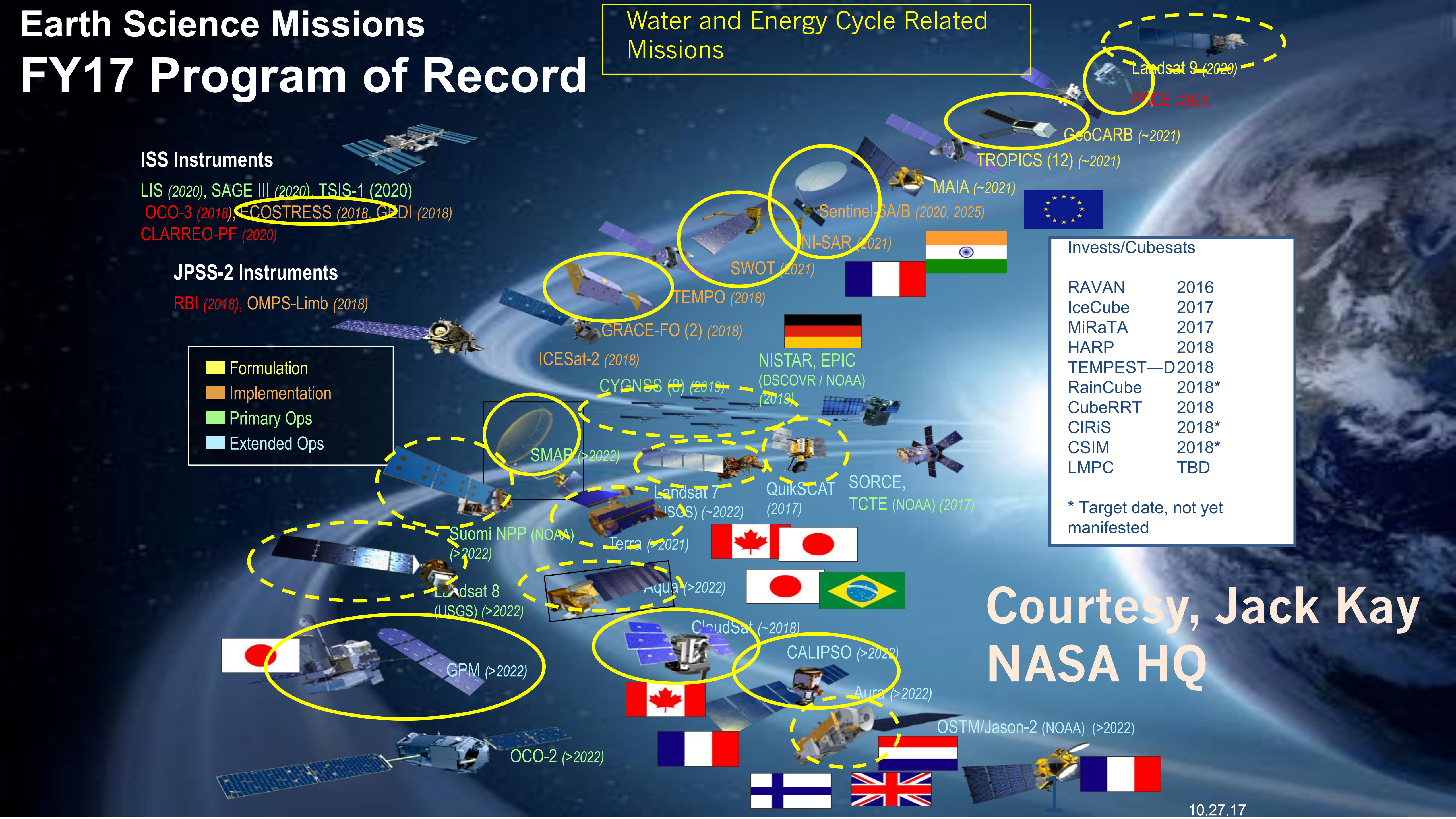

Earth Science Missions
FY17 Program of Record
Water and Energy Cycle Related Missions
ISS Instruments
LIS (2020), SAGE III (2020), TSIS-1 (2020)
OCO-3 (2018), ECOSTRESS (2018, GEDI (2018)
CLARREO-PF (2020)
JPSS-2 Instruments
RBI (2018), OMPS-Limb (2018)
Formulation
Implementation
Primary Ops
Extended Ops
Landsat 9 (2020)
PACE (2022)
GeoCARB (~2021)
TROPICS (12) (~2021)
MAIA (~2021)
Sentinel-6A/B (2020, 2025)
NI-SAR (2021)
SWOT (2021)
TEMPO (2018)
GRACE-FO (2) (2018)
ICESat-2 (2018)
CYGNSS (8) (2019)
NISTAR, EPIC
(DSCOVR / NOAA)
(2019)
SMAP (>2022)
Landsat 7
(USGS) (~2022)
QuikSCAT
(2017)
SORCE,
TCTE (NOAA) (2017)
Suomi NPP (NOAA)
(>2022)
Terra (>2021)
Landsat 8
(USGS) (>2022)
Aqua (>2022)
CloudSat (~2018)
GPM (>2022)
CALIPSO (>2022)
Aura (>2022)
OSTM/Jason-2 (NOAA) (>2022)
OCO-2 (>2022)
Invests/Cubesats
RAVAN 2016
IceCube 2017
MiRaTA 2017
HARP 2018
TEMPEST—D 2018
RainCube 2018*
CubeRRT 2018
CIRiS 2018*
CSIM 2018*
LMPC TBD
* Target date, not yet manifested
Courtesy, Jack Kay
NASA HQ
10.27.17

Thriving on Our Changing Planet

A Decadal Strategy for Earth Observation from Space

A report of the Decadal Survey for Earth Science and Applications from Space

Released: 5 January 2018

Report available at: http://www.nas.edu/esas2017

Quick Summary: Recommendations

1

VISION & STRATEGY

“Thriving on our Changing Planet”

2

SCIENCE & APPLICATIONS

Address **35 key science/applications questions,** from among hundreds suggested. Those with objectives prioritized as most important fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

3

OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified to be implemented:
  - *Aerosols*
  - *Clouds, Convection, & Precipitation*
  - *Mass Change*
  - *Surface Biology & Geology*
  - *Surface Deformation & Change*
- **Three** others to be selected competitively from among seven candidates
- Structure **new NASA mission program elements** to accomplish this
- Methods for new NASA capabilities to be **leveraged by NOAA and USGS**

