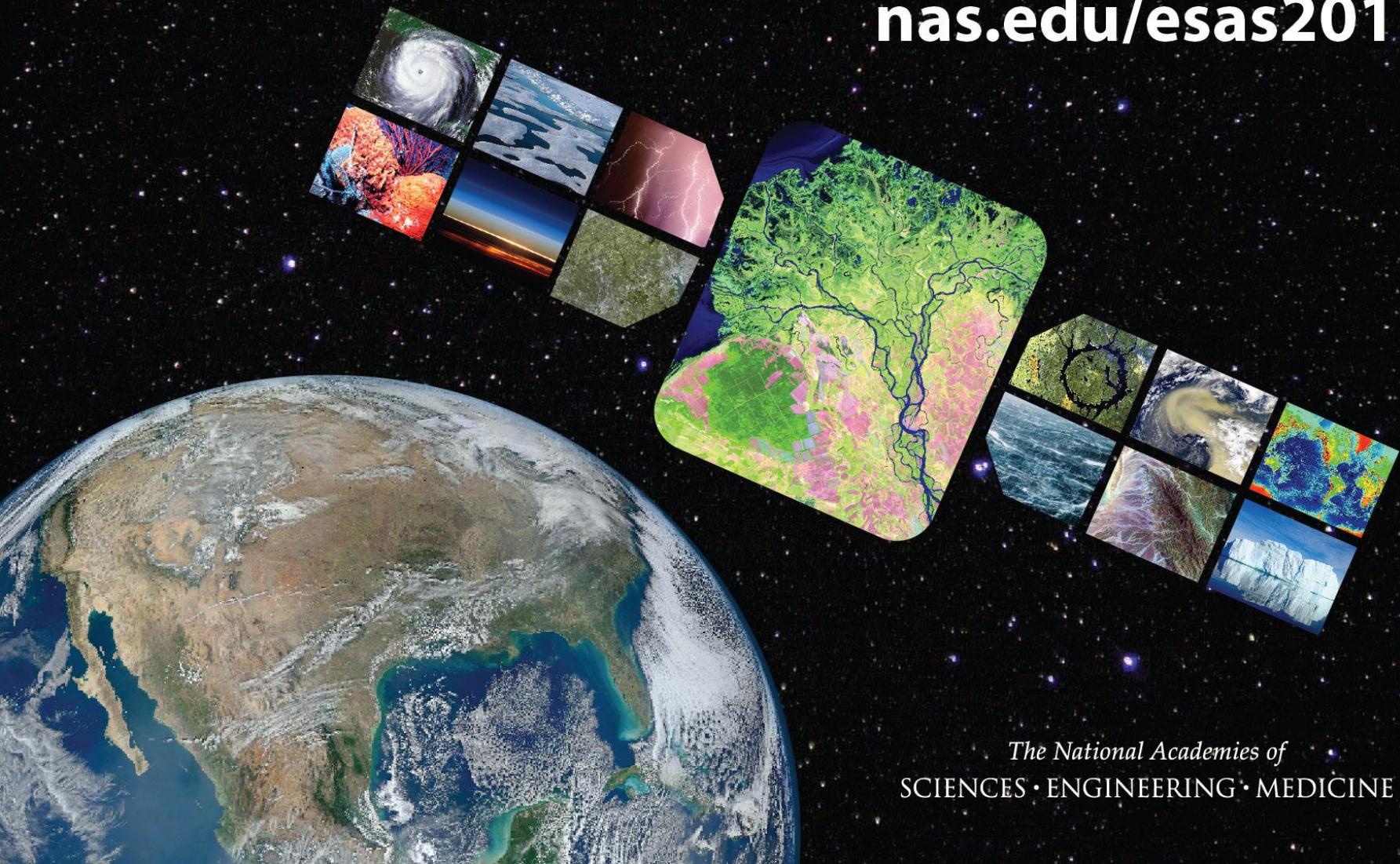


Charting the course for the next decade of Earth observations

nas.edu/esas2017



The National Academies of
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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

AMS Town Hall, January 13, 2016
New Orleans, LA

ESAS 2017 Town Hall

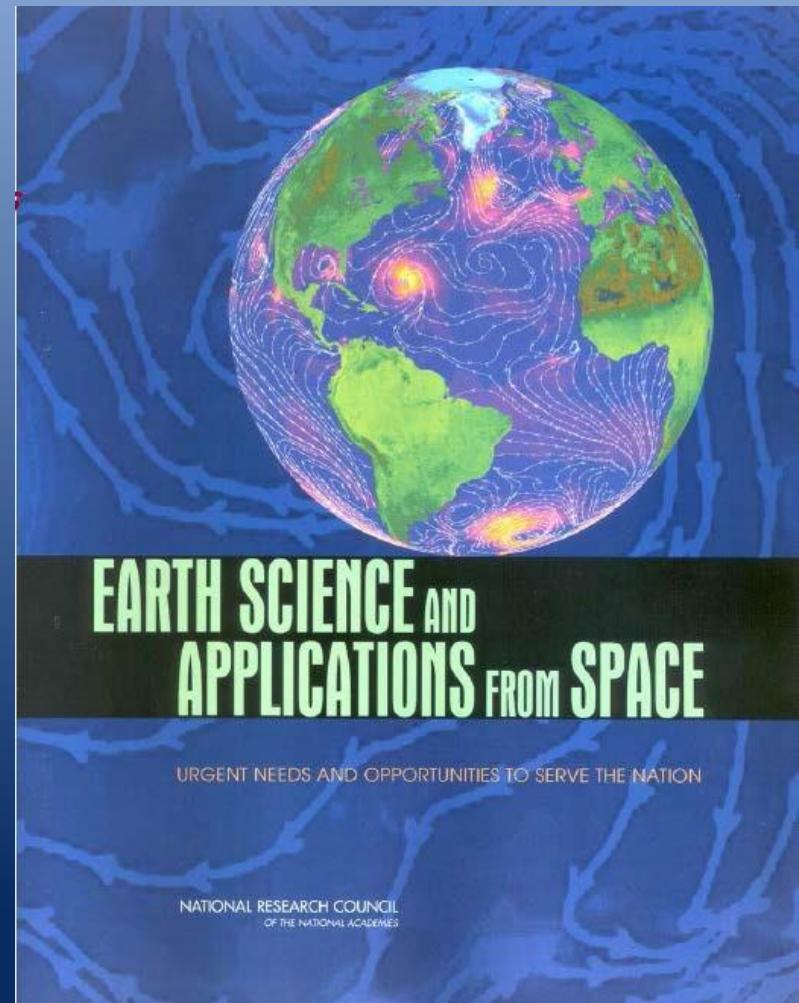
- ESAS 2007, the inaugural decadal survey
- ESAS 2017 versus ESAS 2007
- Agency Backdrop
- ESAS 2017 Statement of Task
- Study Panel Organization
- Request for Information and Community Responses
- Timeline
- Challenges and Considerations
- Comments and Questions

