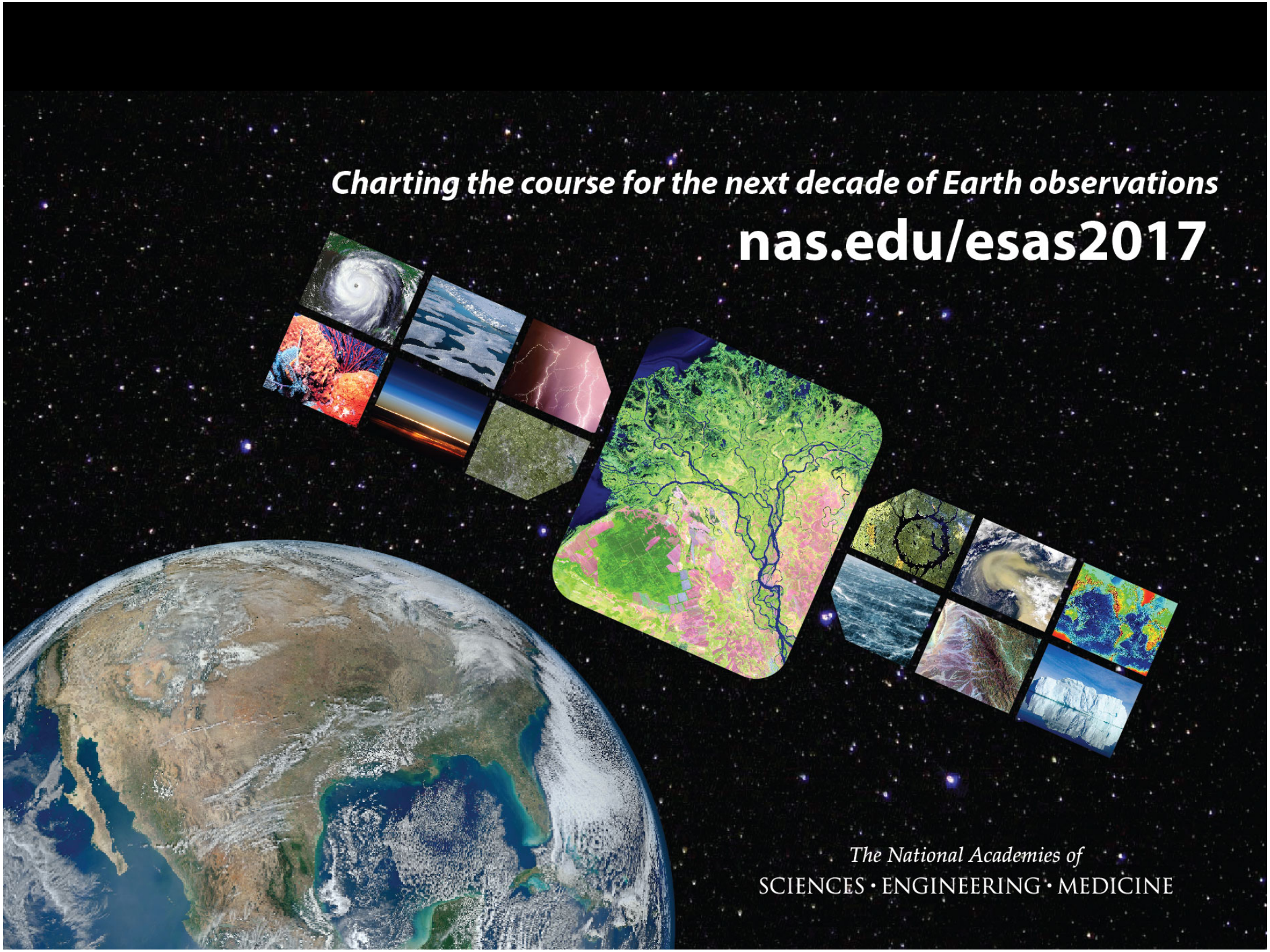
Charting the course for the next decade of Earth observations
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ESAS 2017: The 2017-2027 Decadal Survey for Earth Science and Applications from Space

