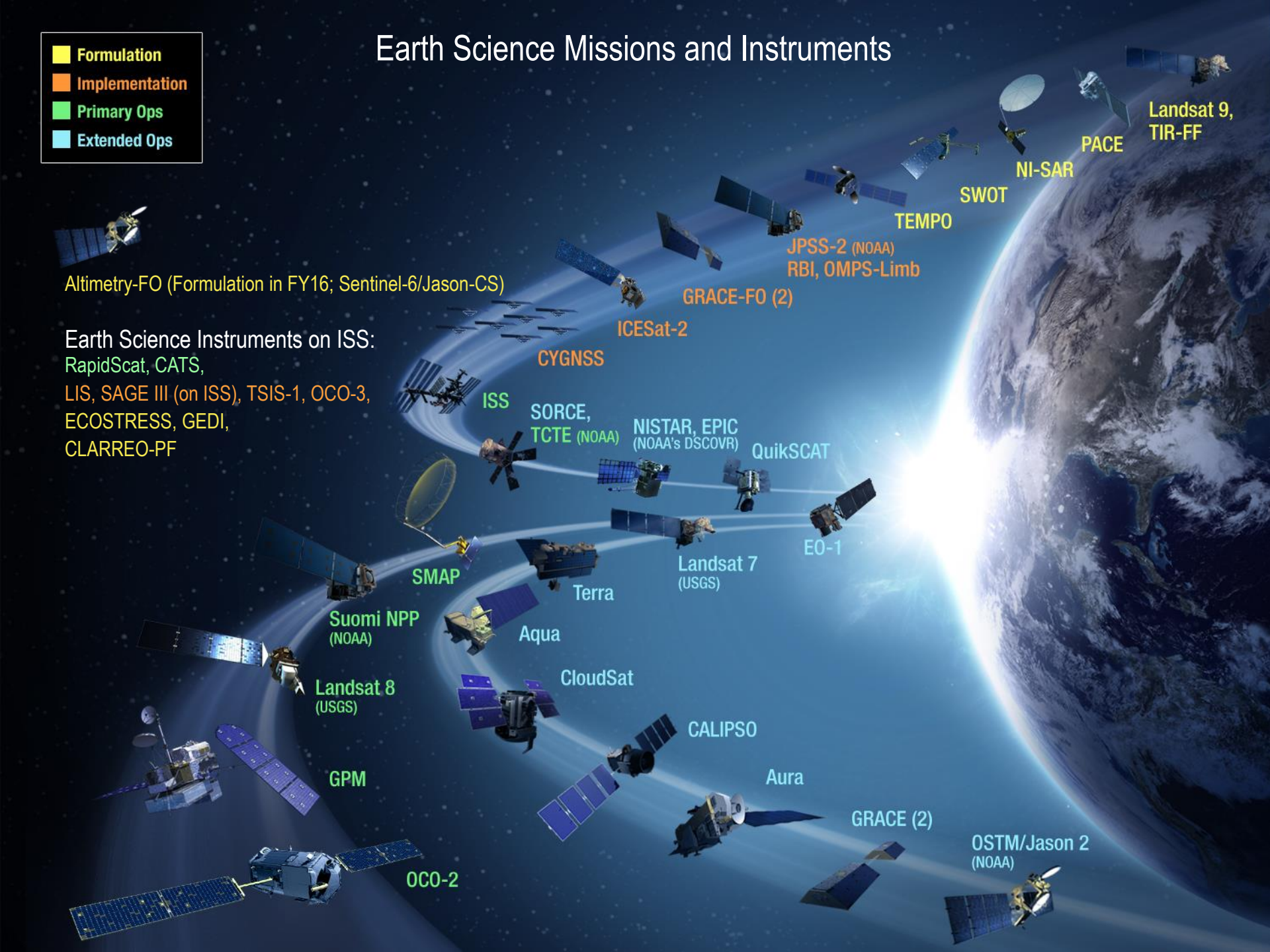