4

PROGRAMMATICS

- CROSS-AGENCY
- NASA
  - Flight
  - Technology
  - Applications
- NOAA
- USGS

What We Were Asked to Do

OVERARCHING TASKS

- Assess **progress from 2007**
- Develop a prioritized list of top-level **science and application objectives** for 2017-2027
- Identify gaps and opportunities in the **programs of record** at NASA, NOAA, and USGS
- Recommend approaches to facilitate the development of a robust, resilient, and **appropriately balanced U.S. program of Earth observations** from space

GENERAL & AGENCY-SPECIFIC TASKS

- **Cross-Agency**
  - Enabling activities
  - Partnerships & synergies
- **NASA**
  - Program balance and scope
  - Ventures flight element
  - Decision principles and measurement continuity
- **NOAA and USGS**
  - Non-traditional observation sources
  - On-ramp of scientific advances
  - Research-to-operations
  - Technology replacement/infusion

Comparison to ESAS 2007

- **Prioritization Method.** Prioritize science and applications instead of missions
- **Operational**. NOAA's operational system was not considered in this report
- **Budget Resources.** Align with planned budgets instead of aspirational
- **Large Missions.** Avoid having one recommended activity grow at expense of all others
- **Innovation.** Consider "new space" technology and business ideas
- **Policy.** Existence of recent high-level US government policy guidance regarding Earth observations
- **International.** Increased recognition of important role of international partners

Steering Committee

WALEED ABDALATI, University of Colorado Boulder, *Co-Chair*
WILLIAM B. GAIL, Global Weather Corporation, *Co-Chair*

STEVEN J. BATTEL, Battel Engineering, Inc.
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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

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

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

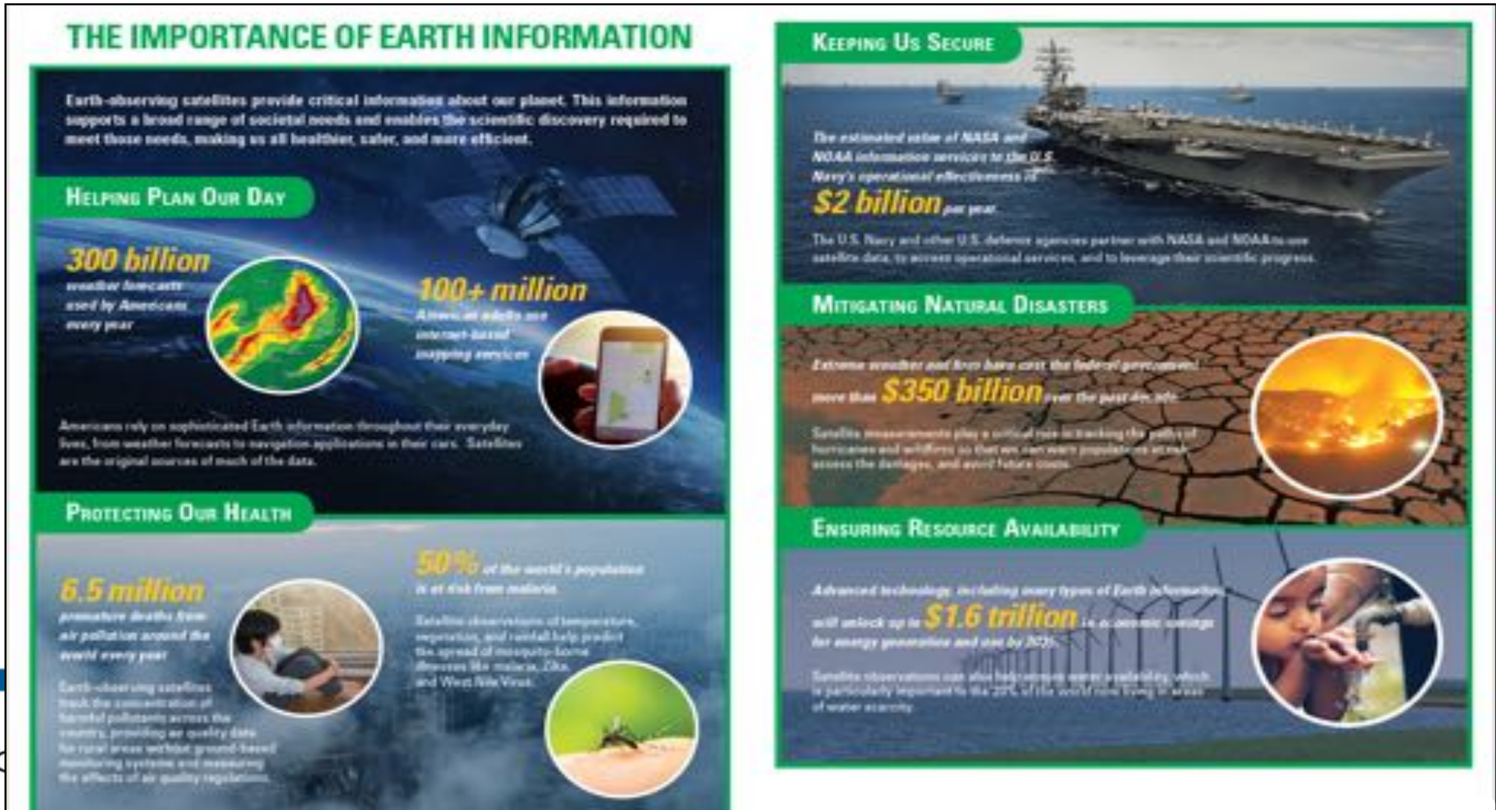
Core, mantle, lithosphere, and surface processes, system interactions, and the hazards they generate