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

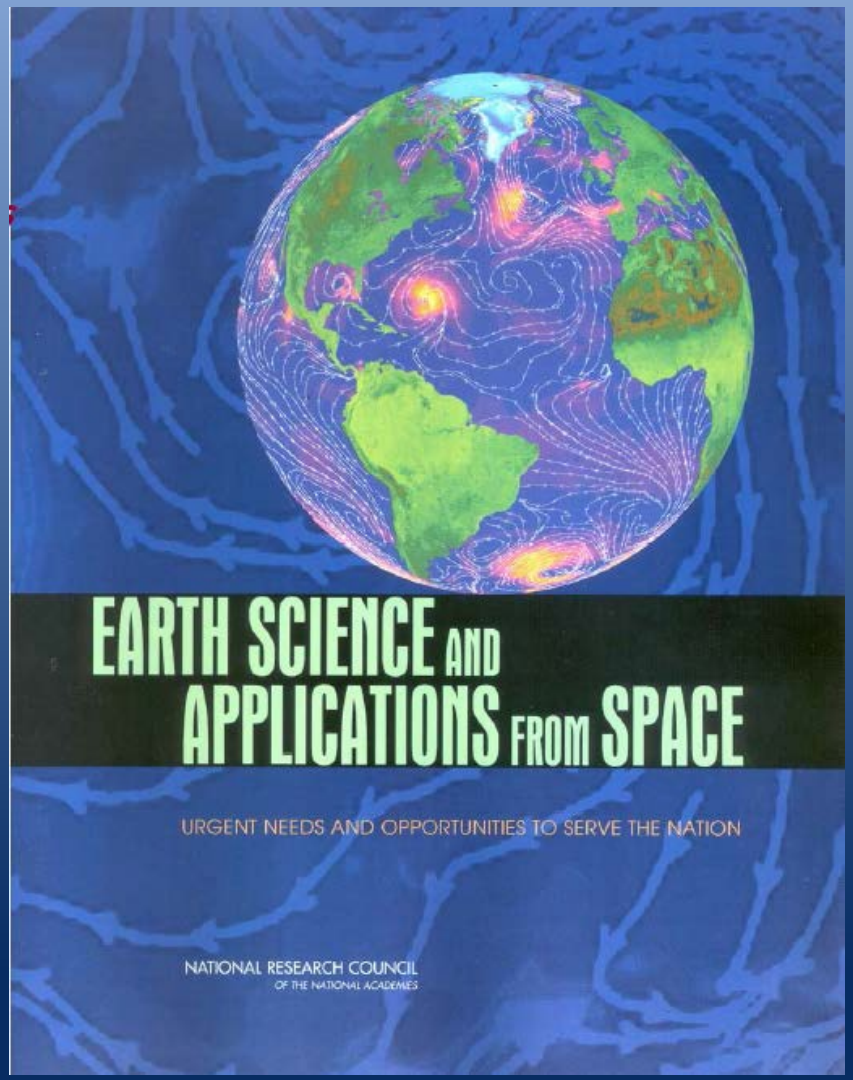
- ESAS 2007, the inaugural decadal survey
- ESAS 2017 versus ESAS 2007
- Agency Backdrop
- ESAS 2017 Statement of Task
- Study Panel Organization
- Request for Information and Community Responses
- Timeline
- Challenges and Considerations
- Comments and Questions

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

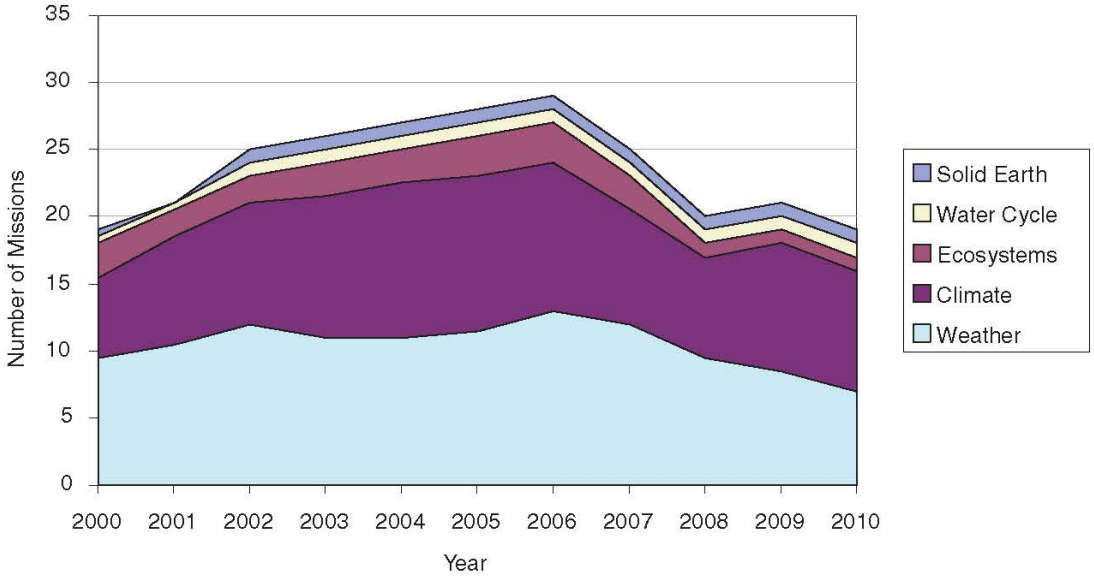


FIGURE ES.1 Number of U.S. space-based Earth observation missions in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of missions near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years past their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