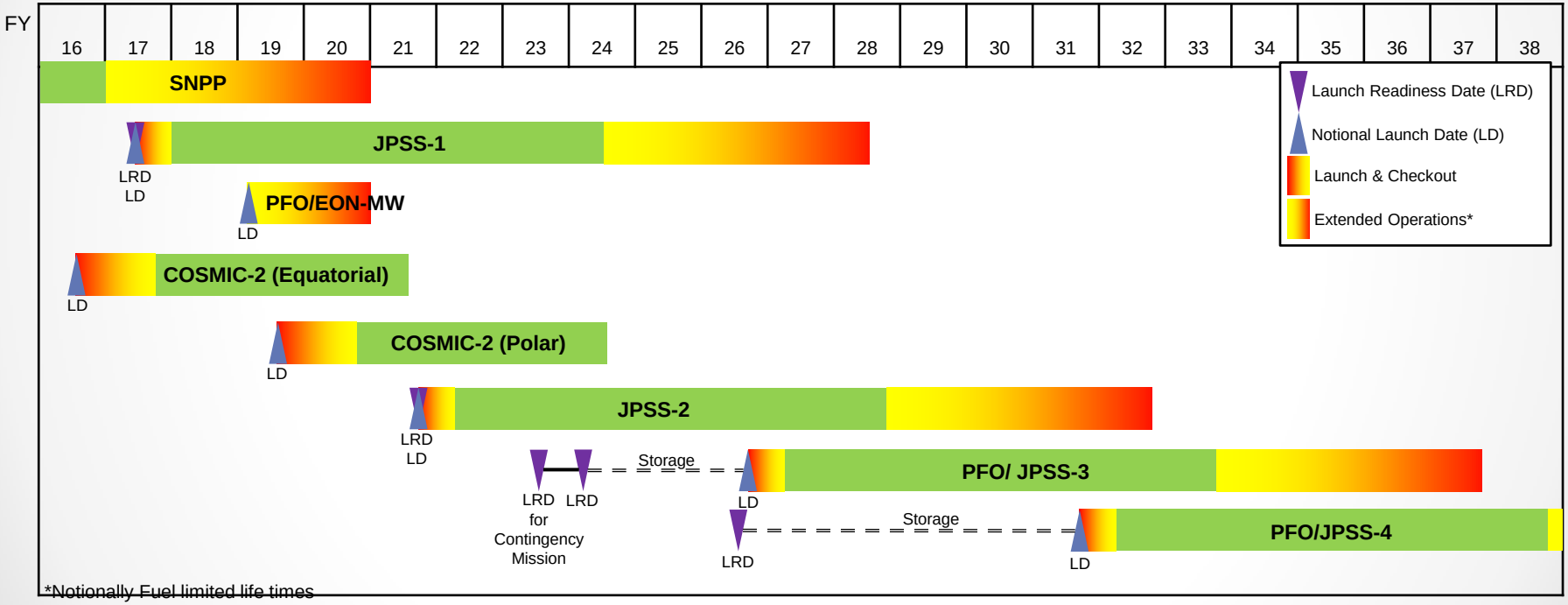