The Decade Ahead

Thriving on our Changing Planet

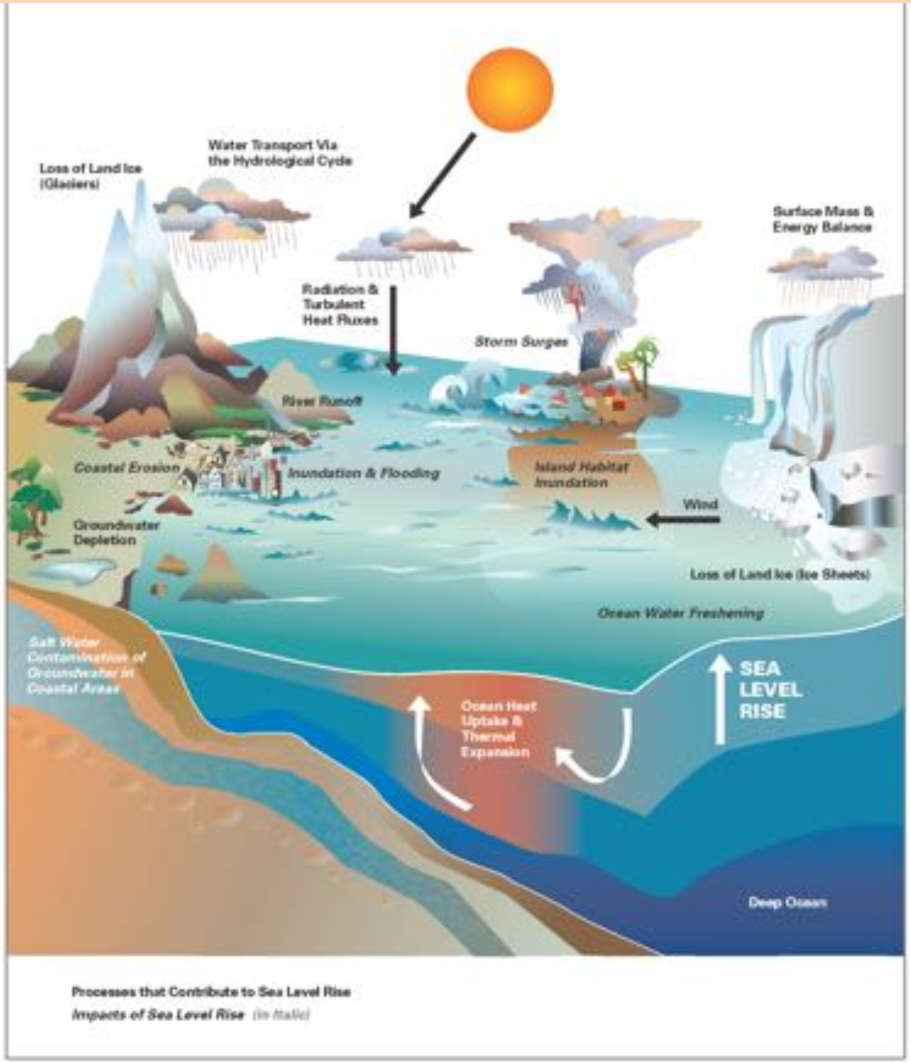
A decade in which we find growing community and public recognition of:

- Society's broad reliance on Earth information to **thrive**
- The challenge - understanding and predicting a moving target, as Earth **change** happens around us through natural and human influence



A Paradigm and Challenge of the decade

UNDERSTANDING SEA LEVEL RISE EXEMPLIFIES EARTH AS A SYSTEM OF INTERACTIONS



i) Prediction is the realm of Earth system science

Earth science and derived Earth information have become an integral component of our daily lives, our business successes, and society's capacity to thrive. Extending this societal progress requires that we focus on understanding and reliably predicting the many ways our planet is changing.

ii) Earth System Science and Applications Paradigm

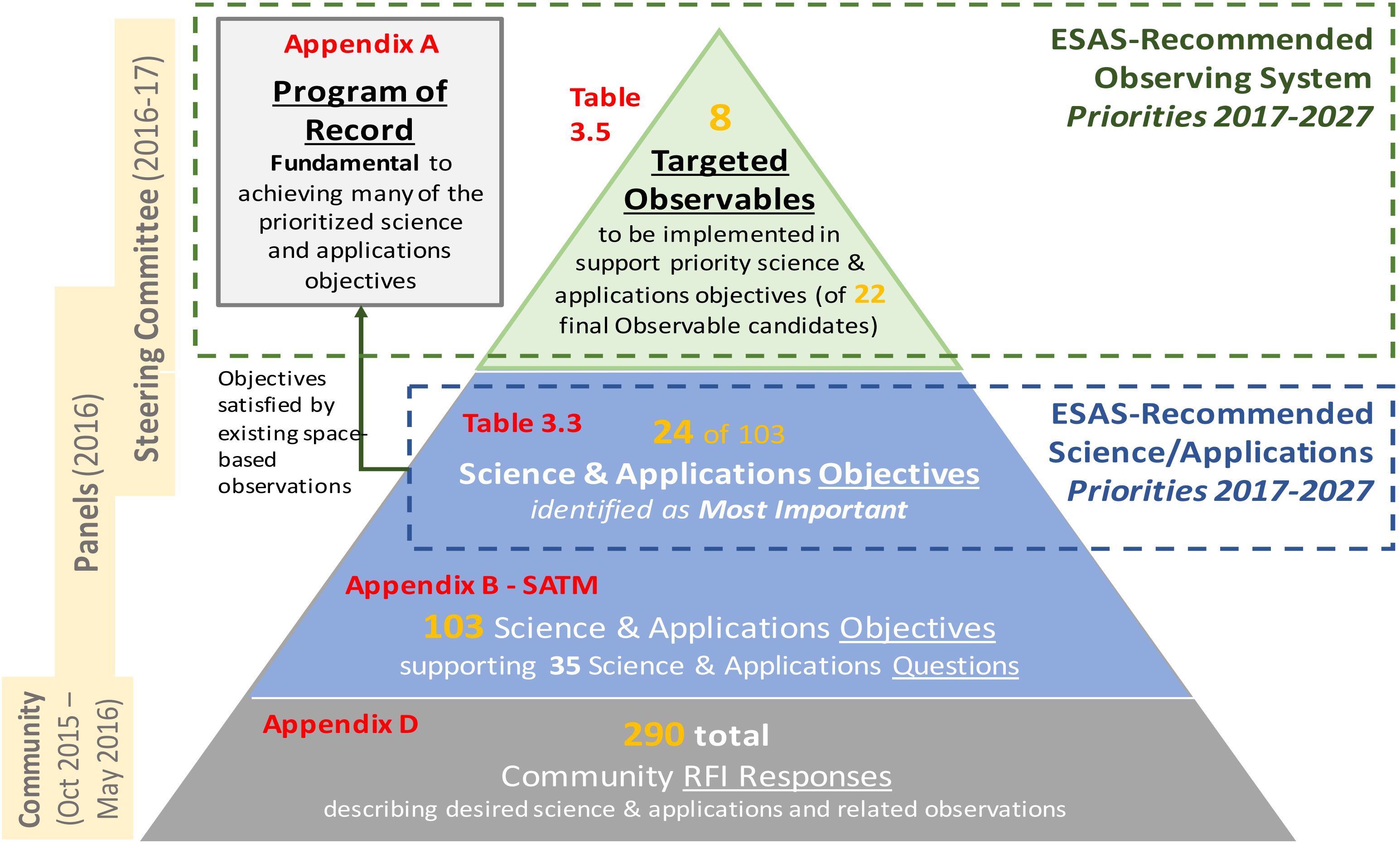
Changes to our planet are a result of processes that couple together in complex ways establishing Earth as a system. Predicting changes to the Earth system requires an integrated Earth system model and a more integrated systems approach to observing Earth