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

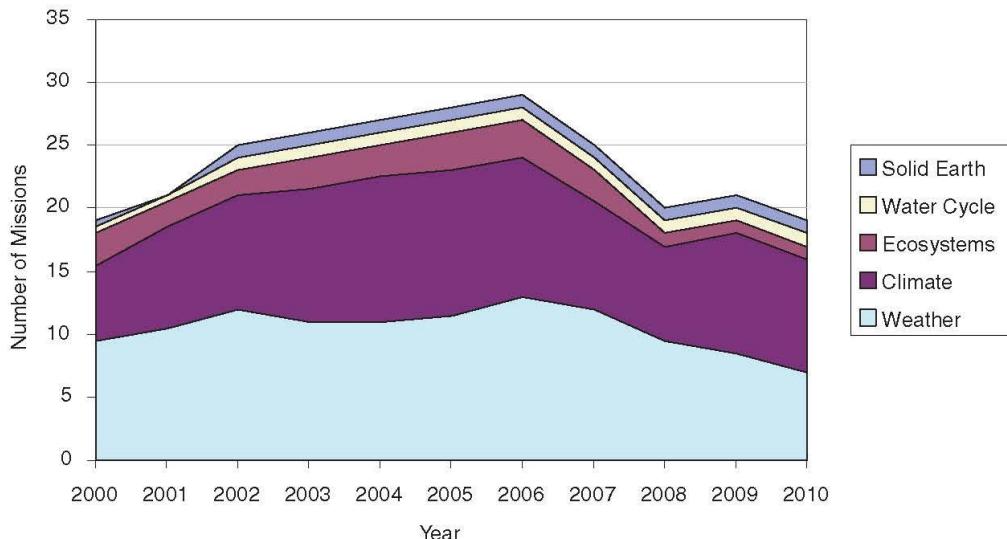


FIGURE ES.1 Number of U.S. space-based Earth observation missions in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of missions near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years past their 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

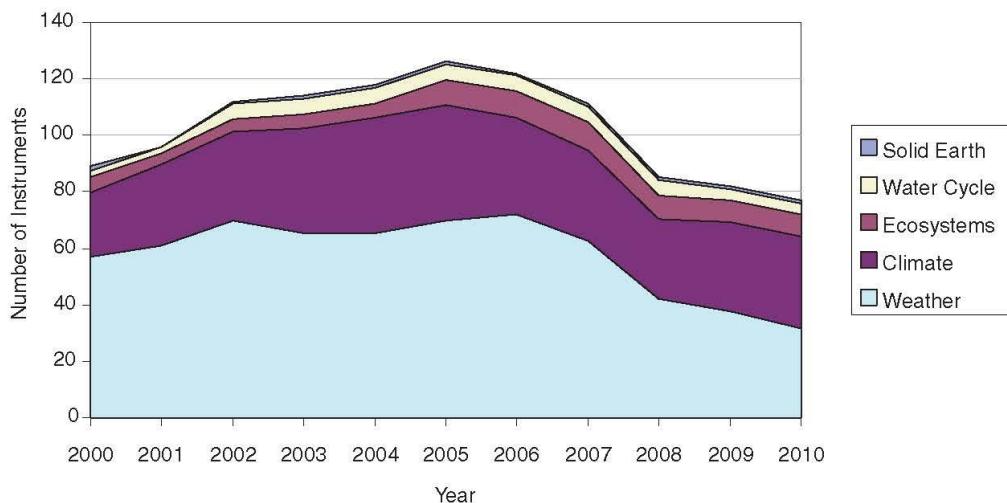


FIGURE ES.2 Number of U.S. space-based Earth observation instruments in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of instruments near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years 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

Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)

Earth Science Instruments on ISS:

RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF



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 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.

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Dr. Antonio Busalacchi, Co-Chair
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NOAA/NESDIS, Ret.

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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

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.

Context for Study Panel Org. from Statement of Task-1

- 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.