FIGURE ES.2 Number of U.S. space-based Earth observation instruments in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of instruments near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years past their nominal lifetimes. Most of the missions were deemed to contribute at least slightly to human health issues, and so health is not presented as a separate category. SOURCE: Information from NASA and NOAA Web sites for mission durations.

Earth Science Missions and Instruments



NOAA NESDIS' Plan for Polar Continuity



ESAS 2017

- Agency Sponsors:
  - NASA—Earth Science Division
  - NOAA—NESDIS
  - USGS—Climate & Land Use Change

  Will actively seek the participation of other relevant federal agencies regarding in situ and other relevant programs

- Within the Academy:

  - Collaboration (inc. staff) of the Space Studies Board (lead) with the Board on Atmospheric Sciences and Climate, Ocean Studies Board, Board on Earth Sciences and Resources, and Water Sciences and Technology Board. Consulting with other relevant Boards.

ESAS 2017 vs. ESAS 2007

- No longer appropriate to base recommendations on an aspirational budget
- Science based vs Mission based
- Congressionally-mandated independent cost appraisal and technical evaluation (CATE) for big ticket items
- Likely that the science will be "valued" to avoid having one recommended activity grow at expense of all others
- Increased opportunities to consider "new space" ideas—new players, smaller and less costly platforms, constellations, hosted payloads
  - Challenge: developing *credible* evaluations of their potential
- Improved consideration of international partners
- Existence of high-level guidance regarding Earth observations: NASA Climate-centric Architecture; OSTP National Strategy for Civil Earth Observations (2014); 2nd National Earth Observation Assessment, forthcoming

Agency Backdrop

NASA:

- Earth Science Div. has a backlog of missions recommended in 2007 survey
- Increased responsibility—without commensurate budget increases—for "continuity" measurements
- Budget under particular scrutiny, but to date has stayed roughly level

NOAA:

- Top priority: stabilize the weather satellite portfolio and avoid a gap in the polar orbiters
- "Climate"-related missions/instruments moving to NASA
  - Earth Radiation Budget, Total Solar Irradiance, Ozone Profiles, Altimetry
- Limited budget flexibility; direction to focus on core mission

USGS:

- Landsat-8 launched in February 2013
- Interest in adding new capabilities to Sustained Land Imaging Program
- Landsat-9 projected to be a near-rebuild of L-8 for launch in in 2023 (unless accelerated); lifetime of TIRS on L-8 is of concern

Primary Elements of the SOT

- Assess progress in addressing the major scientific and application challenges outlined in the 2007 Earth Science Decadal Survey.
- Develop a prioritized list of top-level science and application objectives to guide space-based Earth observations over a 10-year period commencing approximately at the start of fiscal year 2018 (October 1, 2017).
- Identify gaps and opportunities in the programs of record at NASA, NOAA, and USGS in pursuit of the top-level science and application challenges—including space-based opportunities that provide both sustained and experimental observations.
- Recommend approaches to facilitate the development of a robust, resilient, and appropriately balanced U.S. program of Earth observations from space. Consider: Science priorities, implementation costs, new technologies and platforms, interagency partnerships, international partners, and the *in situ* and other complementary programs carried out at NSF, DoE, DoA, DoD.

ESAS 2017 Steering Committee

Dr. Waleed Abdalati, Co-Chair
University of Colorado Boulder

Dr. Antonio Busalacchi, Co-Chair
University of Maryland

Mr. Steven J. Battel
Battel Engineering

Dr. Stacey W. Boland
Jet Propulsion Laboratory

Dr. Robert D. Braun
Georgia Institute of Technology

Dr. Shuyi S. Chen
University of Miami

Dr. William E. Dietrich
University of California, Berkeley

Dr. Scott C. Doney
Woods Hole Oceanographic Inst.

Dr. Christopher B. Field
Carnegie Institution for Science

Dr. Helen A. Fricker
Scripps Inst. of Oceanography

Dr. William B. Gail
Global Weather Corporation

Dr. Sarah T. Gille
Scripps Inst. of Oceanography

Dr. Dennis L. Hartmann
University of Washington

Dr. Daniel J. Jacob
Harvard University

Dr. Anthony C. Janetos
Boston University

Dr. Everette Joseph
University at Albany, SUNY

Dr. Molly K. Macauley
Resources for the Future

Dr. Joyce E. Penner
University of Michigan

Dr. Soroosh Sorooshian
University of California, Irvine

Dr. Graeme L. Stephens
Jet Propulsion Laboratory

Dr. Byron D. Tapley
The University of Texas at Austin

Dr. W. Stanley Wilson
NOAA/NESDIS, Ret.

