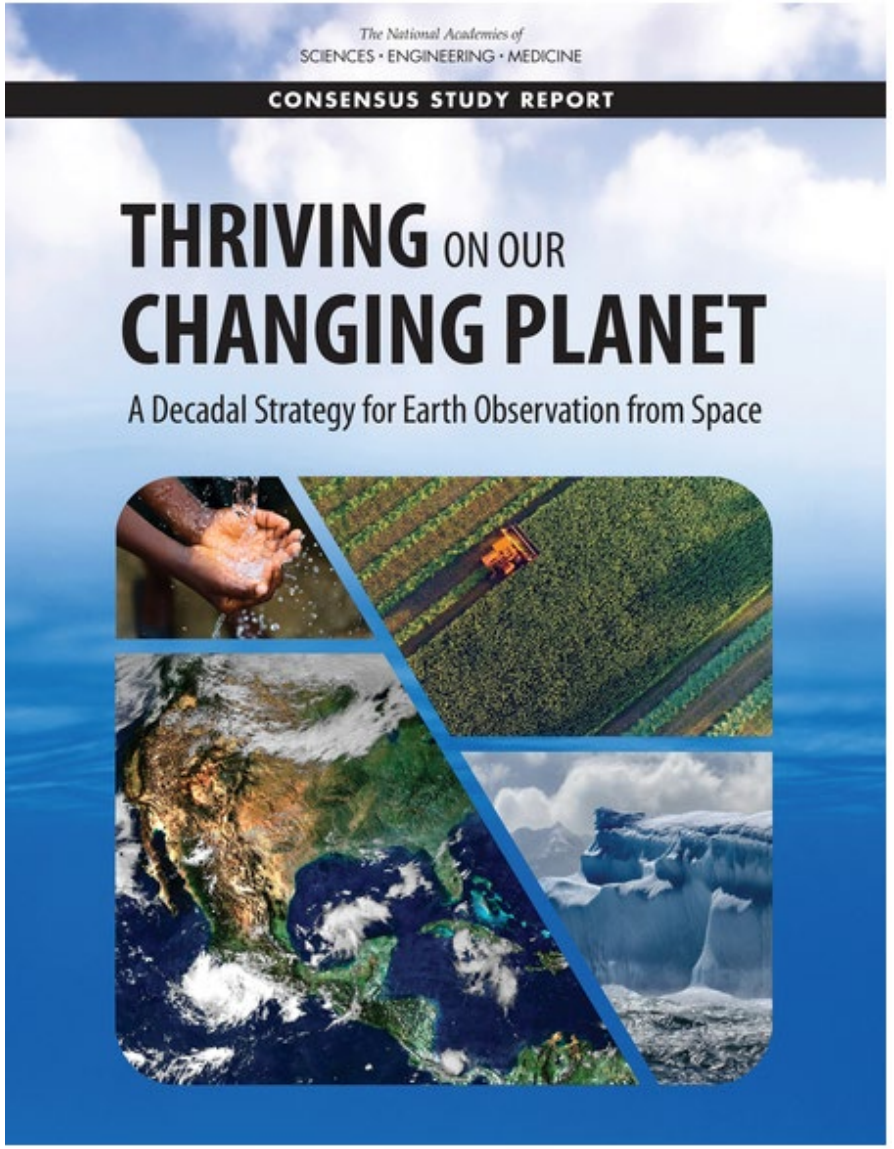
Perspectives on ESAS 2017

Waleed Abdalati and
William Gail, Co-Chairs

28 October 2025



ESAS 2017 Participants

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BYRON D. TAPLEY, The University of Texas at Austin
W. STANLEY WILSON, National Oceanic and Atmospheric Administration (ret.)

ANTONIO J. BUSALACCHI JR., NAE (Original Co-Chair - resigned from committee, 8/19/2015 -- 5/5/2016) UCAR
MOLLY K. MACAULEY [Deceased], (Member, 12/1/2015 -- 7/8/2016) Resources for the Future

Panels

Global Hydrological Cycles and Water Resources

Co-Chairs: Jeff Dozier, UC Santa Barbara and Ana Barros, Duke University

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

Weather and Air Quality: Minutes to Subseasonal

Co-Chairs: Steve Ackerman, University of Wisconsin and Nancy Baker, NRL

Atmospheric Dynamics, Thermodynamics, Chemistry, and their interactions at land and ocean interfaces