Context for Study Panel Org. from Statement of Task-2

- 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

Survey Initial RFI

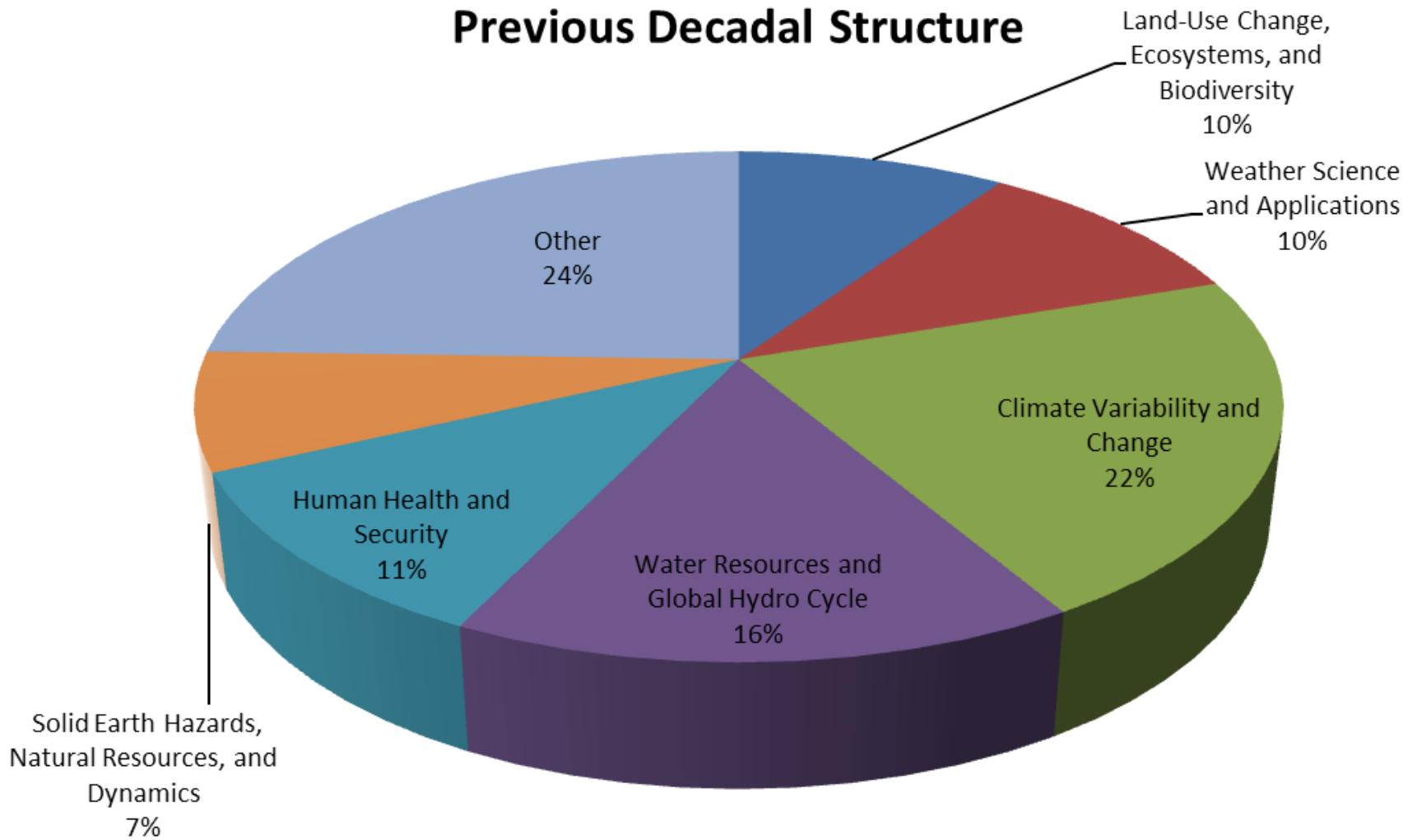
responses at: www.nas.edu/esas2017

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 Categories: Previous Decadal Structure