Steering Committee Staff

Dr. Arthur Charo, Study Director
Ms. Lauren Everett, Program Officer
Mr. Charles Harris, Research Associate
Dr. Michael Moloney, Director, Space Studies Board

Study Panel Organization

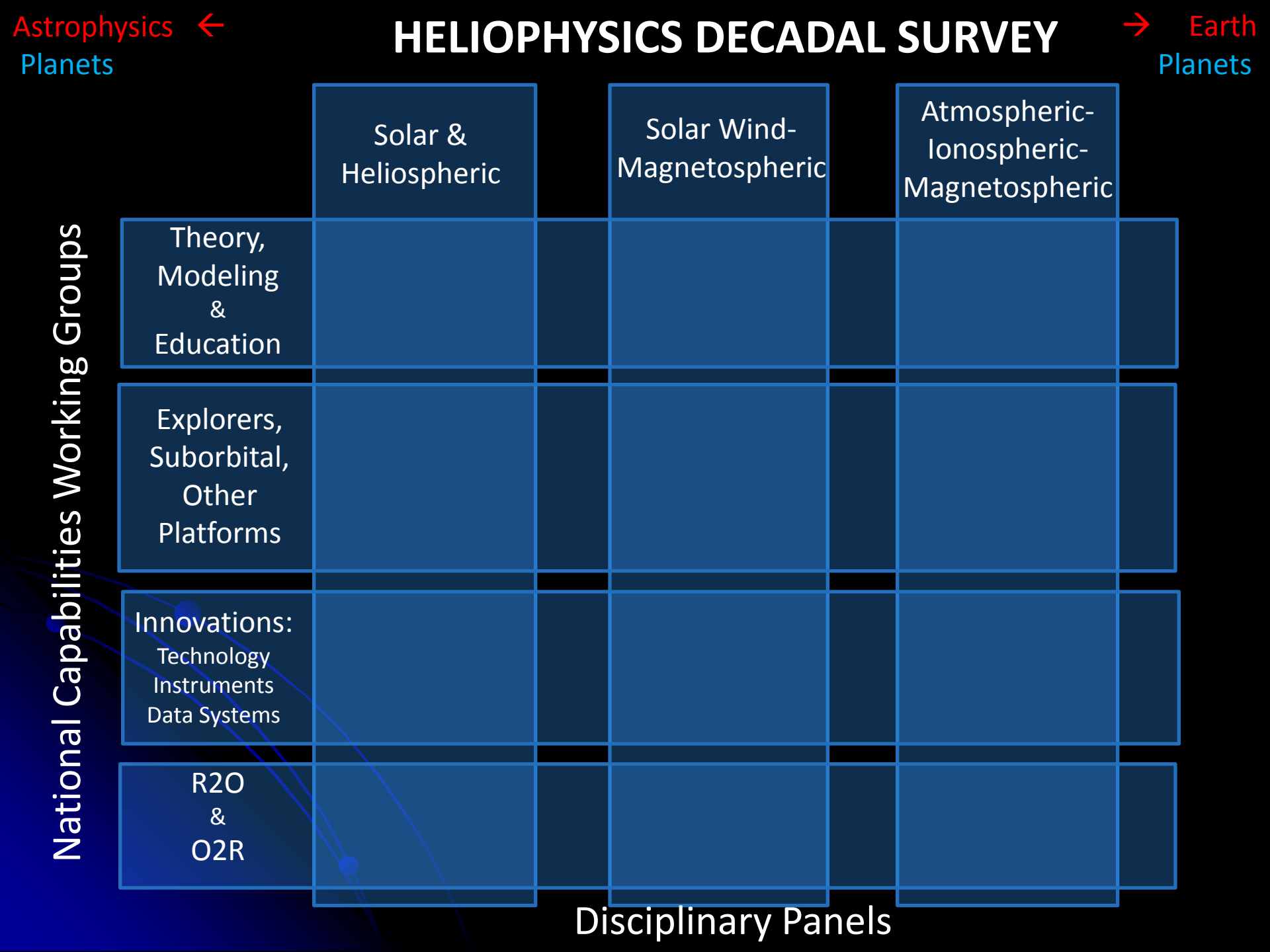
- While addressing Earth System Science, should provide the opportunity for input from traditional disciplines.
- Could organize by societal benefit areas, key science questions/grand challenges, fundamental couplings within the Earth System, or traditional disciplines.
- ESAS 2007: Steering Committee and Thematic Study Panels Mapped Broadly To Societal Benefit Areas.
- ESAS 2017: Adopt a matrix model of overarching survey committee, supported by panels, but also with the possibility of cross-cuts or limited term working groups?