iii) Decadal Community Challenge

Pursue increasingly ambitious objectives and innovative solutions that enhance and accelerate the science/applications value of space-based Earth observation and analysis to the nation and to the world in a way that delivers great value, even when resources are constrained, and ensures that further investment will pay substantial dividends.

Path from Science & Applications to Observational Priorities

Blue: Science & Applications; Green: Observables



Recommended NASA Flight Program Elements

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 new 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. Those determined to be >$500M had to go through the CATE process.
- ***Earth System Explorer.*** A new program element involving competitive opportunities for medium-size instruments and missions serving specified ESAS-priority observations. ***Promotes competition among priorities.***
- ***Incubation.*** A new 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***.
- ***Venture.*** Earth Venture program element, as recommended in ESAS 2007 with the addition of a new Venture-Continuity component to provide ***opportunity for low-cost sustained observations***.

Recommended NASA Priorities: Designated

GEWEX relevant

Implemented first

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		

Implemented first

Relevant to Earth's energy imbalance

Recommended NASA Priorities: Explorer

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Greenhouse Gases	**CO_2 and methane fluxes and trends,** global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		x	
Ice Elevation	**Global ice characterization** including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar**		x	
Ocean Surface Winds & Currents	**Coincident high-accuracy currents and vector winds** to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift.	Radar scatterometer		x	
Ozone & Trace Gases	**Vertical profiles of ozone and trace gases** (including water vapor, CO, NO_2, methane, and N_2O) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		x	
Snow Depth & Snow Water Equivalent	**Snow depth and snow water equivalent** including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		x	
Terrestrial Ecosystem Structure	**3D structure of terrestrial ecosystem** including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation & forest degradation	Lidar**		x	
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		x	x

Fluxes

Hydrology

Land/atm

Many

Recommended NASA Priorities: Incubation/Other

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Atmospheric Winds	**3D winds in troposphere/PBL** for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		x	x
Planetary Boundary Layer	**Diurnal 3D PBL thermodynamic properties and 2D PBL structure** to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights.	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			x
Surface Topography & Vegetation	**High-resolution global topography** including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			x

** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables

Other ESAS 2017 Targeted Observables, not Allocated to a Flight Program Element

Aquatic Biogeochemistry	**Radiance Intercalibration**
Magnetic Field Changes	**Sea Surface Salinity**
Ocean Ecosystem Structure	**Soil Moisture**

Relevant to multiple GEWEX objectives

Partnerships

Finding 4C: NASA, NOAA, and USGS have successfully relied on international partnerships to enhance their programs. Partnerships potentially lower the overall cost to the U.S of space-based observations and enable more of this Decadal Survey's priorities than could otherwise be achieved. In certain cases, current restrictions on potential international partnerships hinder access to observations and thus limit opportunities to reduce U.S. cost and/or enhance science and applications.

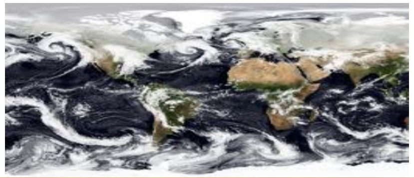
Recommendation 4.5: Because expanded and extended international partnerships can benefit the nation:

- NASA should consider enhancing existing partnerships and seeking new partnerships when implementing the observation priorities of this Decadal Survey.
- NOAA should strengthen and expand its already strong international partnerships, by a) coordinating with partners to further ensure complementary capabilities and operational backup while minimizing unneeded redundancy; and b) extending partnerships to the more complete observing system life-cycle that includes scientific and technological development of future capabilities.
- USGS should extend the impact of the Sustainable Land Imaging (SLI) program through further partnerships such as that with the European Sentinel program.

GEWEX offers a forum to help facilitate these partnerships

Anticipated Science/Applications Accomplishments

DESIGNATED Program Element



Make-up and distributi of **aerosols and clouds**

Severe weather, convective **storms**

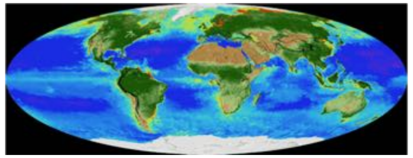
Impacts of **changing cloud cover and precipitation**