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

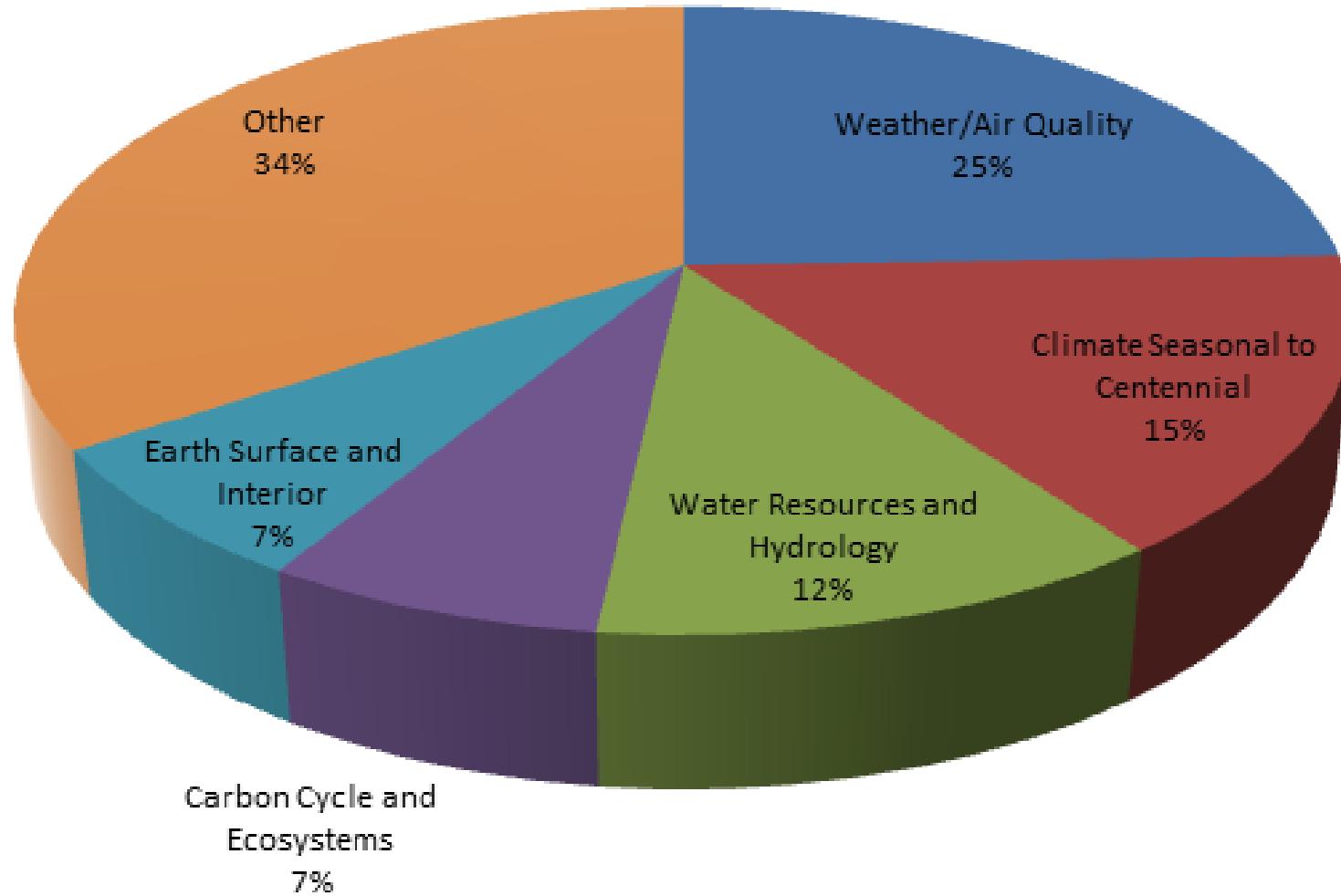
NOAA Long-Term Goals

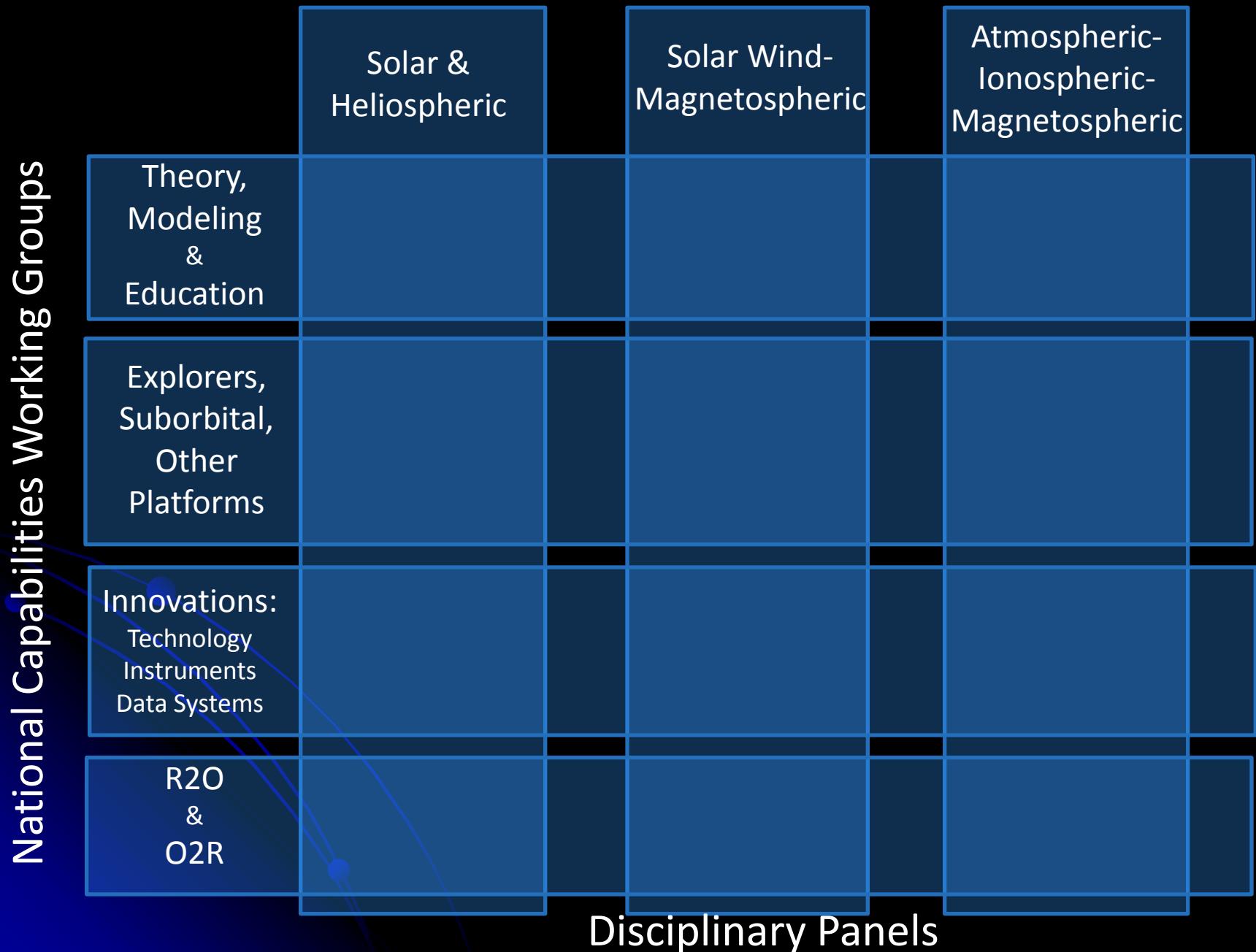
- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Healthy Oceans Marine
- Resilient Coastal Communities and Economies

USGS Mission Areas

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

RFI Categories: Modified Structure





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/implementation focus?) timed to front-end panels
- SC Meetings 2-4 2016
- SC Meetings 4-6 by end of April 2017
 - Additional splinter meetings likely
- Panel Meetings 3 in 2016; 1st targeted for April/May
- 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 Information: www.nas.edu/esas2017

Survey Mailbox: esas2017@nas.edu

Comments Welcome-Participation Needed!