Marine and Terrestrial Ecosystems and Natural Resource Management

Co-Chairs: Compton (Jim) Tucker, NASA GSFC and Jim Yoder, WHOI

Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and factors that influence health and ecosystem services

Climate Variability and Change: Seasonal to Centennial

Co-Chairs: Carol Anne Clayson, WHOI and Venkatachalam (Ram) Ramaswamy, NOAA GFDL

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

Earth Surface and Interior: Dynamics and Hazards

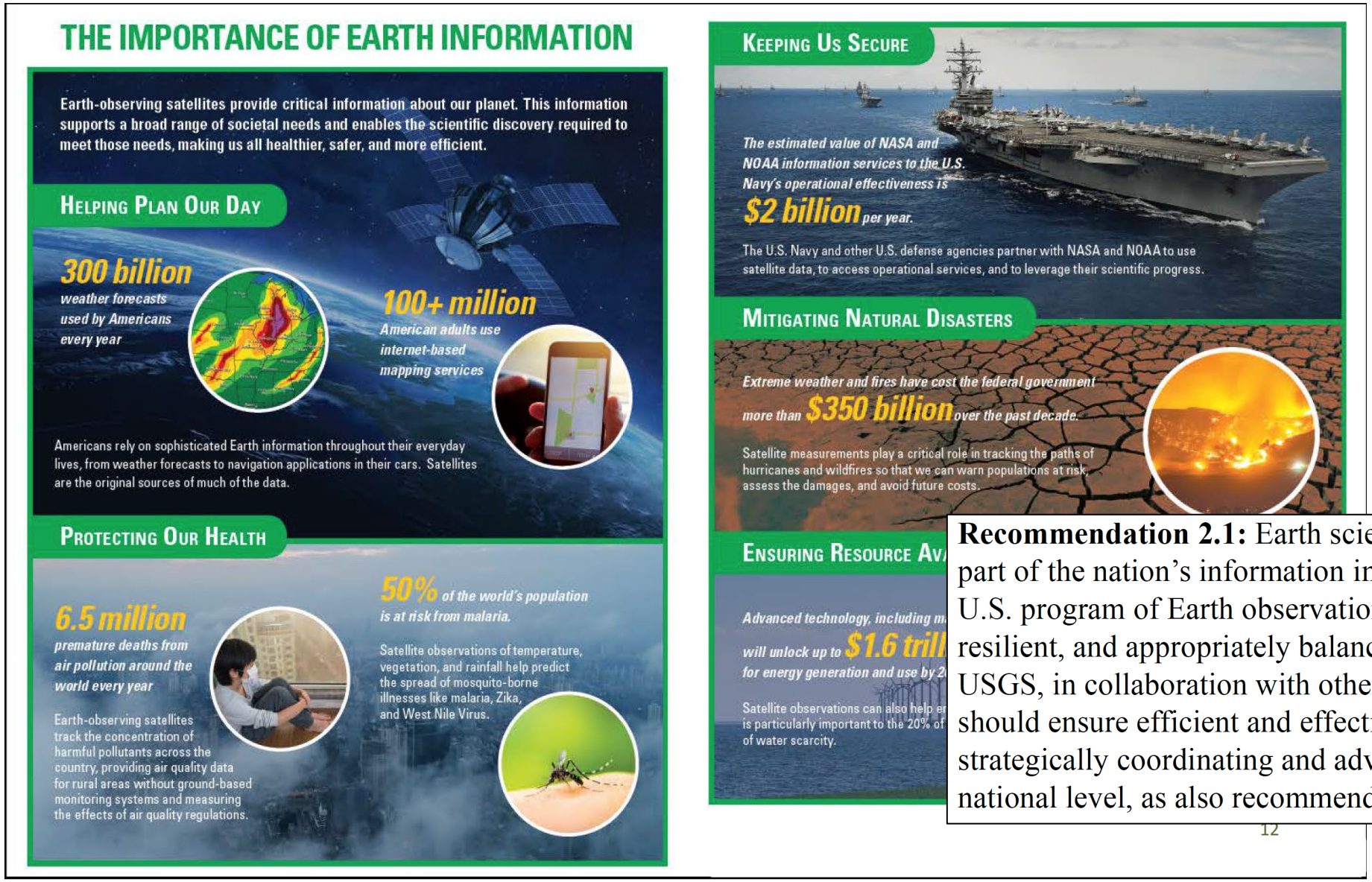
Co-Chairs: Dave Sandwell, Scripps and Doug Burbank, UC Santa Barbara