Organization of ESAS 2007

Steering Committee (18 members)

Thematically-Organized Study Panels
(each ~12 members)

1. Earth Science Applications and Societal Needs
2. Land-use Change, Ecosystem Dynamics and Biodiversity
3. Weather (incl. space weather and chemical weather)
4. Climate Variability and Change
5. Water Resources and the Global Hydrologic Cycle
6. Human Health and Security
7. Solid-Earth Hazards, Resources and Dynamics


Astrophysics
Planets
HELIOPHYSICS DECADAL SURVEY
Earth
Planets
Solar & Heliospheric
Solar Wind-Magnetospheric
Atmospheric-Ionospheric-Magnetospheric
Theory, Modeling & Education
Explorers, Suborbital, Other Platforms
Innovations: Technology Instruments Data Systems
R2O & O2R
National Capabilities Working Groups
Disciplinary Panels

Context for Study Panel Organization

- The various components of the global integrated Earth system are interconnected and interdependent to such an extent that advances in understanding one component of the Earth system may require scientific progress across multiple disciplines.

- Acquisition of the data needed to enable advances in understanding the global integrated Earth system ("Earth system science") requires—over a very broad range of spatial and temporal scales, and with attention to sampling issues—active and passive measurements from instruments on space, airborne, and in situ platforms.

- It is increasingly evident that knowledge derived from improving our understanding of the Earth as a system can better inform policies and programs to further economic prosperity, national security, and sustainability.

Panel Organization—Context from Statement of Task

- The study will generate consensus recommendations from the environmental monitoring and Earth science and applications communities for an integrated and sustainable approach to the conduct of the U.S. government's civilian space-based Earth-system science programs.

- Recommend NASA research activities to advance Earth system science and applications by means of a set of prioritized strategic "science targets" for the space-based observation opportunities in the decade 2018-2027

- For NASA, the committee will pay particular attention to prioritizing and recommending balances among the full suite of Earth system science research, technology development, flight mission development and operation, and applications/capacity building development conducted in the Earth Science Division (ESD) of the Science Mission Directorate.

Panel Organization—Context from Statement of Task (con't)

- For NOAA and the USGS, the decadal survey committee's recommendations will be framed around national needs, including, but not limited to research priorities.

- Will consider which scientific advances are needed to add to NOAA's future predictive capabilities. This includes taking into the account the overlap and interdependencies between water, weather and climate, and encouraging the development of extended, and diversified forecasts.

- The committee will similarly consider advances needed to meet the needs of USGS science priorities and data users, for example advising on advances that can support both the natural resource management community and the climate research community.

Themes that Must be Accommodated by the Study Panel Organization

- Earth System Science
- Weather
- Water
- Climate
- Natural Resource Management

NASA Science Focus Areas

- Atmospheric Composition
- Weather
- Climate Variability & Change
- Water & Energy Cycle
- Carbon Cycle & Ecosystems
- Earth Surface & Interior

NOAA Long-Term Goals

- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Healthy Oceans Marine
- Resilient Coastal Communities and Economies

USGS Mission Areas

- Climate and Land Use Change
- Core Science Systems
- Ecosystems
- Energy and Minerals
- Environmental Health
- Natural Hazards
- Water

Whatever structure we decide upon must be able to clearly map onto:

SoT

Earth System Science
Weather
Water
Climate
Natural Resource Management

NOAA Long-Term Goals

Climate Adaptation and Mitigation
Weather-Ready Nation
Healthy Oceans Marine
Resilient Coastal Communities and Economies