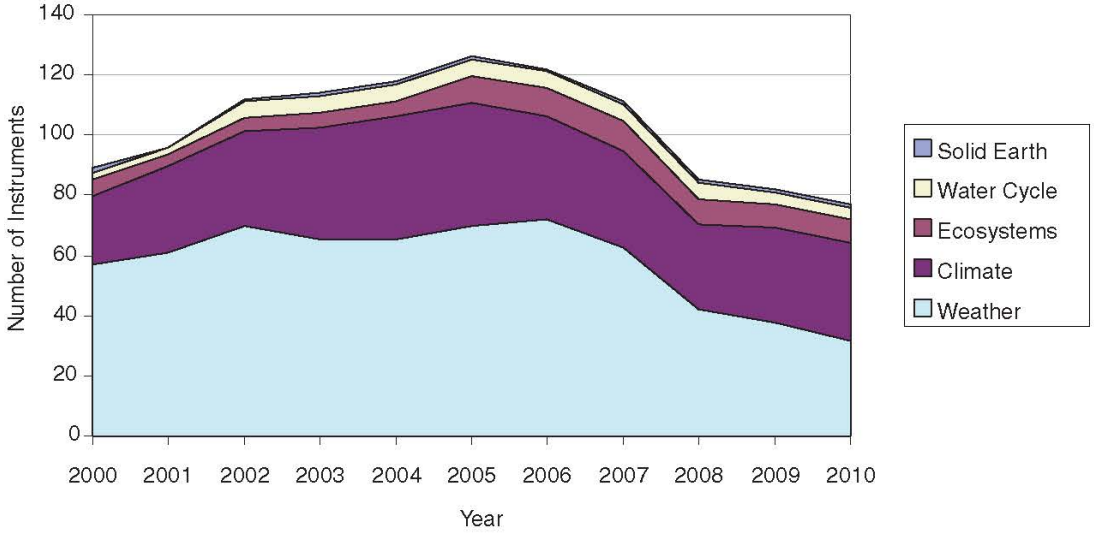