Growth or shrinkage of **glaciers and ice sheets**

Also EEI

Trends in **water stored on land**

Alterations to **surface characteristics and landscapes**



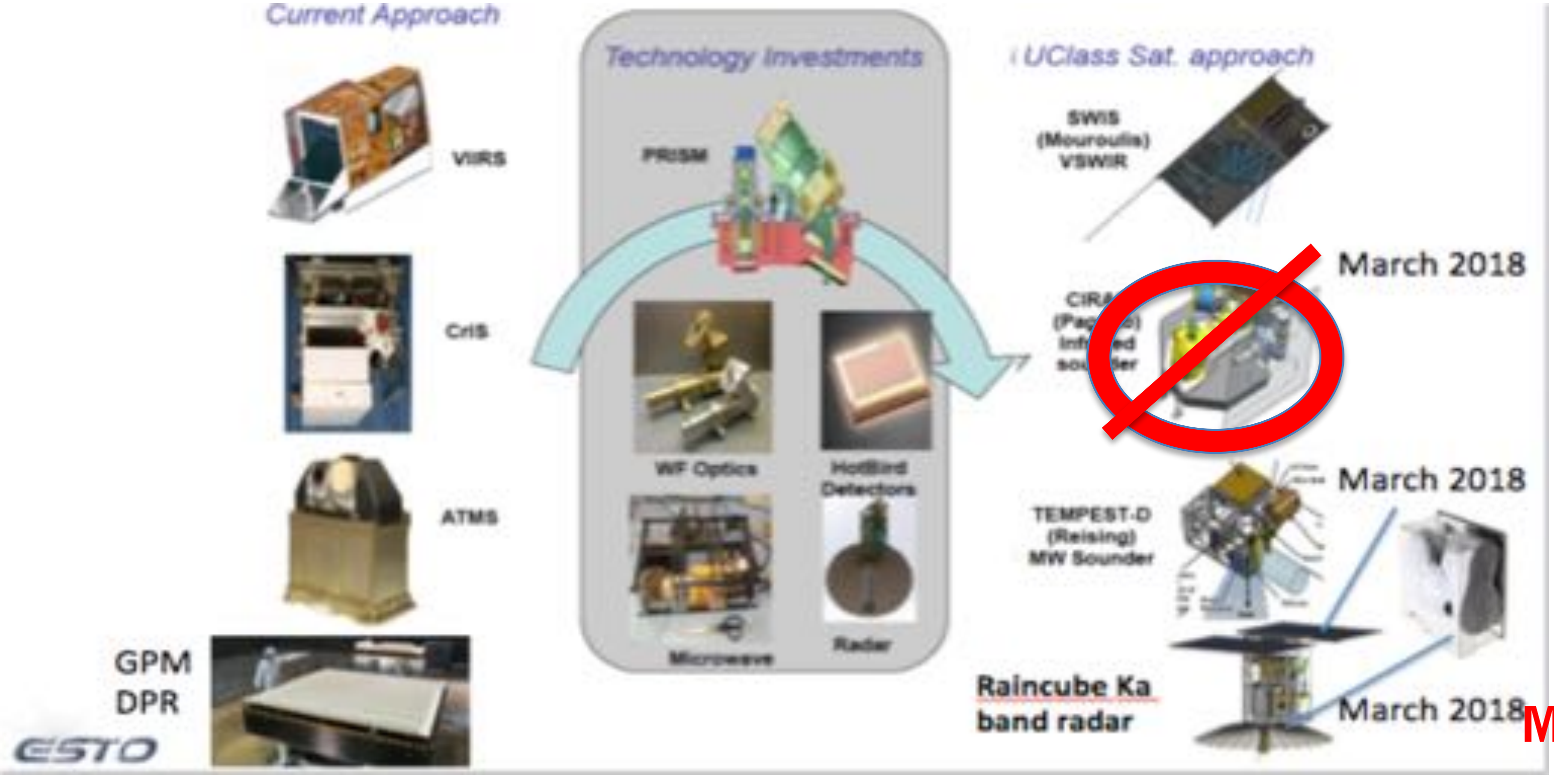
Movement of **land and ice surfaces**

Evolving characteristics and health of **terrestrial vegetation and aquatic ecosystems**

Candidate EXPLORER Program Element

- Sources and sinks of **CO2 and methane**
- Contributions of glaciers and ice sheets to **sea level rise**
- Impacts of **ocean circulation and exchange with atmosphere** on weather and climate
- Changes in **ozone and other gases** and impacts on health and climate
- **Snow amounts and melt rates** and implications for water resources
- Impact of changes in **land cover and related carbon uptake** on resource management
- Transport of **pollutants** and energy between land, ocean, and atmosphere

Technology innovation was seen as an essential ingredient for advancing Earth Science objectives for the decade



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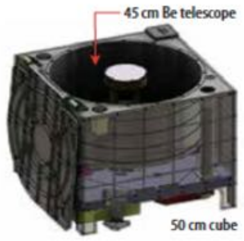
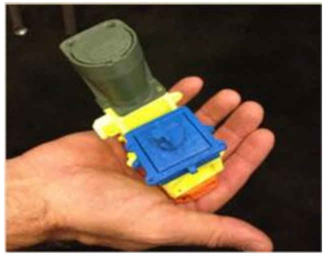


Small-sat lidar



3U IR spectrometer

Advanced GPS receiver – GNSS-refl

Thriving on our Changing Planet

A decade in which we find growing community and public recognition of: Society's broad reliance on Earth information to **thrive.**

The growing challenge of understanding and predicting a moving target, as Earth **change** happens around us through natural and human influence

Traceability: Science/Apps to Obs

QUESTION	SUMMARY OF OBJECTIVE (MI ONLY)	PRIMARY FLIGHT ELEMENTS TO ADDRESS OBJECTIVE		
		DESIGNATED	*EXPLORER*	*Incubation*
H-1	(H-1a) *Interact. Water & Energy Cycles*	A, CCP, MC	SDSWE	
	(H-1b) *Precipitation*	CCP	SDSWE	
	(H-1c) *Snow Cover*	CCP, SBG, SDC		
H-2	(H-2c) *Land Use & Water*	MC, SDC		
W-1	(W-1a) *Planetary Boundary Layer*	A, CCP	AW, OSWC	AW, PBL
W-2	(W-2a) *Extending Forecast Lead Times*	A, CCP	AW, OSWC, OTG	AW, PBL
W-4	(W-4a) *Convection & Heavy Precip*	CCP	AW, OTG	AW
W-5	(W-5a) *Mitigating Air Pollution*	A	OTG	
E-1	(E-1b) *Structure*		TES	STV
	(E-1c) *Primary Production*	SBG		
E-2	(E-2a) *Fluxes of CO_2 and CH_4*	SBG	GG	
E-3	(E-3a) *Flows Sustaining Lifecycles*	CCP, SBG	GG, TES	
C-1	(C-1a) *Mean Sea Level Rise*	MC		
	(C-1b) *Ocean Heat Uptake*	MC		
	(C-1c) *Ice Sheet Mass Balance*	MC, SDC	IE	STV
C-2	(C-2a) *Cloud Feedback*	A, CCP		
	(C-2d) *Carbon Cycle Feedback*		GG, TES	
	(C-2h) *Aerosol Feedback*	A, CCP		
S-1	(S-1a) *Volcanic Eruptions*	A, SBG, SDC		STV
	(S-1b) *Seismic Activity & Earthquakes*	MC, SDC		STV
S-2	(S-2a) *Response to Disasters*	SDC		
S-3	(S-3a) *Sea Level Change*	MC, SDC		STV
	(S-3b) *Coastline Vertical Motion*	SDC		STV
S-4	(S-4a) *Landscape Change*	MC, SDC		STV