BACKUP SLIDES

Summary of the Study

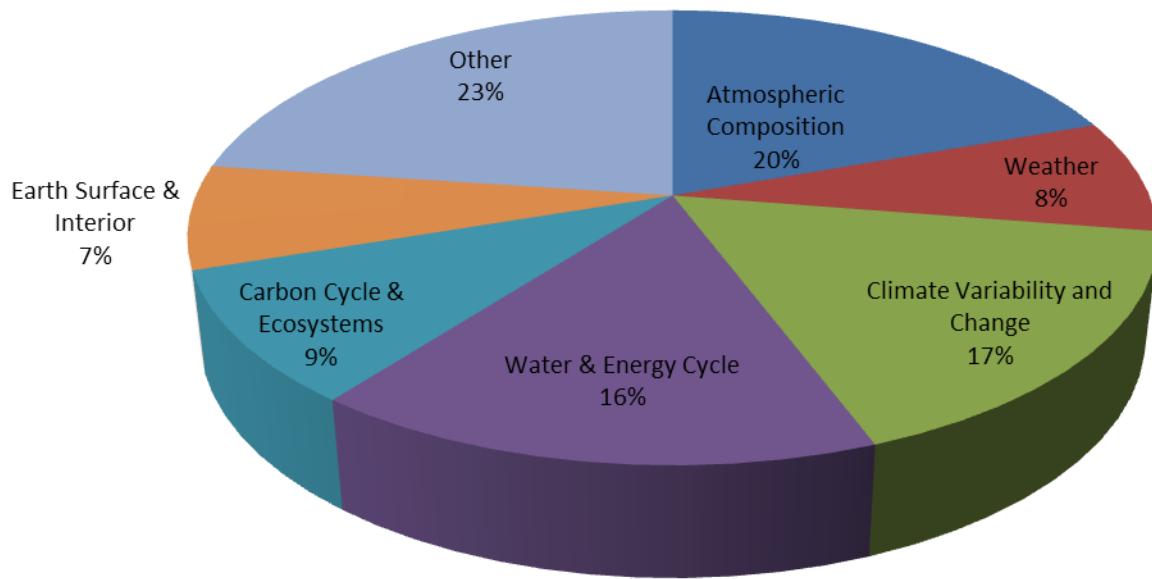
- NASA ESD is in a capped budget environment
 - Increasing demand for implementation of new measurements
 - Growing demand for continuing important measurements from current mission suite
 - Executive and Congressional Branch priorities
 - ESD Program Plans
 - Survey from NRC Decadal Survey
 - International Collaboration opportunities
- Response to the study charge is constrained to Climate Change focus
 - Most demanding requirements and likely largest set of actionable options
 - Include issues of instrument performance, stability, cross calibration and the data issues associated with algorithm change in processing and reprocessing
- Recommendations focus is on the *measurements required to determine geophysical variables*, not on instruments or missions
 - NRC Decadal Survey will recommend a prioritized set of science objectives and associated geophysical variables
 - ESD will provide the instrument and missions required to meet the science objectives.
- Emphasis placed on quantitative decision approaches
 - A valuation framework is recommended, but implementation data base still needs development

What Happens to Missions Recommended in the Previous Survey?

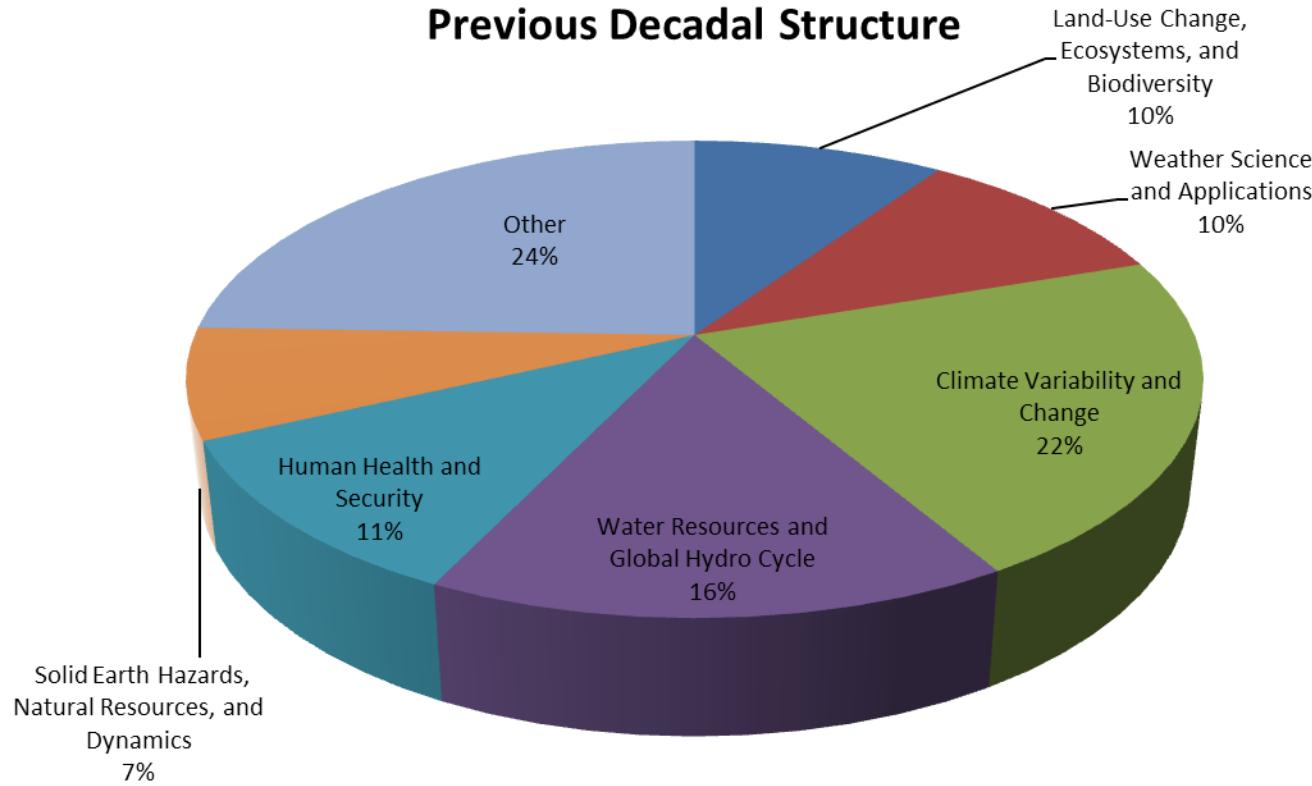
TBD, but:

- In developing its recommendations, survey to “include reconsideration of the scientific priorities associated with the named missions from the 2007 decadal survey.”
 - The 2007 survey did not prioritize among the 15 missions for NASA; placement in 1 of 3 time periods (Tiers I, II, III: 2010-13, 2013-2016, 2016-2020) based on factors including technical readiness; cost; synergy with existing, planned, or recommended missions; and consideration of int'l activities.
 - ESD has expressed an interest in having the survey provide guidance on technology investments that will be needed to address recommended science targets.
 - Previous surveys treated missions in formulation as part of the baseline program of record—they were not prioritized.

RFI Categories: NASA Science Focus Areas



RFI Categories: Previous Decadal Structure



WHY UNDERTAKE A “DECadal SURVEY”

- Take a long-term look at the field and recommend top priority scientific goals and directions for the future;
- Direct recommendations to the principal agencies that support facilities and research in the relevant fields;
- Provide recommendations for programmatic directions and explicit priorities for government investment in research facilities, including space flight missions; and
- Address issues of advanced technology, infrastructure, interagency coordination, education, and international cooperation.