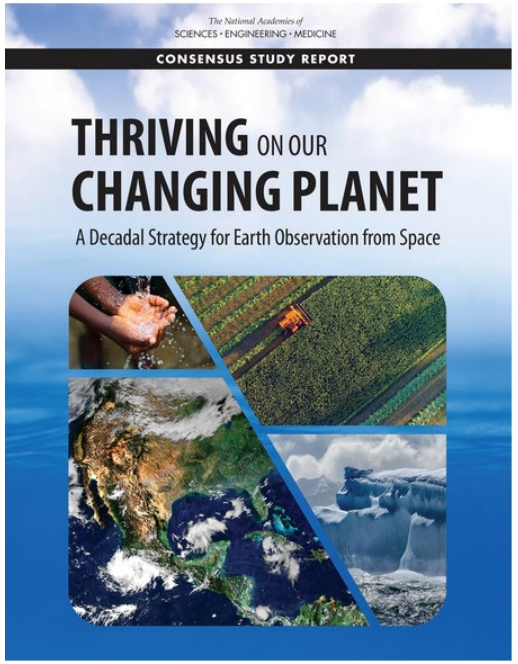
Core, mantle, lithosphere, and surface processes, system interactions, and the hazards they generate

National Academies

- Space Studies Board (lead)
- Board on Atmospheric Sciences and Climate
- Board on Earth Sciences and Resource
- Ocean Studies Board
- Polar Research Board
- Water Sciences and Technology Board

Earth Info is Critical to Thriving on our Changing Planet





Recommendation 2.1: Earth science and applications are a key part of the nation's information infrastructure, warranting a U.S. program of Earth observations from space that is robust, resilient, and appropriately balanced. NASA, NOAA, and USGS, in collaboration with other interested U.S. agencies, should ensure efficient and effective use of U.S. resources by strategically coordinating and advancing this program at the national level, as also recommended in ESAS 2007.

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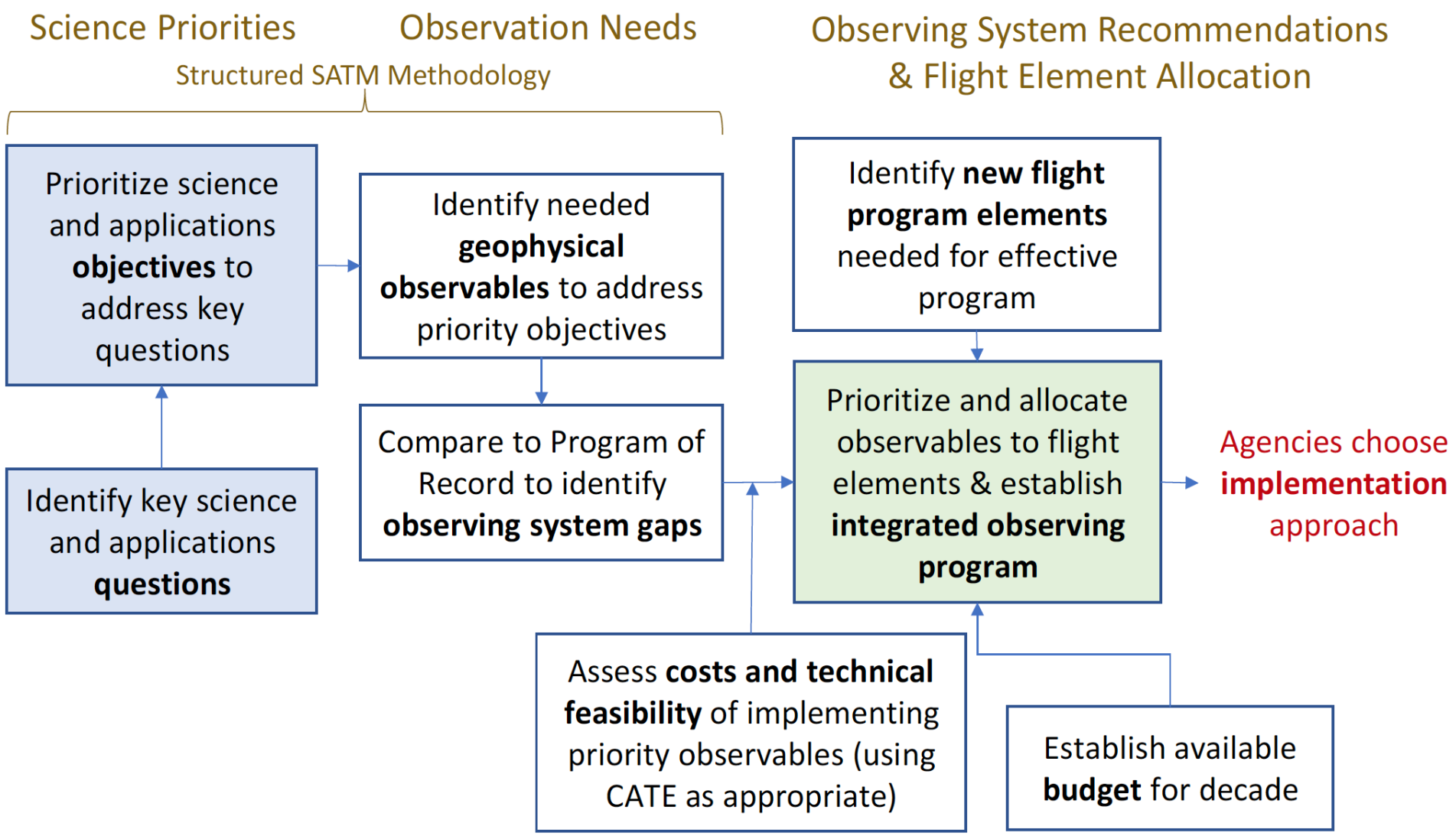
A Questions-Driven Implementation Process