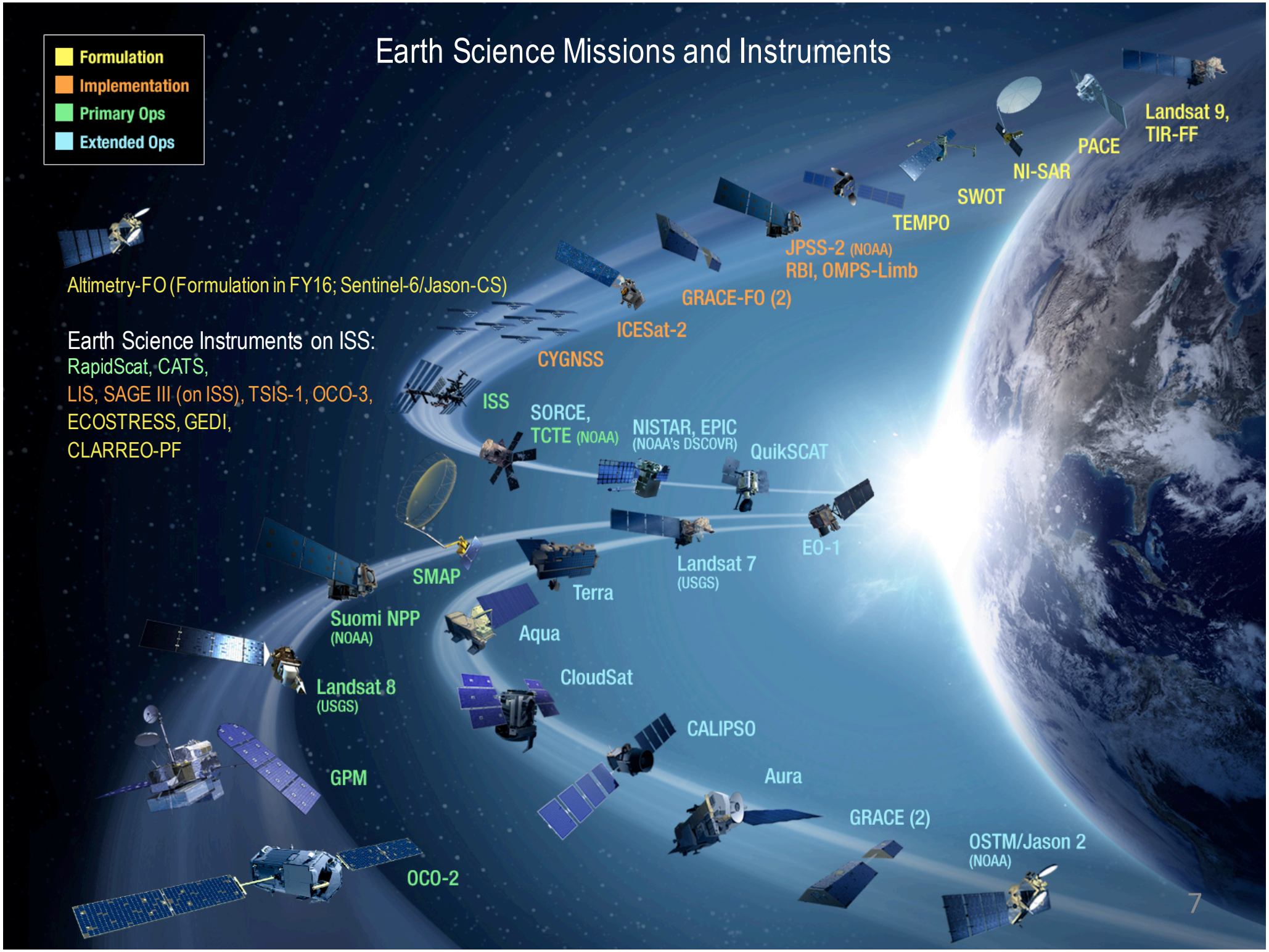