TARGETED OBSERVABLE	SCIENCE & APPLICATIONS SUMMARY	SCI/APPS PRIORITIES (MI, VI, I)	RELATED ESAS 2007 and POR	IDENTIFIED NEED/GAP	CANDIDATE MEASUREMENT APPROACH	ESAS 2017 DISPOSITION
TO-5 Clouds, Convection, & Precipitation	• Cloud coverage & optical properties • Solid & liquid precipitation rate • Liquid and ice water path • Convection & cloud dynamics • Diurnal cycle of clouds and precipitation	- H-1a, 1b, 1c, 3b, 4b - W-1a, 2a, W3a, 4a, 9a, 10a - S-1c, 4a, 4b - E-3a - C-2a, 2g, 2h, 3f, 5d, 7e, 8h	*ESAS 2007*: ACE *POR*: CPR/EarthCARE, GPM, CloudSat, MODIS, VIIRS, SSMI, TROPICS	POR does not address diurnal cycle and does not cover precipitation after EarthCARE, GPM and SSMI, or snowfall, convection, and cloud dynamics after EarthCARE	*Similar to*: CloudSat, CPR/EarthCARE • Radar(s) and multi-frequency microwave radiometer • Sampling with 1-4 km horiz & 250 m vert resolution & 0.2 mm/hr precip (rain) accuracy • Doppler for dynamics/ convection (1 m/s) • Spatial resolution ~4-10 km for global precip & snowfall; 1mm/hr snowfall accuracy	DESIGNATED PROGRAM ELEMENT Maximum development cost $800M; considerable synergistic value in TO-5 being coordinated in time with TO-1 and TO-2

It was mandated that a CATE cost analysis would be performed for 'large' investments (>$500M). Any large investment that did not pass the CATE test would be disqualified as designated

CATE Evaluation. The CATE evaluation considered a reference concept consisting of a backscatter lidar and polarimeter. It found that the concept is based on mature technology and is consistent with a cost cap of $800M or less (excluding operations). High Spectral Resolution Lidar (HSRL) was a desired capability as part of *Aerosols*, but cost and technical readiness considerations precluded its consideration.

NASA Portfolio Balance

- Earth Science research and analysis: *maintain* at approximately 24% of the ESD budget (22-26%)
  - Includes 18% for openly competed research and analysis
  - Includes approximately 3% each for computing and administration
- Flight program (including Venture): *maintain* at 50-60% of the ESD budget
- Mission operations: *maintain* at 8-12% of the ESD budget
- Technology program: *increase* from current 3% to about 5% of the ESD budget
- Applications program: *maintain* at 2-3% of the ESD budget

Programmatics - NASA

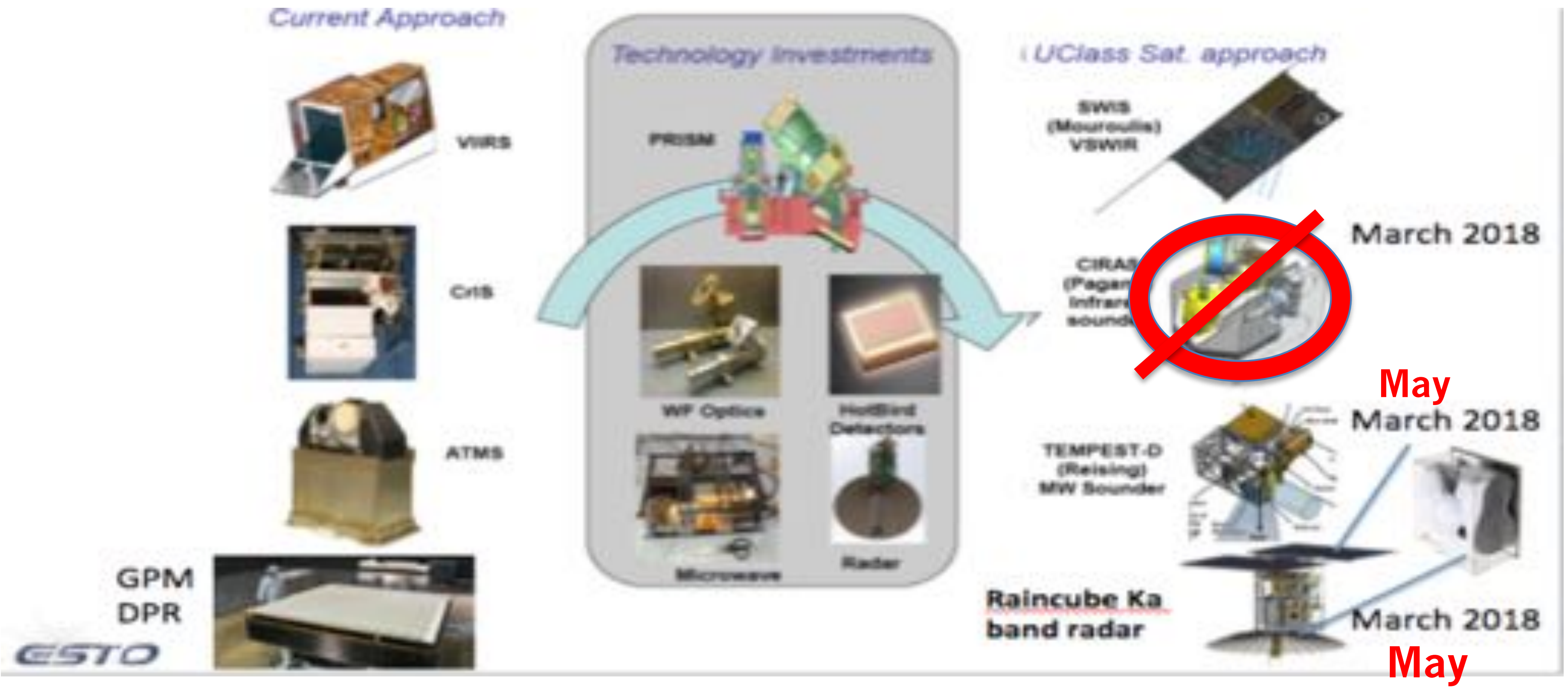
Rec 4.6 Apply **decision rules** (included) to maintain programmatic balance (programmatic balance was a high priority)