The Traceability Matrix

Science & Applications **Questions**

Science & Applications **Objectives**

Importance Ranking of Objective

Required **Geophysical Observable** and Measurement Requirements

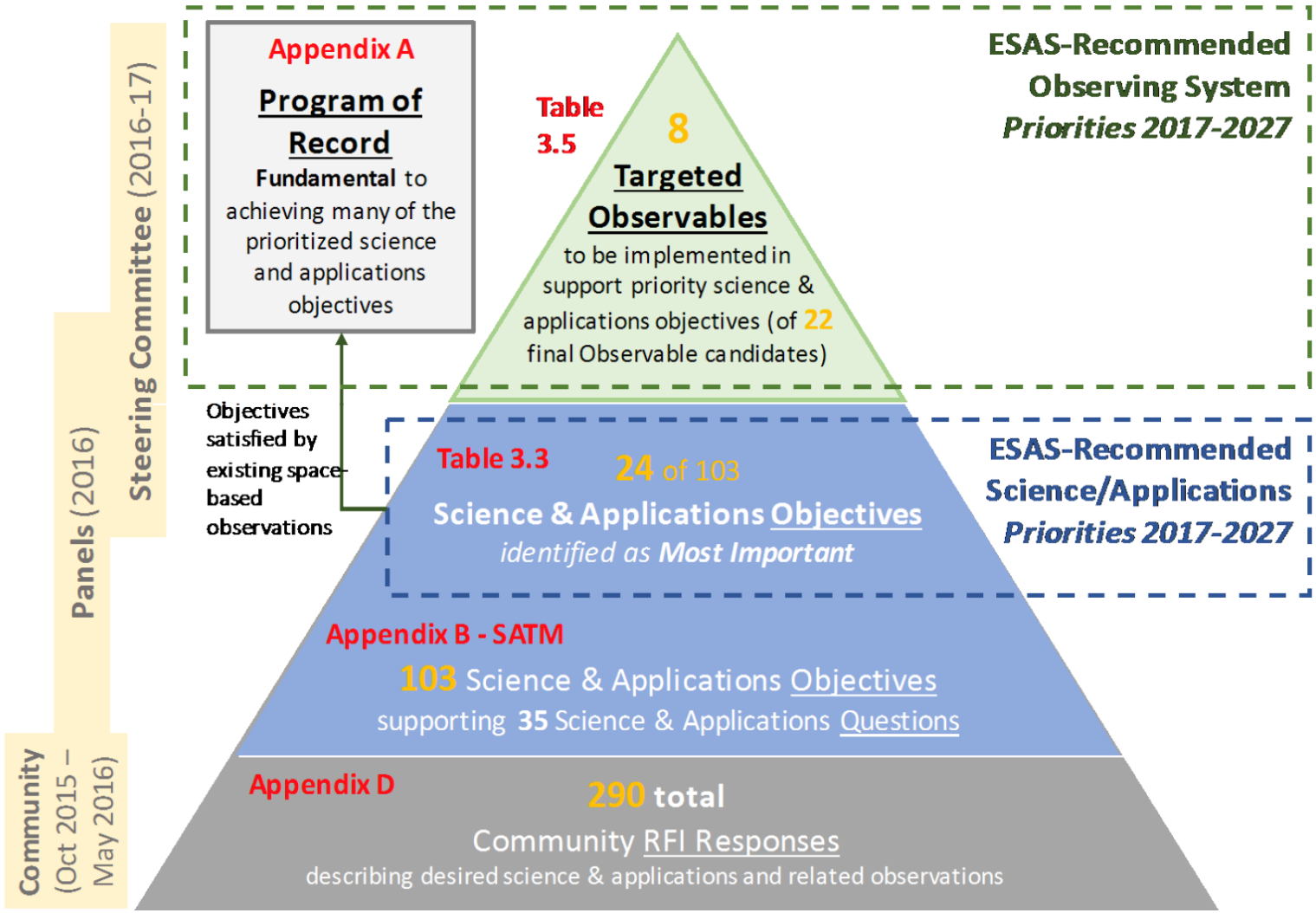
Example **Measurement Approach**, including POR availability and ESAS options