Study Panels for ESAS 2007

1. Earth Science Applications and Societal Needs
 - » Tony Janetos, PNL/Univ. of Maryland, chair
 - » Roberta Balstad, Columbia Univ, vice-chair
2. Land-use Change, Ecosystem Dynamics and Biodiversity
 - » Ruth DeFries, Columbia, chair
 - » Otis Brown, Univ. of Miami, vice-chair
3. Weather (including space weather and chemical weather)
 - » Susan Avery, Univ. of Colorado, chair
 - » Tom Vonder Haar, Colorado State, vice-chair
4. Climate Variability and Change
 - » Eric Barron, Penn State, chair
 - » Joyce Penner, Univ. of Michigan, vice-chair
5. Water Resources and the Global Hydrologic Cycle
 - » Dennis Lettenmaier, Univ. of Washington, chair
 - » Anne Nolin, Oregon State Univ., vice-chair
6. Human Health and Security
 - » Mark Wilson, Univ. of Michigan, chair
 - » Rita Colwell, Univ. of Maryland, vice-chair
7. Solid-Earth Hazards, Resources and Dynamics
 - » Brad Hager, MIT, chair
 - » Susan Brantley, Penn State, vice-chair

2007 ESAS Decadal Survey Final Report

- ❑ Overarching recommendation: *Renew investment in satellite Earth observing systems*
- ❑ Recommended specific, integrated mission suite
 - Rolled-up panel recommendations preserve highest priorities
 - Sequenced 2010-2020+ launches
 - Full execution of the plan over the decade required NASA ESD yearly budgets to increase by ~ \$550M and remain steady at this level (approximately equal to the budget in 2000)
- ❑ Guidance on actions to take in the event of budget shortfalls or technology problems

Recommendations build on current instruments & offer a new level of integration to address key science & yield critical societal benefits

Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond (January 2007)

- Referring to the 2005 interim report's warning of a system in danger of collapse, the 2007 final report stated:

“In the short period since the Interim Report, budgetary constraints and programmatic difficulties at NASA have greatly exacerbated this concern. At a time of unprecedented need, the nation’s Earth observation satellite programs, once the envy of the world, are in disarray.”

Agency-Specific Tasks-I

NASA

- 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. (A science target in this instance comprises a set of science objectives that could be pursued and significantly advanced by means of a space- based observation.)
..... For each science target, the committee will identify a set of objectives and measurement requirements/capabilities for space-based data acquisitions.

If appropriate and usually only for recommendations associated with major investments, the committee will (via a “CATE” process) assemble notional proof-of-concept missions with the recommended capabilities in order to better understand the top-level scientific performance and technical risk options associated with mission development and execution.

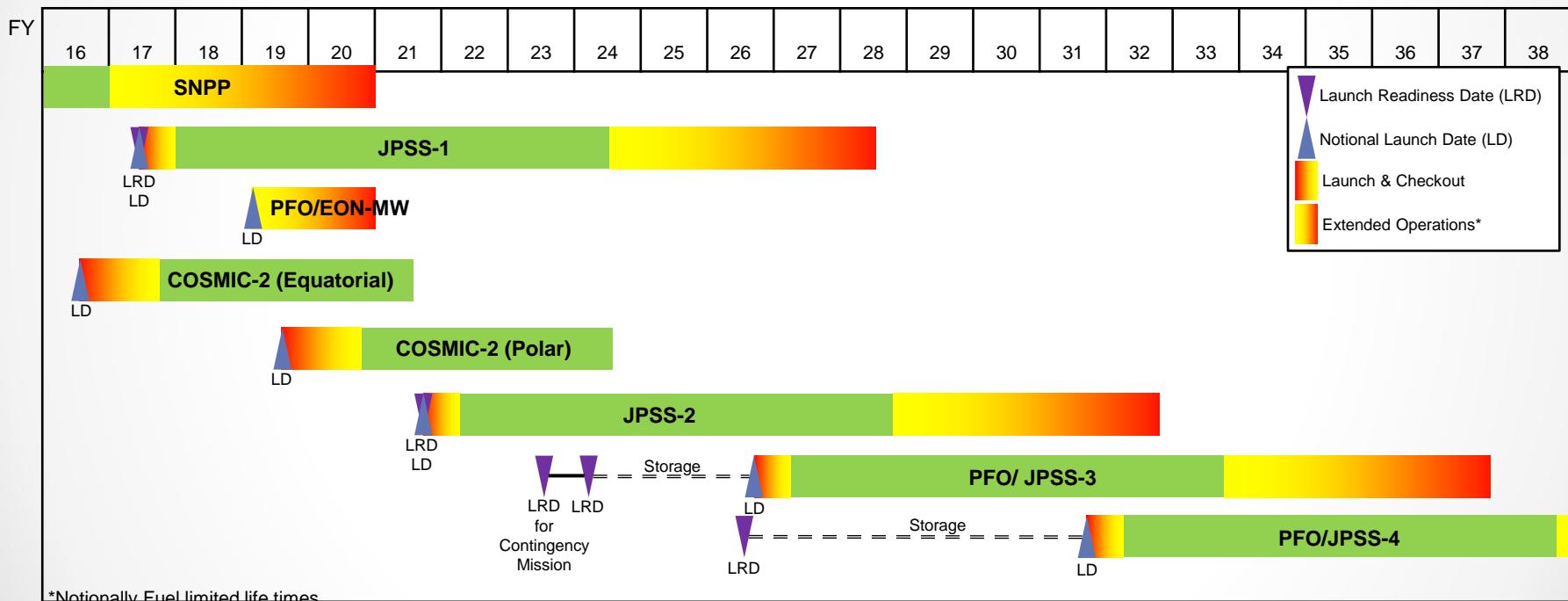
- Other NASA tasks include: The committee will pay particular attention to prioritizing and recommending balances among the full suite of Earth system science research, technology development, flight mission development and operation, and applications/capacity building development conducted in the Earth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