NASA Science Focus Areas

Atmospheric Composition
Weather
Climate Variability & Change
Water & Energy Cycle
Carbon Cycle & Ecosystems
Earth Surface & Interior

USGS Mission Areas

Climate and Land Use Change
Core Science Systems
Ecosystems
Energy and Minerals
Environmental Health
Natural Hazards
Water

Survey Initial RFI

responses at: www.nas.edu/esas2017

Issued in late September 2015 to inform the steering committee and the organization of the panels:

1. What are the key challenges or questions for Earth System Science across the spectrum of basic research, applied research, applications, and/or operations in the coming decade?
2. Why are these challenge/questions timely to address now especially with respect to readiness?
3. Why are space-based observations fundamental to addressing these challenges/questions?

> 200 Responses!

RFI Responses

Ocean Sciences

- Establishing new satellite observations to observe climate change effects on oceans
- Consistent decadal climate data record for ocean heat content products
- Near-shore salinity measurements
- Sea-level rise
- Sea surface temperatures
- Ocean-atmosphere coupling (wind/current coupling)

Polar Sciences and Cryosphere

- Decadal variability observed in 20th century changing to weak inter-annual changes
- Measuring speed of sea and land ice progress (melt and melt volume) and sensitivity to climate and ocean forcing
- Snow accumulation and mass redistribution processes, impacts on snow-atmosphere heat and chemical exchange from the ice sheet, sea ice, and ocean
- Assessing feedback loop contributions to cryosphere albedo, its contribution to climate change
- Arctic clouds reaction to expected sea ice-free Arctic summers, Arctic reaction to cloud changes

Study Panels

Weather and Air Quality: Minutes to Subseasonal
Atmospheric Dynamics, Thermodynamics, Chemistry, and their Interactions at Land and Ocean Interfaces

Climate Variability and Change: Seasonal to Centennial
Forcings and Feedbacks of the Ocean, Atmosphere, Land, and Cryosphere within the Coupled Climate System

Marine and Terrestrial Ecosystems and Natural Resource Management
Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and Factors that Influence Health and Ecosystem Services

Global Hydrological Cycle and Water Resources
The Movement, Distribution, and Availability of Water and How these are Changing Over Time

Earth Surface and Interior: Dynamics and Hazards
Core, Mantle, Lithosphere, and Surface Processes, System Interactions, and the Hazards they Generate

Study Panels

Weather and Air Quality: Minutes to Subseasonal
*Atmospheric Dynamics, Thermodynamics, Chemistry, and their Interactions at Land and **Ocean** Interfaces*

Climate Variability and Change: Seasonal to Centennial
*Forcings and Feedbacks of the **Ocean**, Atmosphere, Land, and Cryosphere within the Coupled Climate System*

Marine and Terrestrial Ecosystems and Natural Resource Management
Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and Factors that Influence Health and Ecosystem Services

Global Hydrological Cycle and Water Resources
The Movement, Distribution, and Availability of Water and How these are Changing Over Time

Earth Surface and Interior: Dynamics and Hazards
Core, Mantle, Lithosphere, and Surface Processes, System Interactions, and the Hazards they Generate

ESAS 2017 Panels

WORKING GROUPS (Ten-tative)	Weather: Minutes to	Climate Variability and Change	Marine & Terrestrial	Global Hydrological Cycle	Earth Surface & Interior
Extreme Events					
Water Cycle	Sub-seasonal		Eco-systems	& Water Resources	
Carbon Cycle					
Technology & Innovations Cross-Cut					
Applications' Science Cross-Cut					

RFI #2

"We now invite you to submit ideas for specific science and applications targets (i.e. objectives) that promise to substantially advance understanding in one or more Earth System Science themes.

Submitted ideas will be reviewed by one or more of the survey's study panels, which are organized to address the above-mentioned themes.

Suggested targets that are cross-cutting among these themes are particularly encouraged**.**

Submissions should also identify the key geophysical variables/measurements, and the observational requirements, needed to address the science and application targets.