CLIMATE VARIABILITY AND CHANGE PANEL

SCIENCE			MEASUREMENT				
					Example Measurement Approach(s)		
Societal or Science Question	Earth Science/Application Objective	Sci/App Importance	Geophysical Observable	Measurement Parameters	*Method*	*POR*	*New*
QUESTION C-1. How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage?	C-1a. Determine the global mean sea level rise to within 1 mm/yr/decade.	Most Important	Sea surface height	Space/Time Sampling: 7 km along track/10 day; Space/Time Coverage: global/10 days; Accuracy/Stability: 3 cm @ 7 km & 1 mm/global/yr	Radar altimeter, with microwave water vapor radiometer and precision orbit	POR-26, 27	TO-21
			Terrestrial reference frame	Space/Time Sampling: monthly; Space/Time Coverage: global/year-decade; Accuracy/Stability: 1 mm/ 0.1 mm/yr/decade	GNSS RO	POR-7,13 (GRACE-FO, Jason-3, LAGEOS, GRASP)	
			Ocean mass distribution	Space/Time Sampling: 300 km2/monthly; Space/Time Coverage: global/monthly; Accuracy/Stability: 15 mm@300km2, 0.1 mm/yr/decade	Gravity (e.g., GRACE FO)	POR-30	
	C-1b. Determine the change in the global oceanic heat uptake to within 0.1 W/m2/yr/decade.	Most Important	Sea surface height	Space/Time Sampling: 7 km along track/10 day, equivalent to 150 km2/10 day; Space/Time Coverage: global/10 days; Accuracy/Stability: 3 mm@7km, 1 mm/global/yr	Radar altimeter, with microwave water vapor radiometer and precision orbit	POR-26, 27	TO-21
			Ocean mass distribution	Space/Time Sampling: 300 km2/monthly; Space/Time Coverage: global/monthly; Accuracy/Stability: 15 mm@300km2, 0.1 mm/yr/decade	Gravity (e.g., GRACE FO)	POR-30	
			Ocean temp and salinity profile	Space/Time Sampling: 3degx3deg/10 day, equivalent to 150 km2/10 day; Space/Time Coverage: global/10 days; Accuracy/Stability: 0.01 deg/0.01 psu	[in situ, such as Argo]	[Argo, Deep Argo]	TERRESTRIAL
	C-1c. Determine the changes in total ice sheet mass balance within 15 Gton/yr/decade and the changes in surface mass balance and glacier ice discharge within the same accuracy.	Most Important	Ice sheet mass	Horizontal resolution/range: 100 km / Global; Temporal sampling: Monthly; Precision: 1 cm water equivalent on scale of 200 km	Gravity (e.g., GRACE FO), NISAR/Landsat, [re-analysis], Operation IceBridge.	POR-30	
			Ice sheet velocity	Horizontal resolution/range: 100 m / pole to pole; Temporal sampling: weekly to daily; Precision: 1 m/yr in fast flow areas, 1 cm/yr near ice divides	SAR (e.g., NISAR), Landsat	POR-12	TO-19
			Ice sheet elevation	Vertical resolution/range: 10-20 cm; Horizontal resolution/range: 100 m/ pole to pole; Temporal sampling: weekly to daily; Precision: 10-20 cm	Operation IceBridge, ICESat-2, {WorldView satellites}, GLISTIN	POR-14	TO-20
			Ice sheet thickness, ice shelf thickness	Vertical resolution/range: 10 m pole to pole; Horizontal resolution/range: 100 m/ pole to pole; Temporal sampling: yearly; Precision: 10 m	Operation IceBridge, ICESat-2 (ice shelf), {WorldView satellites}	POR-14	TO-20
			Ice sheet bed elevation, ice shelf cavity shape	Vertical resolution/range: 30 m; Horizontal resolution/range: 100 m/ pole to pole; Temporal sampling: one time; Precision: 30 m	Operation IceBridge, EVS-2 OMG, new EVS Antarctica		TO-20