Agency-Specific Tasks-II

NOAA & USGS

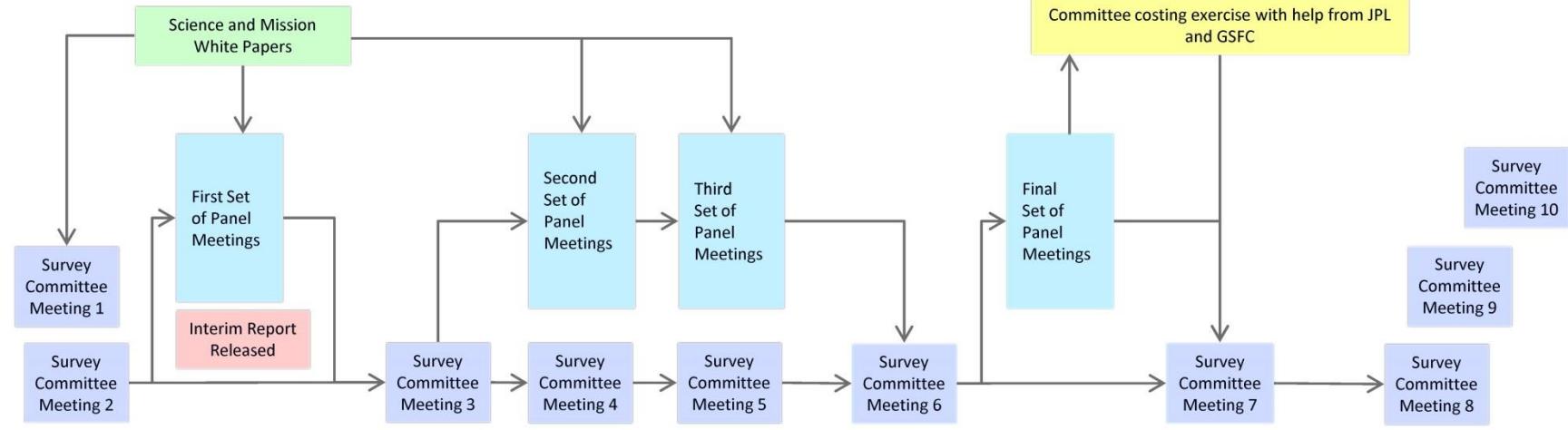
- The decadal survey committee's recommendations will be framed around **national needs**, including, but not limited to research priorities. Recommendations may be organized around 1) how **new technology** may enhance current operations, and 2) what **new science** is needed to expand current operations, either to enable new capabilities or to include new areas of interest. In making these recommendations, the committee will consider the need to bridge current operations and support a viable path forward for the uninterrupted delivery of public services through these generational changes.
- Other tasks include: suggest approaches for evaluating and integrating new capabilities from **non traditional suppliers** of Earth observations; may offer recommendations concerning “**research to operations**” (or “innovation for continuity and service improvements across agencies”); and consider the agencies’ ability to replicate existing technologies to improve and sustain operational delivery of public services.

NOAA NESDIS' Plan for Polar Continuity



ESAS 2007 Flow Chart

(note absence of a formal CATE)



Nov 2004	//	Apr 2005	May 2005	June 2005	July 2005	Aug 2005	Sept 2005	Oct 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	Mar 2006	Apr 2006	May 2006	Jun 2006	Jul 2006	Aug 2006	Sept 2006
1	//	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

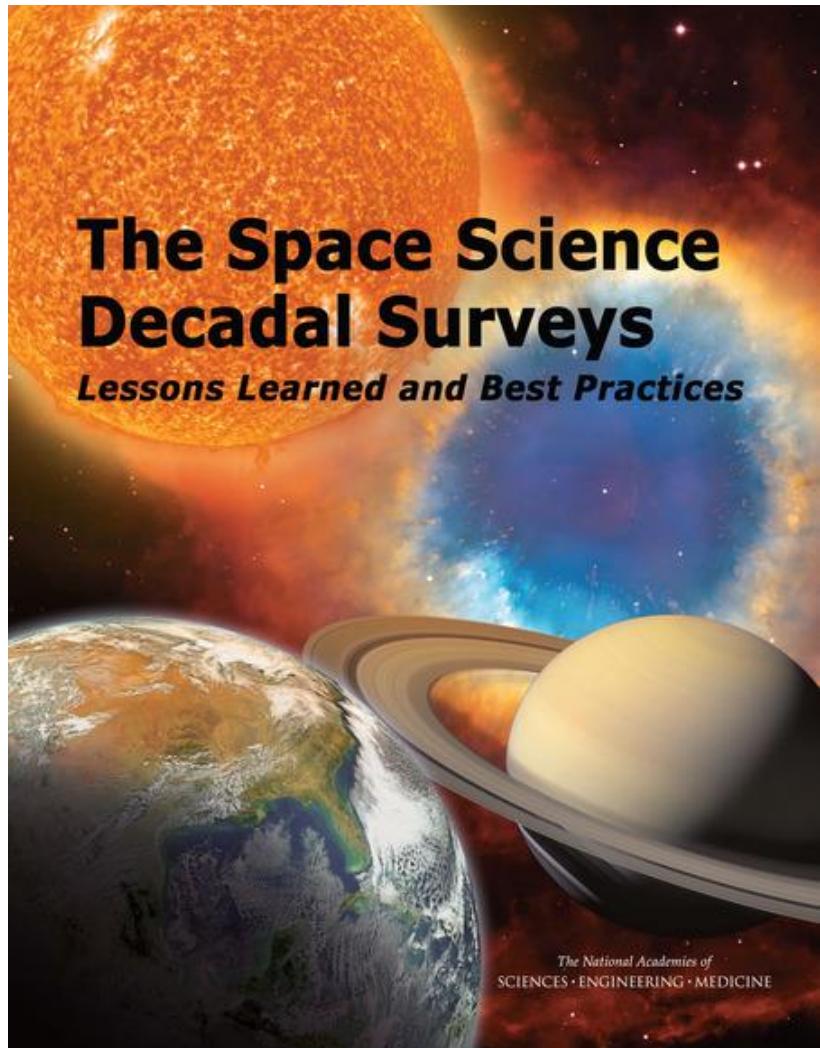
Months

Personal solicitations and a community-wide request for information, released following the second meeting of the survey committee, leads to the generation of white papers relating to science and mission activities. An interim report is issued following the second meeting of the survey committee. The first panel meetings are held.

