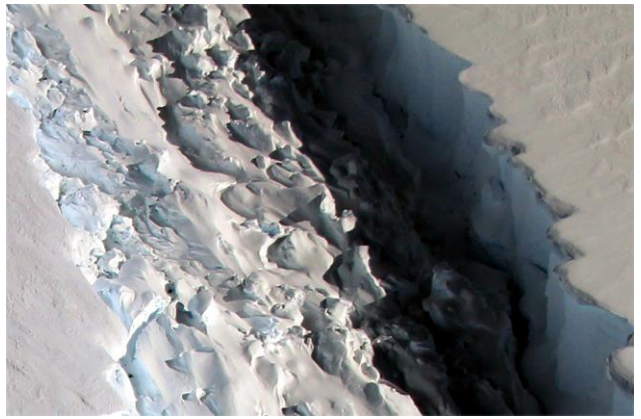
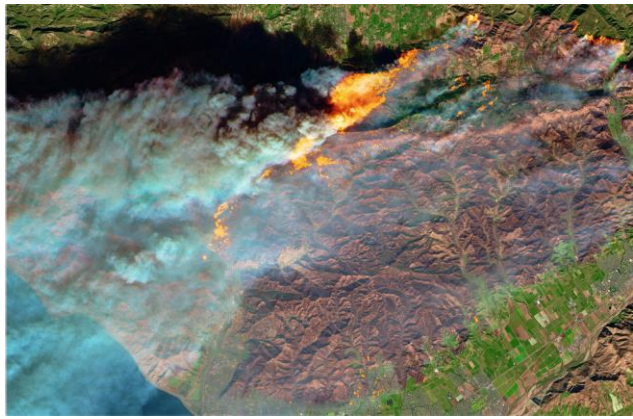
SCIENCE



NASA Earth Science Division Decadal Survey Implementation Overview

Garvey McIntosh
NASA Attaché
U.S. Embassy Tokyo

November 16, 2018

NASA Organizational Structure

NASA Administrator
James F. Bridenstine

10 NASA Centers

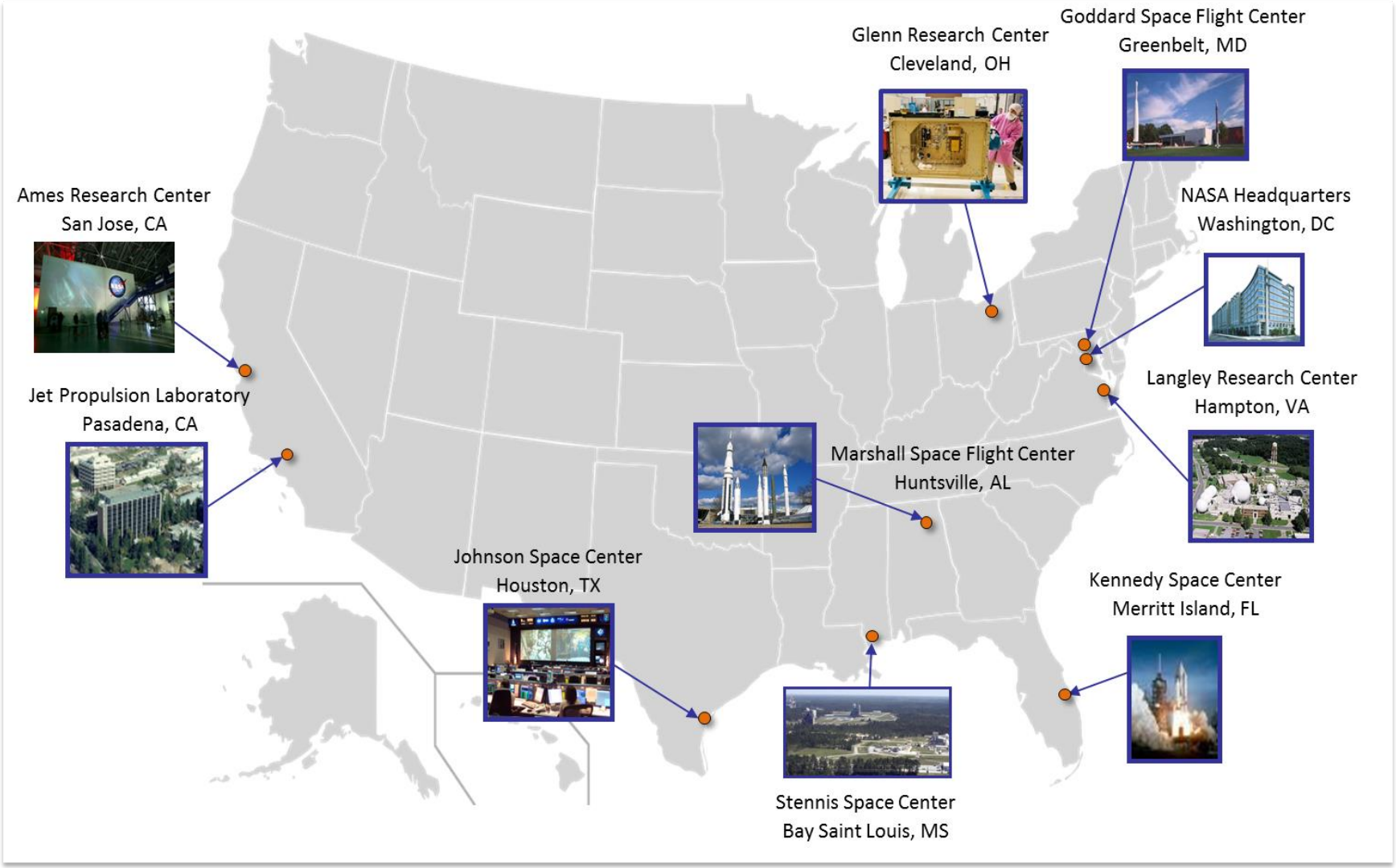
Aeronautics Research Mission Directorate
ARMD