			Ice sheet surface mass balance	Vertical resolution/range: 1 mm/yr; Horizontal resolution/range: 5 km/ pole to pole; Temporal sampling: monthly; Precision: 1 mm/yr	Gravity (e.g., GRACE FO), ICESat-2, Operation IceBridge, [re-analysis data]	POR-14, 30	TO-20
	C-1d. Determine regional sea level change to within 3-5 mm/yr/decade (3 corresponds to region 6000 km2, 5 corresponds to region 4000 km2).	Very Important	Sea surface height	Space/Time Sampling: 250 m/weekly @ mid-latitudes; Space/Time Coverage: 20 days/global; Accuracy: 10 cm	e.g., SWOT to be launched 2021		TO-21
			Land vertical motions	Space/Time Sampling: 100 m along coast; Space/Time Coverage: global coastline/monthly; Accuracy/stability: 1 mm/ 1 mm/yr	[ground GPS]		TERRESTRIAL
			Ocean mass distribution	Same as 1a		POR-30	
			Wind vector	Space/Time Sampling: 25x25 km/weekly; Space/Time Coverage: global/weekly; Accuracy/stability: 2 m/s speed, 15deg direction	METOP A/B, Oceansat-3, HY-2B	POR-28	TO-11
	C-2a. Reduce uncertainty in low and high cloud feedback by a factor of 2.	Most Important	Top of Atmosphere Shortwave (SW), Longwave (LW) and Net Radiative Fluxes for All-sky and Clear-sky conditions	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: global SW TOA flux @ 0.3% (95% conf), global LW TOA flux @ 0.4% (95% conf); Ultimate requirement is on use for Cloud Radiative Effect for SW and LW	Earth radiation monitor (e.g., CERES), RBI for space-time-angle sampling, CLARREO-like intercalibration (to achieve decadal trend accuracy/stability)	POR-3, 24	TO-14
			Cloud fraction	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: 0.1% relative to global mean (1 σ)	Cloud imagers (e.g., MODIS/VIIRS), or lidar (e.g., CALIPSO) or HSRL	POR-24	TO-2
			Cloud optical depth	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: 0.3% relative to global mean log optical depth (95% conf)	Cloud imagers (e.g., MODIS/VIIRS) plus CLARREO-like intercalibration (to achieve optical depth trend accuracy/stability)	POR-24	TO-14
			Cloud infrared emissivity	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: TBD	Cloud imagers (e.g., MODIS/VIIRS), or lidar (e.g., CALIPSO) or HSRL	POR-24	TO-2 or TO-14
			Cloud top height	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: Accuracy/Stability: 0.04K (1 σ)	Cloud imagers (e.g., MODIS/VIIRS) plus CLARREO-like intercalibration or lidar (e.g., CALIPSO) or HSRL	POR-24	TO-2 or TO-14
			Cloud effective radiating temperature	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: Accuracy/Stability: Accuracy/Stability: 0.04K (1 σ)	Cloud imagers (e.g., MODIS/VIIRS) plus CLARREO-like intercalibration	POR-24	TO-2 or TO-14
			Cloud phase (water, ice)	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: TBD	Cloud imagers (e.g., MODIS/VIIRS), or lidar (e.g., CALIPSO) or HSRL	POR-24	TO-14
			Cloud particle size	Space/Time Sampling: 100km, monthly; Space/Time Coverage: global, decadal trends; Accuracy/Stability: Accuracy/Stability: TBD	Cloud imagers (e.g., MODIS/VIIRS) plus CLARREO-like intercalibration	POR-24	TO-14