FIGURE ES.2 Number of U.S. space-based Earth observation instruments in the current decade. An emphasis on climate and weather is evident, as is a decline in the number of instruments near the end of the decade. For the period from 2007 to 2010, missions were generally assumed to operate for 4 years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


Formulation
Implementation
Primary Ops
Extended Ops
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
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2

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
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Battel Engineering

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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 in 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 Organization 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.

Context for Study Panel Organization from Statement of Task

- 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.

Panel Structure

I. Global Hydrological Cycles and Water Resources

The movement, distribution, and availability of water and how these are changing over time

II. Weather: Minutes to Subseasonal

Atmospheric Dynamics and Thermodynamics, Air Quality, and interactions at land and ocean interfaces

III. Marine and Terrestrial Ecosystems and Natural Resource Management

Biogeochemical Cycles and Ecosystem Functioning, and factors that influence resource availability

IV. Climate Variability and Change: Seasonal to Centennial

Forcings and Feedbacks of the Ocean, Atmosphere, Land, and Cryosphere within the Coupled Climate System

V. Earth Surface and Interior: Dynamics and Hazards

Core, mantle, lithosphere, and surface processes and their implications for physical and human systems.

Notional Integrating Themes/Crosscuts

Crosscuts

- Applications
- Innovation/Technology

Integrating themes

- Water
- Carbon
- Extreme Events

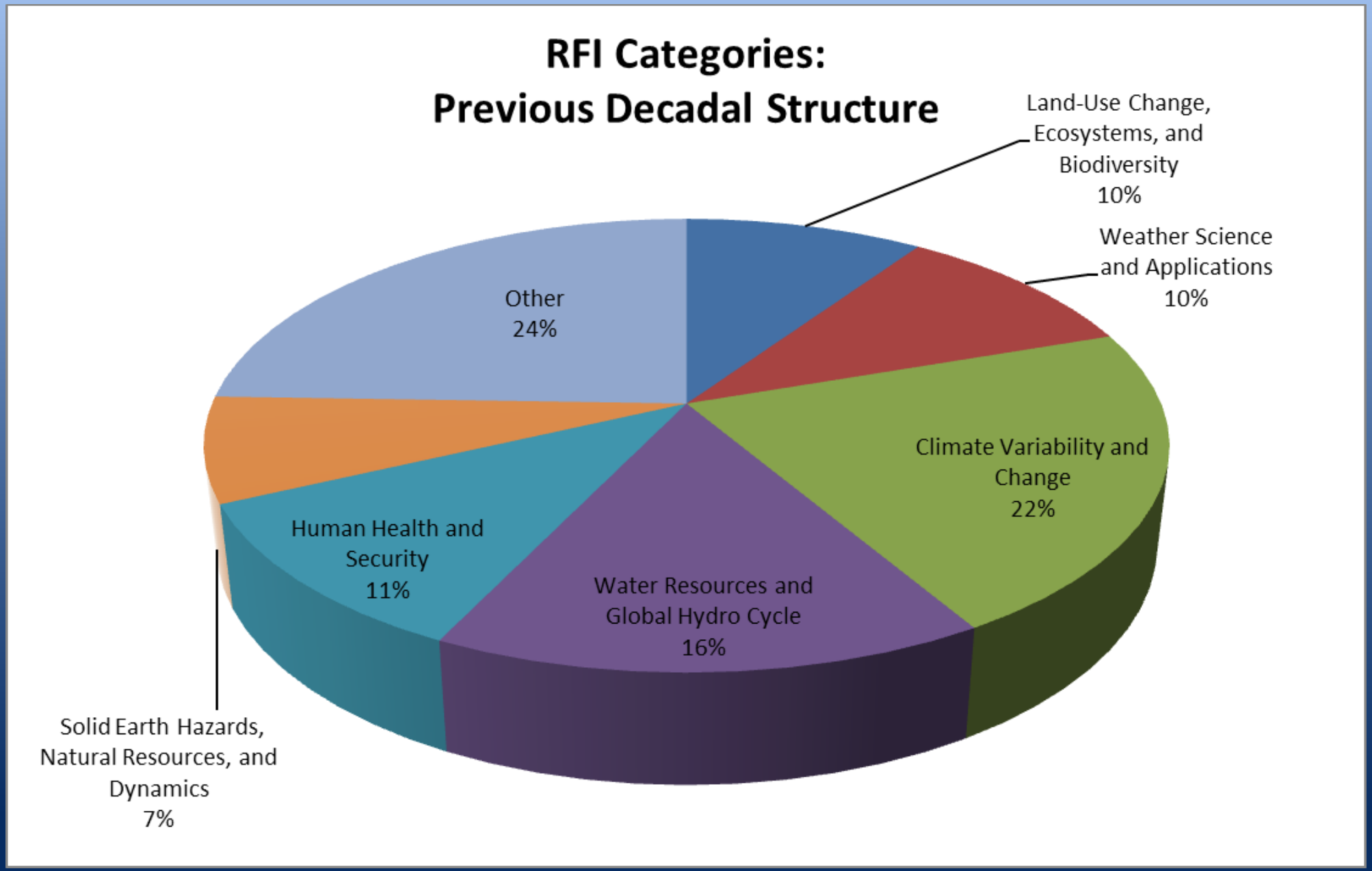
Survey Initial RFI

responses at: www.nas.edu/esas2017

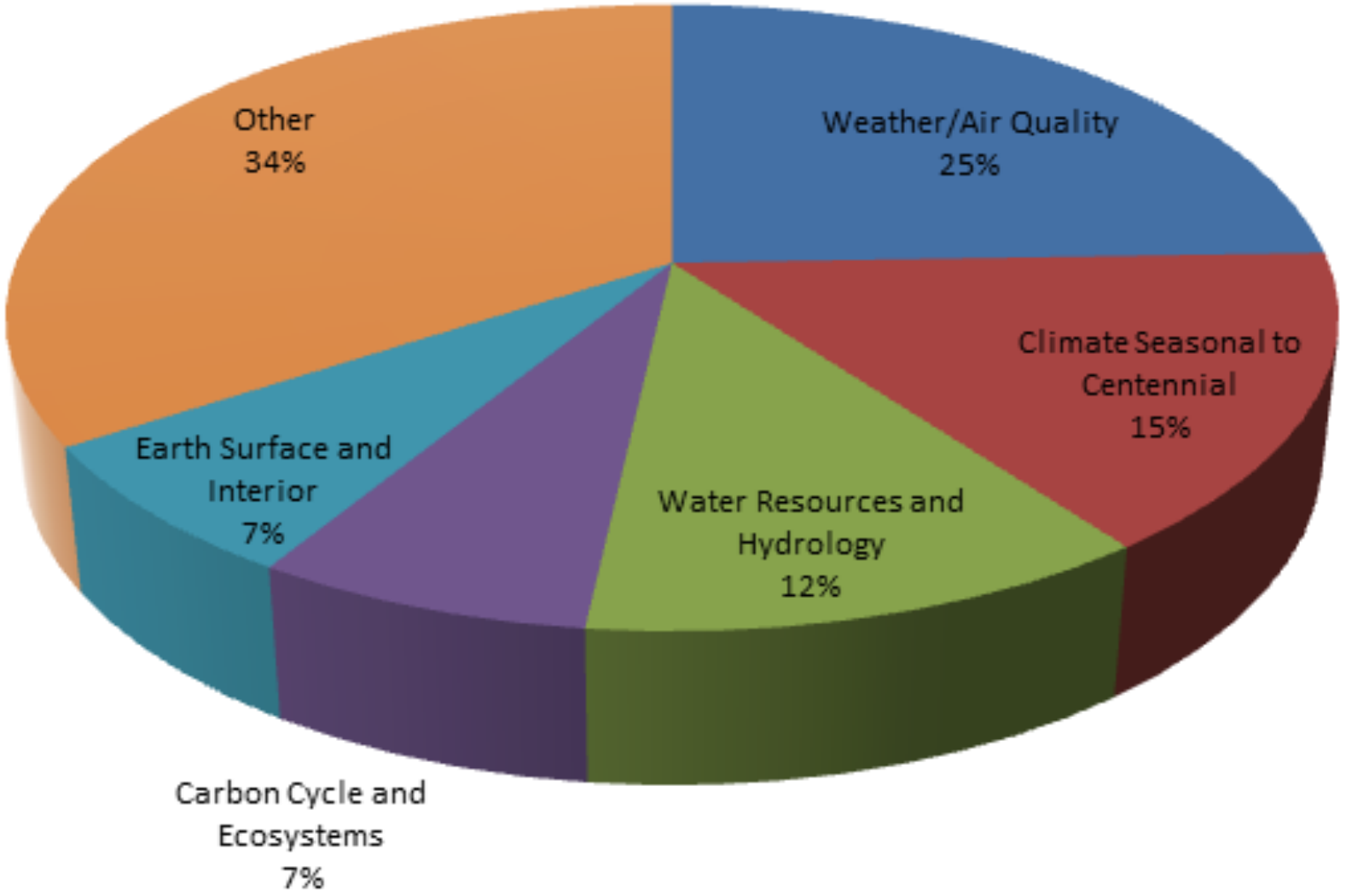
Issued in late September 2015 to inform the steering committee and the organization of the panels:

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
Land-Use Change, Ecosystems, and Biodiversity 10%
Weather Science and Applications 10%
Climate Variability and Change 22%
Water Resources and Global Hydro Cycle 16%
Human Health and Security 11%
Solid Earth Hazards, Natural Resources, and Dynamics 7%
Other 24%

RFI Categories: Modified Structure



Information Requested in RFI #2

1. A clear description of the Science and Application target, its importance to [one or more panel] Theme as evidenced in previous reports or community roadmaps, and how, by addressing it, understanding in one or more of the above-mentioned Decadal Survey Themes is advanced.

2. An explanation of the utility of the measured geophysical variable(s) to achieving the science and application target.

3. The key requirements on the quality (i.e. the performance and coverage specifications) of the measurement(s) needed for achieving the science and application target.

4. The likelihood of affordably achieving the required measurement(s) in the decadal timeframe given the heritage and maturity of current and near-future instruments and data algorithms, and the potential for leveraging similar or complementary measurements, especially from international partners.