Rec 4.7 Small scope changes to **applications & technology progra**

Rec 4.8 Reevaluate **Ventures structure** at mid-term

Rec 3.3 **Avoiding cost growth** is critical to program’s success (capability and reliability are where the flexibility must be found)

We can expect to see real advances in sensor innovation



plus others (e.g. PREFIRE, and other miniaturization activities…)

Thriving on our Changing Planet

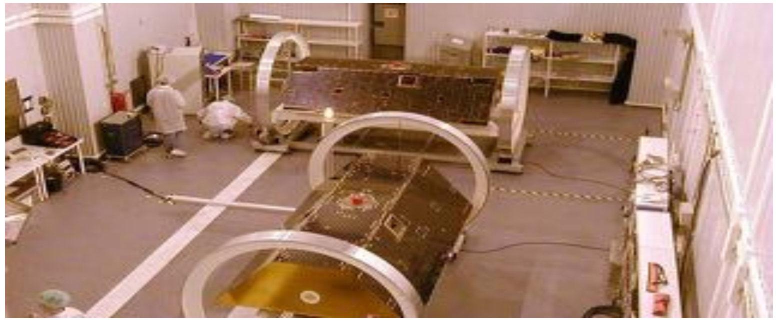
A decade in which we find growing community and public recognition of: Society's broad reliance on Earth information to **thrive.**

The growing challenge of understanding and predicting a moving target, as Earth **change** happens around us through natural and human influence

Anticipated Programmatic Progress

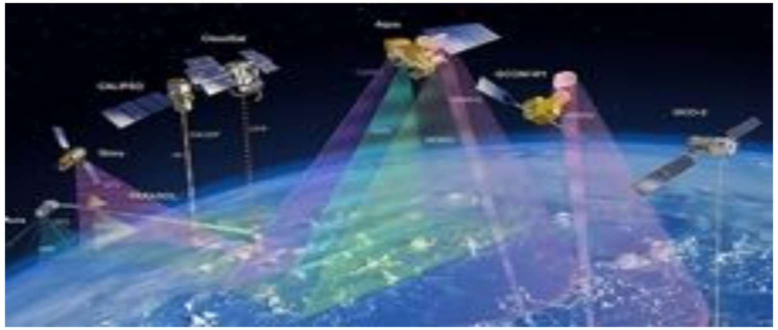
Programmatic implementation within the agencies will be made more efficient by:

- *Increasing program cost-effectiveness*
- *Institutionalizing sustained science continuity*
- *Enabling untapped interagency synergies*



Improved observations will enable exciting **new science and applications** by:

- *Initiating or deploying more than eight new priority observations of our planet*
- *Achieving breakthroughs on key scientific questions*



Enhanced societal value will be provided to businesses and individuals from scientific advances and improved Earth information, such as:

- *Increased benefits to operational system end-users*
- *Accelerated public benefits of science*
- *New enabling data for innovative commercial uses*

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Rec 3.3 **Avoiding cost growth** is critical to program's success (capability and reliability are where the flexibility must be found)

Programmatics - NOAA

Rec 4.9 Make it easier to extend use of satellite data for **NOAA purposes beyond weather**

Rec 4.10 Further leverage US and international government **partner observations,** allocating budget as needed to do so

Rec 4.11 Be a leader in exploiting **commercial observations**

Rec 4.12 Establish with NASA a flexible framework to **co-develop technology** that will be used by NOAA

Programmatics - USGS

Rec 4.13 Ensure Landsat **user needs** continue to be understood and addressed

Rec 4.14 Constrain and reduce **Landsat development cost**

Rec 4.15 Leverage **Landsat-related partnerships**, including international complements