The Path from Candidate S&A to Priority Obs

Blue: Science & Applications; Green: Observables



Observation Prioritization Criteria

AREA	DESCRIPTION
Science Questions	Science objectives that contribute to answering the most important basic and applied scientific questions in Earth System science. These questions may span the entire space of scientific inquiry, from discovery to closing gaps in knowledge to monitoring change.
Applications & Policy	Science objectives contributing directly to addressing societal benefits achievable through use of Earth System science.
Interdisciplinary Uses	Science objectives with benefit to multiple scientific disciplines, thematic areas, or applications.
Long-Term Science and/or Applications	Objectives that can support scientific questions and societal needs that may arise in the future, even if they are not known or recognized today.
Value to Related Objectives	Science objectives that complement other objectives, either enhancing them or providing needed redundancy.
Readiness	Are we in a position to make meaningful progress to advance the objective, regardless of measurement?
Timeliness	Is now the time to invest in pursuing this objective? Examples include recently occurring phenomena that require focused near-term attention and the existence of complementary observing assets that may not be available in the future.

Prioritized S&A Topics & Targeted Observables

Science & Applications Topics → Targeted Observables

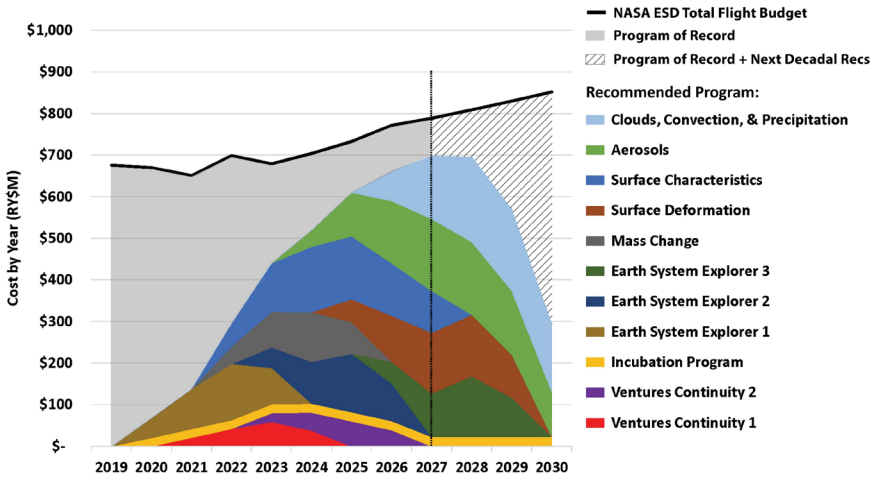
* Complete set of Questions and Objectives in Table 3.3

Science & Applications Topic	Science & Applications Questions addressed by **MOST IMPORTANT** Objectives
Coupling of the Water and Energy Cycles	**(H-1)** How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods? **(H-2)** How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?
Ecosystem Change	**(E-1)** What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space? **(E-2)** What are the fluxes (of carbon, water, nutrients, and energy) *between* ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing? **(E-3)** What are the fluxes (of carbon, water, nutrients, and energy) *within* ecosystems, and how and why are they changing?
Extending & Improving Weather and Air Quality Forecasts	**(W-1)** What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations? **(W-2)** How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months? **(W-4)** Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? **(W-5)** What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Reducing Climate Uncertainty & Informing Societal Response	**(C-2)** How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity that drives uncertainty in future economic impacts and mitigation/adaptation strategies?
Sea Level Rise	**(C-1)** How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage? **(S-3)** How will local sea level change along coastlines around the world in the next decade to century?
Surface Dynamics, Geological Hazards	**(S-1)** How can large-scale geological hazards be accurately forecasted and eventually predicted in a socially relevant timeframe?

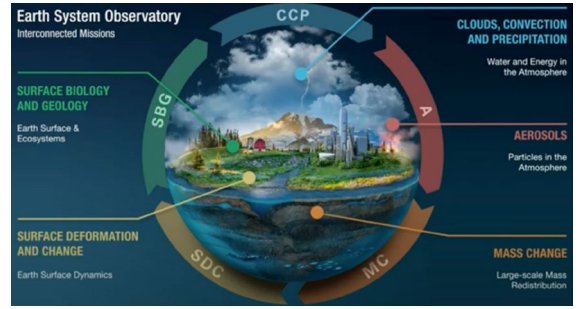
TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	**Large-scale Earth dynamics** measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	**Earth surface geology and biology,** ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		