Fourth meeting of the survey committee coincides with the second set of panel meetings. Panels hear briefings, assess science and mission activities proposed in white papers, and hear from the authors of selected white papers.

Fifth meeting of the survey committee coincides with the third set of panel meetings. Assessment of white papers continues. Conceptual missions are devised.

The final panel meetings are held in Spring 2006. NASA mission designers assist the survey committee in developing a budget spreadsheet to determine the likely costs of mission components (e.g., instruments, spacecraft, launch vehicle, integration and test, ground data system, mission operations, data downlink and archiving, science team, and data validation). At the seventh meeting of the survey committee in May 2006, the panels present their prioritized missions. The survey committee sets the final science and mission priorities. Three subsequent meetings are devoted to the drafting of the survey report. Report is delivered to sponsors in January 2007.



COMMITTEE ON SURVEY OF SURVEYS: LESSONS LEARNED FROM THE DECADAL SURVEY PROCESS

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THOMAS YOUNG, Lockheed Martin Corporation (retired)

Staff:

DAVID H. SMITH, Senior Program Officer, Study Director

DIONNA J. WILLIAMS, Program Coordinator

CATHERINE A. GRUBER, Editor

KATIE E. DAUD, Research Associate

ANGELA M. DAPREMONT, Lloyd V. Berkner Space Policy Intern

MICHAEL H. MOLONEY, Director, Space Studies Board

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About the Study

- Follow-on to the November 2012 Workshop “Lessons Learned in Decadal Planning in Space Science”
- Collects lessons learned from planetary, heliophysics, astronomy & astrophysics, and Earth science experiences with decadal surveys and mid-term assessments
- Written with future survey committees in mind
 - “Handbook” approach
 - Time-ordered discussion with collection of lessons learned and best practices as an appendix

A Framework for Analyzing the Needs for NASA-Sustained Remote Sensing Observations of the Earth: Background

- NASA's Earth Science Division (ESD) faces difficult choices among competing priorities, including new responsibilities, without commensurate budget increases, for the continuation of existing measurements and developing new measurement capability to address new research priorities
- The problem is compounded by responsibility for existing missions from:
 - *Foundational Continuity Measurements*: Stratospheric and Upper Tropospheric Ozone (OMPS-L), Solar Irradiance (TSIS), Earth Radiation Budget (CERES), and Ocean Altimetry (Jason-3 FO)
 - *2010 Climate Architecture*: Global Temporal Mass Change(GRACE –FO, Polar Ice Mass Change(ICESat-2), Ocean Color and Clouds/Aerosols (PACE), Ozone and Aerosols(SAGE III) and Atmospheric CO₂(OCO-2)
 - *Federal Concerns*: Landsat Data Continuity (Landsat-8 FO)
- In 2013, at the request of the ESD, an ad hoc committee of the Academies was convened to recommend a framework for deciding when an ESD measurement or dataset should be collected for extended periods.

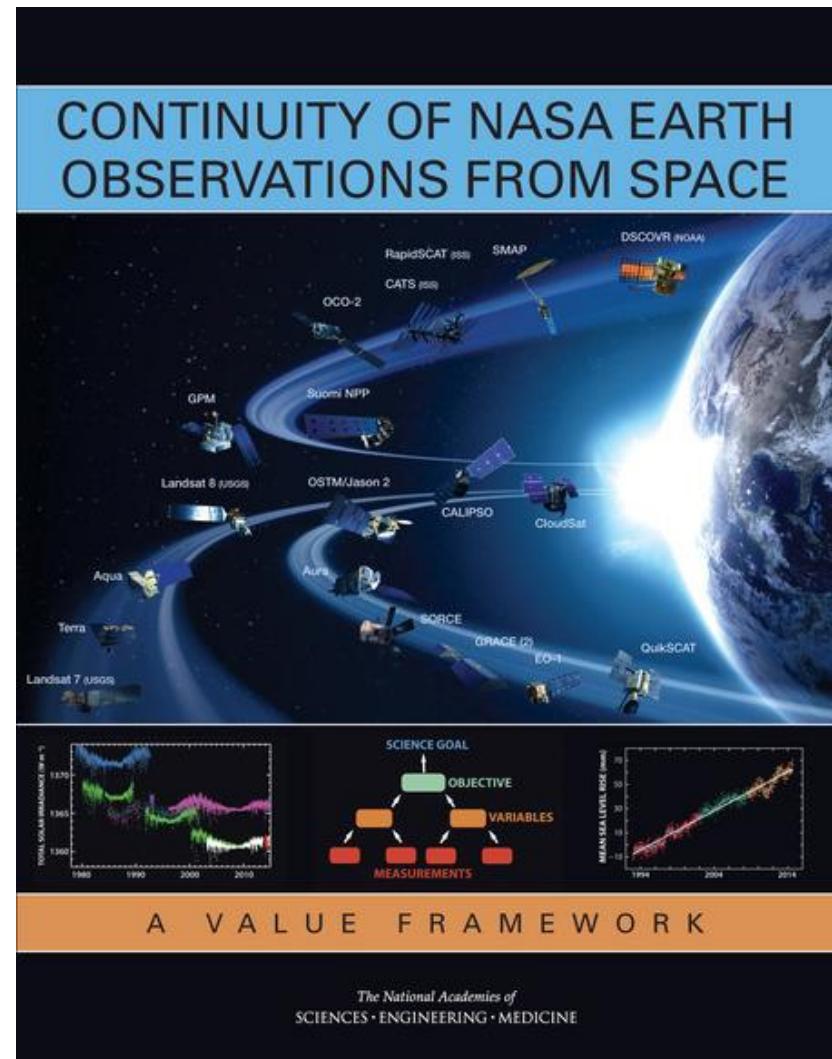
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Staff

ARTHUR A. CHARO, Senior Program Officer, Study Director
LEWIS B. GROSWALD, Associate Program Officer

* Represents members of CESAS, the oversight committee for the decadal survey



<http://www.nap.edu/catalog/21789/continuity-of-nasa-earth-observations-from-space-a-value-framework>