ESAS 2017 Timeline

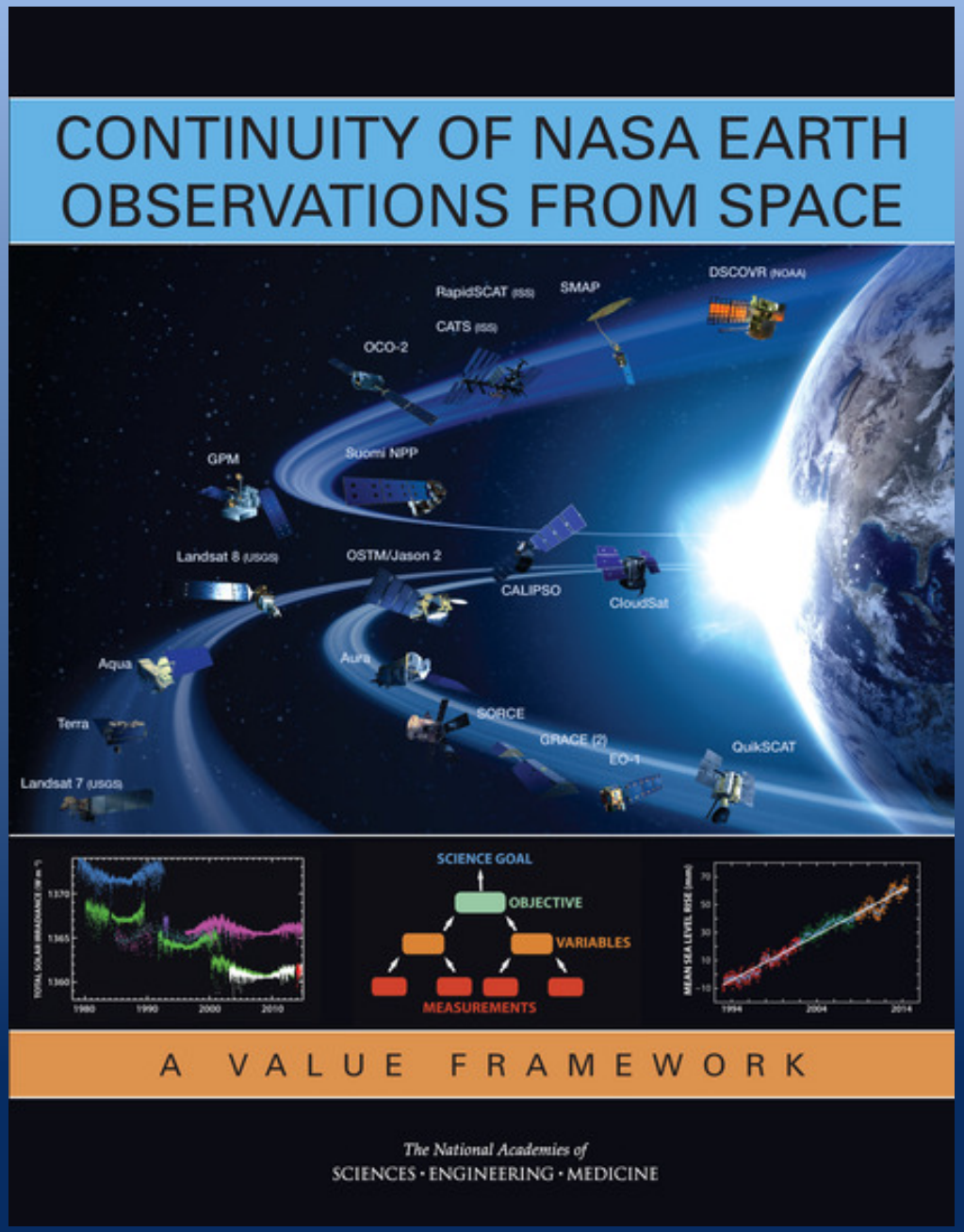
Provision of funds/formal start	August 17, 2015
Appointment of survey chairs	August 20, 2015
First RFI (ESS objectives)	September 28, 2015
Steering Committee (SC) approved	December 2, 2015
Panels appointed	by end of March 2016
Town Halls: AGU, AMS, Ocean Sciences	Dec. 14th, Jan. 13th, and Feb. 22nd
First meeting of the SC	January 18-20, 2016 in DC
2nd RFI (targets/science objectives)	**Responses due April 20th**
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**

Quantifiable Earth Science Objective (QESO)

Framework for quantifying the value of a science objective

Draws from NRC Continuity Report

http://www.nap.edu/read/21789



Quantifiable Earth Science Objective (QESO)

Framework for quantifying the value of a science objective in terms of:

- The scientific importance of achieving an objective (*importance I*),
- The utility of a geophysical variable record for achieving an objective (*utility U*),
- The quality of a measurement for providing the desired geophysical variable record (*quality Q*), and
- The success probability of achieving the measurement and its associated geophysical variable record (*success probability S*).