We anticipate that some of the targets, and their associated measurements, recommended by the Panels will be selected by the Steering Committee for detailed technical and cost analysis of potential implementation architectures.

To assist those efforts, you are encouraged to provide information on measurement approaches, including technical, performance and maturity/heritage specifications, for relevant current and near-future instrumentation."

NOTIONAL PLAN FOR PANEL MEETINGS

	Day 1	Day 2	Day 3	Day 4
Panel Pre-Jamboree Meetings (WebEx)	**Panels**	**Panels**	-	
Jamboree 1 May-June 2016	**Steering Committee** 1/2 day	**Steering Committee & Integrated Themes** 1/2 day each	**Panels** Review previous Decadal Survey priorities and current observations, discuss applications, review RFIs, identify critical data needs & measurements	**Panels**
Jamboree 2 July	**Steering Committee** 1/2 day	**Integrated Theme Breakout Day** Full day session organized by Integrating Themes	**Panels** Prioritize measurements informed by breakout day	**Panels** Continue prioritization, start drafting report after this meeting
Jamboree 3 Sept/Oct	**Panels** Get feedback from the Steering Committee, "finalize" draft report	**Panels**	**Integrating Themes** Discuss / finalize "inputs" to the report	**Steering Committee**

ESAS 2017 Timeline

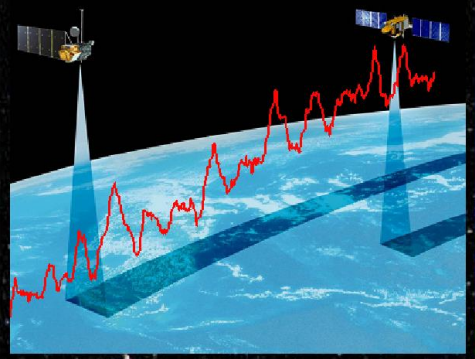
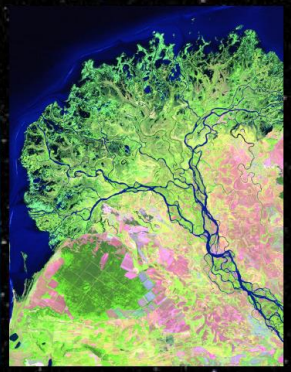
- Provision of funds/formal start — August 17, 2015
- Appointment of survey chairs — August 20, 2015
- First RFI (ESS objectives) — September 28, 2015
- Steering Committee (SC) approved — December 2, 2015
- Panels appointed — by end of March 2016
- Town Halls: AGU, AMS, **Ocean Sciences** — Dec. 14th, Jan. 13th, and **Feb. 22nd**
- First meeting of the SC — January 18-20, 2016 in DC
- 2nd RFI (targets/measurement approaches) ~ May 1, 2016
- SC Meetings 2-4 — 2016; #2 in May-June
- SC Meetings 4-6 — by end of April 2017
  - Additional splinter meetings likely
- Panel Meetings, all held with SC — 3 in 2016; 1st targeted for May-June
- Panel Outputs to Steering Committee — NLT January 2017
- **Pre-Pub Report approval** — **NLT July 31, 2017**

ESAS 2017
Challenges and Considerations

- Budget
  - Historical vs. Aspirational—Even Inspirational—and Being Realistic
- "CATE" and Recommendations to NASA:
  - Reference Missions vs. Implementation
  - High-profile missions & need for decision rules
- For NOAA and USGS:
  - Actionable recommendations to improve services
- A Question of Balance:
  - Across societal benefit areas, application science, size/class of missions
  - Balance is also required across R+A, technology development, and the missions themselves, i.e., flight/non-flight

EARTH SCIENCE AND APPLICATIONS FROM SPACE



DECADAL SURVEY 2017-2027

Survey Website: www.nas.edu/esas2017

Survey Mailbox: esas2017@nas.edu

Comments Welcome. Participation Needed!