Procurement & Budget Recommendations

Program of Record. The series of existing or previously planned observations, which **should be completed as planned**. Execution of the ESAS 2017 recommendation requires that the total cost to NASA of the Program of Record *flight missions from FY18-FY27 be capped at $3.6B.*



- ***Designated.*** A <u>new</u> program element for ESAS-designated cost-capped medium- and large-size missions to address ***observables essential to the overall program*** and that are outside the scope of other opportunities in many cases. Can be competed, at NASA discretion.
- ***Earth System Explorer.*** A <u>new</u> program element involving competitive opportunities for medium-size instruments and missions serving specified ESAS-priority observations. ***Promotes competition among priorities.***
- ***Venture.*** Earth Venture program element, as recommended in ESAS 2007 with the addition of a <u>new</u> Venture-Continuity component to provide ***opportunity for low-cost sustained observations***.
- ***Incubation.*** A <u>new</u> program element, focused on investment for priority observation opportunities needing advancement prior to cost-effective implementation, including an Innovation Fund to respond to emerging needs. ***Investment in innovation for the future***.



Critical Decision Points in the Decadal

PRE-STUDY

- Statement of Task
- Budget & Costing Guidance
- Partner Scope
- Operational Guidance

EARLY STUDY

- Panel Structure & Collaboration
- Community Input Process
- Prioritization Methodology
- Underlying Challenges
- Theme (and Title)

MID TO LATE STUDY

- Acquisition Approach(s)
- Writing Process
- Decision Rules
- Enabling Topics

POST-STUDY

- Implementation Process
- Ongoing Community Guidance

Decision Points – Pre-Study

- Statement of Task
  - Defines sponsor roles, including balance/interaction of research and operations
  - Chooses approach (e.g., question-based or outcome-based)
  - Establishes objectives and constraints
  - Provides process guidance, if any, including committee makeup
- Budget & Costing Guidance
  - Defines starting point for available budget & growth over decade
  - Determines liens on that budget (e.g., Program of Record, partner roles)
  - Identifies extent to which budgetary changes are accommodated
  - Defines fidelity of cost estimation (and level of work needed) – more is not always better
- Partner Scope
  - Which agencies are included as sponsors
  - What is the role of international partners, NGOs, etc.
  - What is the role of commercial space
  - How do science and operational recommendations differ in treatment/priority
- Obligations
  - Are prior decadal recommendations still to be implemented
  - What is the priority of the Program of Record

Decision Points – Early Study

- Panel Structure & Collaboration
  - Establishes structure (e.g., discipline, cross-discipline, or results focused) that impacts how prioritization is done and how report is written
  - Important to consider how panels interact with each other and with Ex Comm
- Community Input Process
  - Options include RFI's, presentations at open meetings
- Prioritization Methodology
  - Relative roles of science and applications
  - Question-based or outcome-based
  - Quantitative versus traceable
  - Guiding criteria; need, feasibility, cost, importance
  - Community preference vs committee consensus in prioritization
- Underlying Challenges
  - Key challenges such as balance of exploration vs continuity, science vs ops
- Theme (as reflected in title)
  - Drives tone of work and can influence cultural change over decade

Decision Points – Mid to Late Study

- Acquisition Approach
  - Options such as competed versus directed, role of centers
- Writing Process
  - How panel work gets integrated (e.g., chapters vs appendices)
  - Role of panels in prioritization and review
- Decision Rules
  - Increasing importance with each Decadal
  - How to include decisions when external factors (e.g., top line budget) change program
- Enabling Topics
  - How to include the many enabling topics such as education, technology, modeling, etc.

Decision Points – Post-Study

- Implementation Process
  - Largely managed by sponsors
  - Community feedback desirable but not always possible due to embargoes and other issues – how can this be optimized?
- Ongoing Community Guidance
  - Accomplished through CESAS and Midterm, as needed and possible
  - Limited impact when agency decisions are embargoed or fast turnaround
  - Optimal cadence varies

Decision Points – Impact of Reduced Budget

- Each decision point may have a substantially different result under a severely constrained budget scenario, such as
  - Rethinking of entire process desirable to match new resource constraints
  - Cost-cutting of continuity observations becomes priority
  - Flexibility and resilience essential to recommendations
  - Comprehensive decision rules increasingly important
  - Adjustments needed to ensure Midterm and CESAS feedback responsive

- During the Pre-Study phase, community guidance for how to define and resolve these issues could improve success likelihood of next Decadal