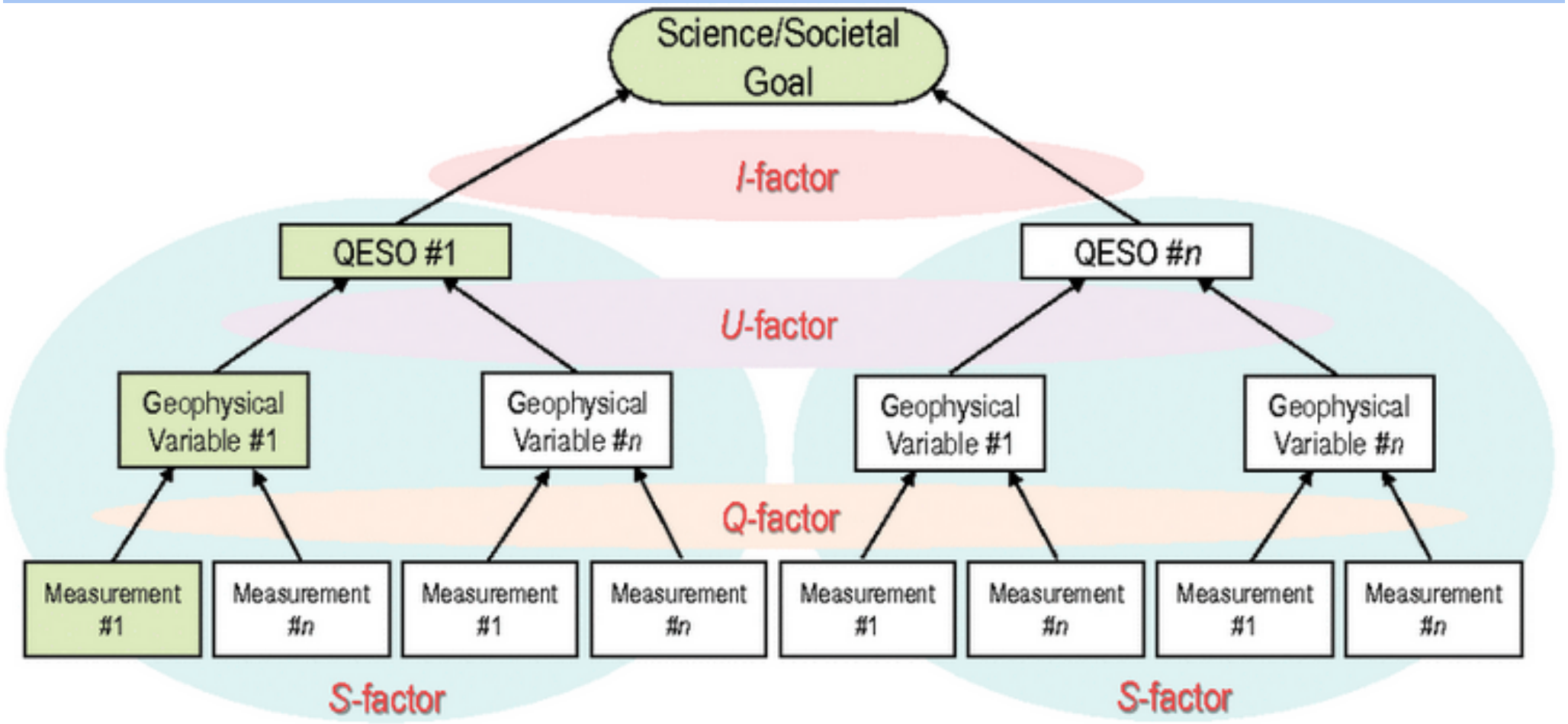


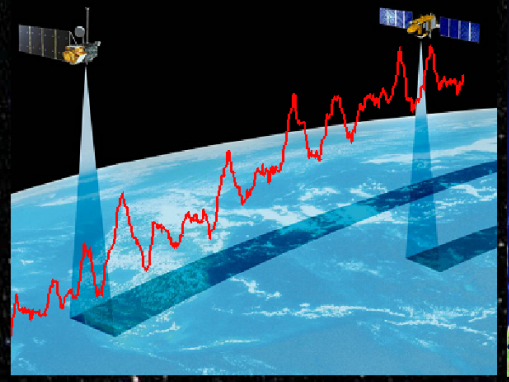
FIGURE 3.1 A schematic representation of the relationship between benefit metric (B) factors and key measurement-related terms and characteristics defined in this study—importance (I), utility (U), quality (Q), and success probability (S). The shaded areas denote the specific connections between framework factors and the appropriate terms. In particular, the I-factor connects an important science/societal goal with one or more quantified Earth science objectives (QESOs). The U-factor relates the utility of a particular geophysical variable record to achieving a quantified objective. The Q-factor ties together a needed geophysical variable record with the quality of a proposed continuity measurement (and the instrument specific to that measurement). Finally, the S-factor broadly connects, through a probability of success analysis, a quantified objective with a geophysical data record and its associated measurements. Evaluation of benefit is accomplished for specific measurement, geophysical variable, objective, and science goal sets (green boxes illustrate an example set for evaluation).

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!