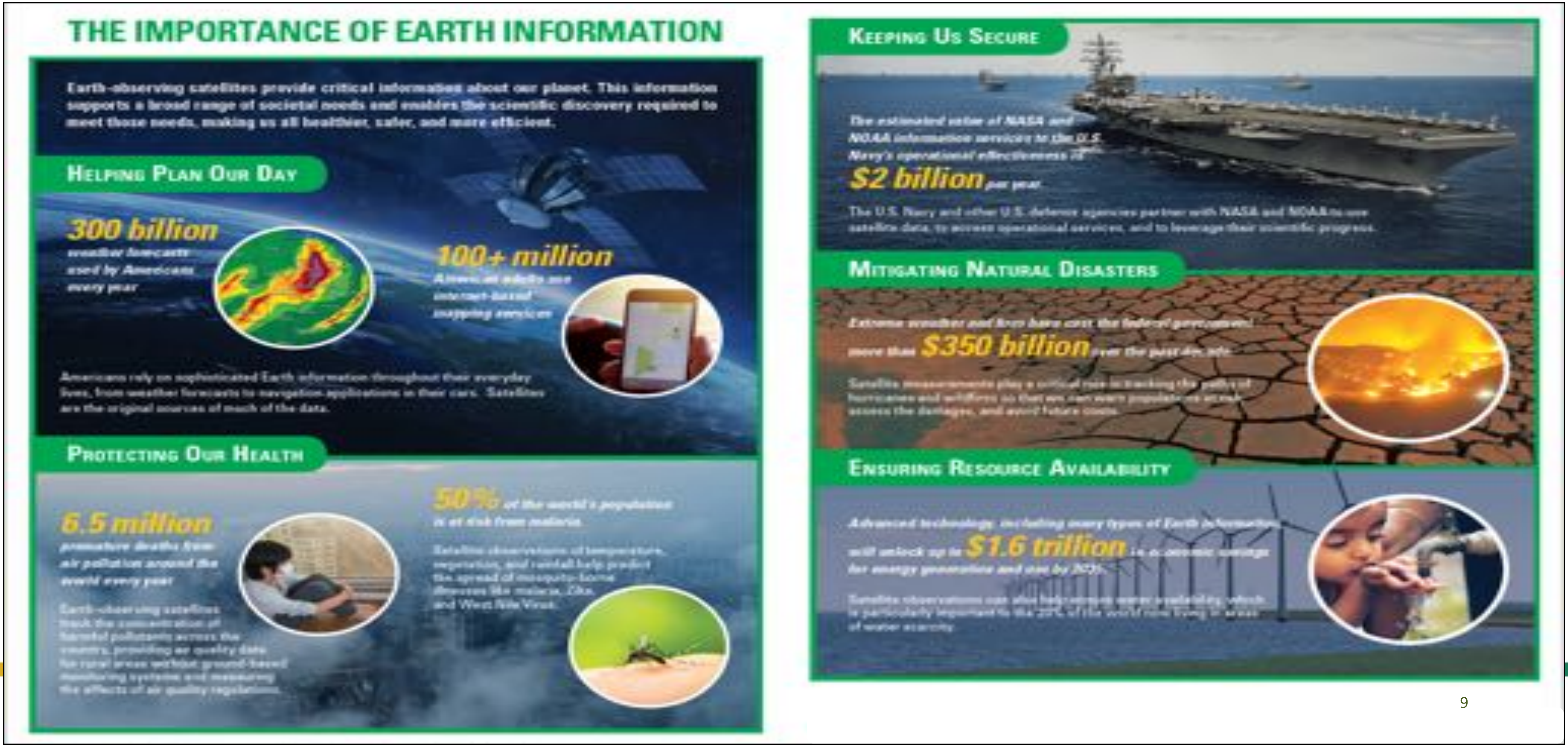
USGS
science for a changing world

Summary of Top Science & Applications Priorities*

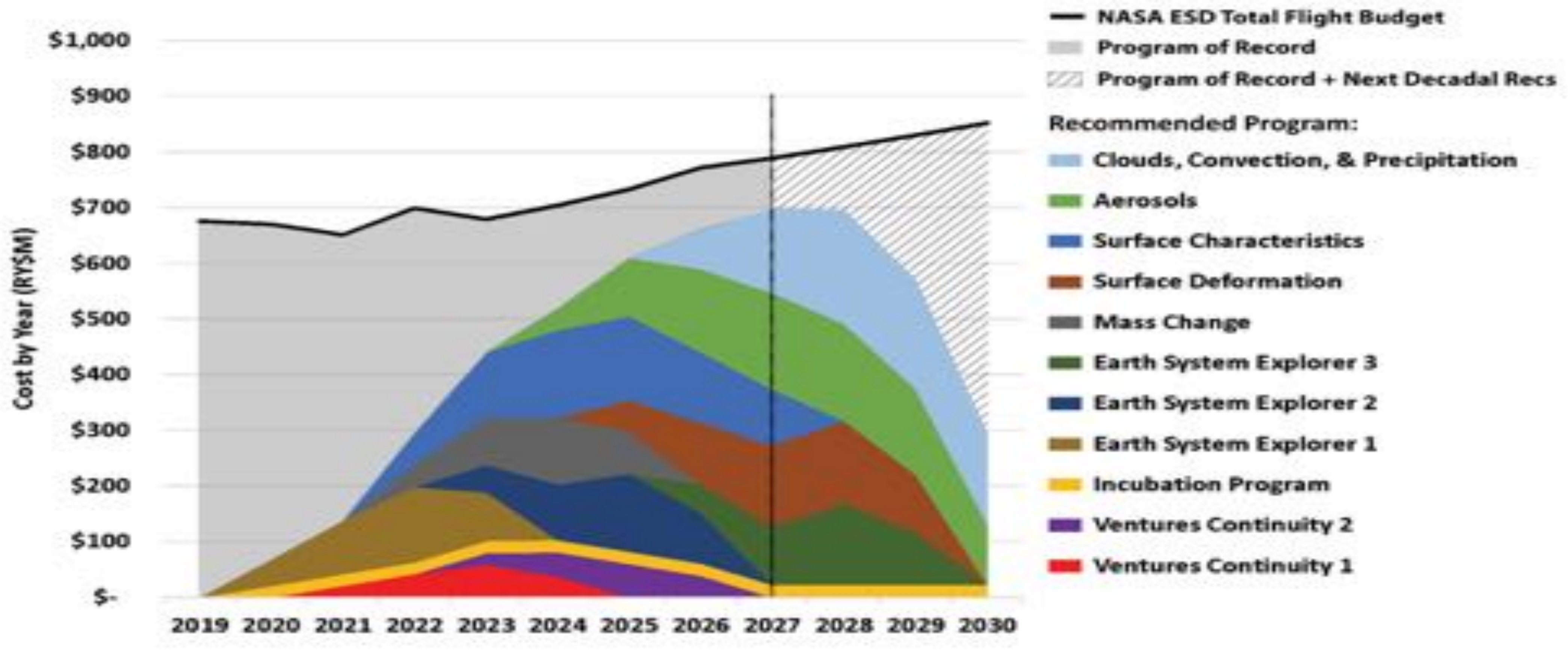
* Complete set of Questions and Objectives in Table 3.3

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?

Earth Information is Increasingly Critical to *Thriving* on our Planet



NASA Budget Compliance



- Liens from last decade into this one are substantial
- Very little flexibility to absorb funding challenges until mid decade
- Committee sought to keep liens lower on next decade
  - Allows more flexibility for next decadal survey
  - Some carry over of programs into subsequent decade is required

Quick Summary: Recommendations

1

VISION & STRATEGY

"Thriving on our Changing Planet"

2

SCIENCE & APPLICATIONS

Address **35 key science/applications questions,** from among hundreds suggested. Those with objectives prioritized as most important fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

3

OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified to be implemented:
  - *Aerosols*
  - *Clouds, Convection, & Precipitation*
  - *Mass Change*
  - *Surface Biology & Geology*
  - *Surface Deformation & Change*
- **Three** others to be selected competitively from among seven candidates
- Structure **new NASA mission program elements** to accomplish this
- Methods for new NASA capabilities to be **leveraged by NOAA and USGS**

4

PROGRAMMATICS

- CROSS-AGENCY
- NASA
  - Flight
  - Technology
  - Applications
- NOAA
- USGS