Human Exploration and Operations Mission Directorate
HEOMD

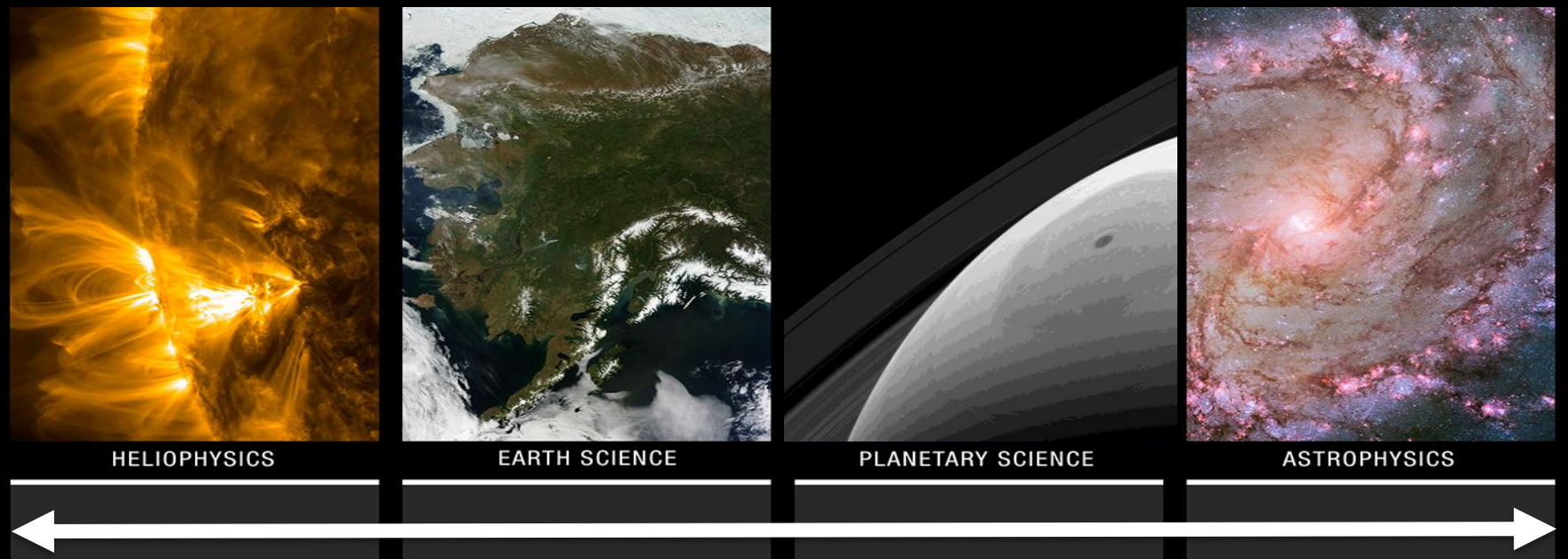
Science Mission Directorate
SMD

Space Technology Mission Directorate
STMD

10 NASA Centers



Answering Fundamental Questions



An Integrated Program of Science

Dr. Michael Freilich, Earth Science Director

Decadal Survey Overview

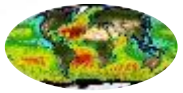
- The National Academies of Sciences led by the Space Studies Board in collaboration with other Earth Science related boards, will organize a “decadal survey” that will generate consensus recommendations from the environmental monitoring and Earth science and applications community on an integrated and sustainable approach to the conduct of the U.S. government’s civilian space-based Earth-system science programs.

- These programs are carried out predominantly by the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS), with supporting and complementary contributions from agencies including the National Science Foundation (NSF), Department of Agriculture (USDA), Department of Energy (DoE), and Department of Defense (DoD).

NASA Earth Science Division Elements

Flight (incl. Data Systems)

Develops, launches, and operates NASA's fleet of Earth-observing satellites, instruments, and aircraft. Manages data systems to make data and information products freely and openly available.

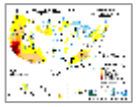


Research & Analysis

Supports integrative research that advances knowledge of the Earth as a system. Six focus areas plus field campaigns, modeling, and scientific computing.

Technology

Develops and demonstrates technologies for future satellite and airborne missions: Instruments, Information Systems, Components, InSpace Validation (cubesat and small-sat form factors).



Applied Sciences

Develops, tests, and supports innovative uses of Earth observations and scientific knowledge to inform private and public sector planning, decisions, and actions. Activities include disaster response support and capacity building.

The ESD annual budget remains at the FY16 level of ~$1.92B

NASA Earth Science Research Missions

Missions: Present through 2023
(no DS new starts or future Venture Class shown)

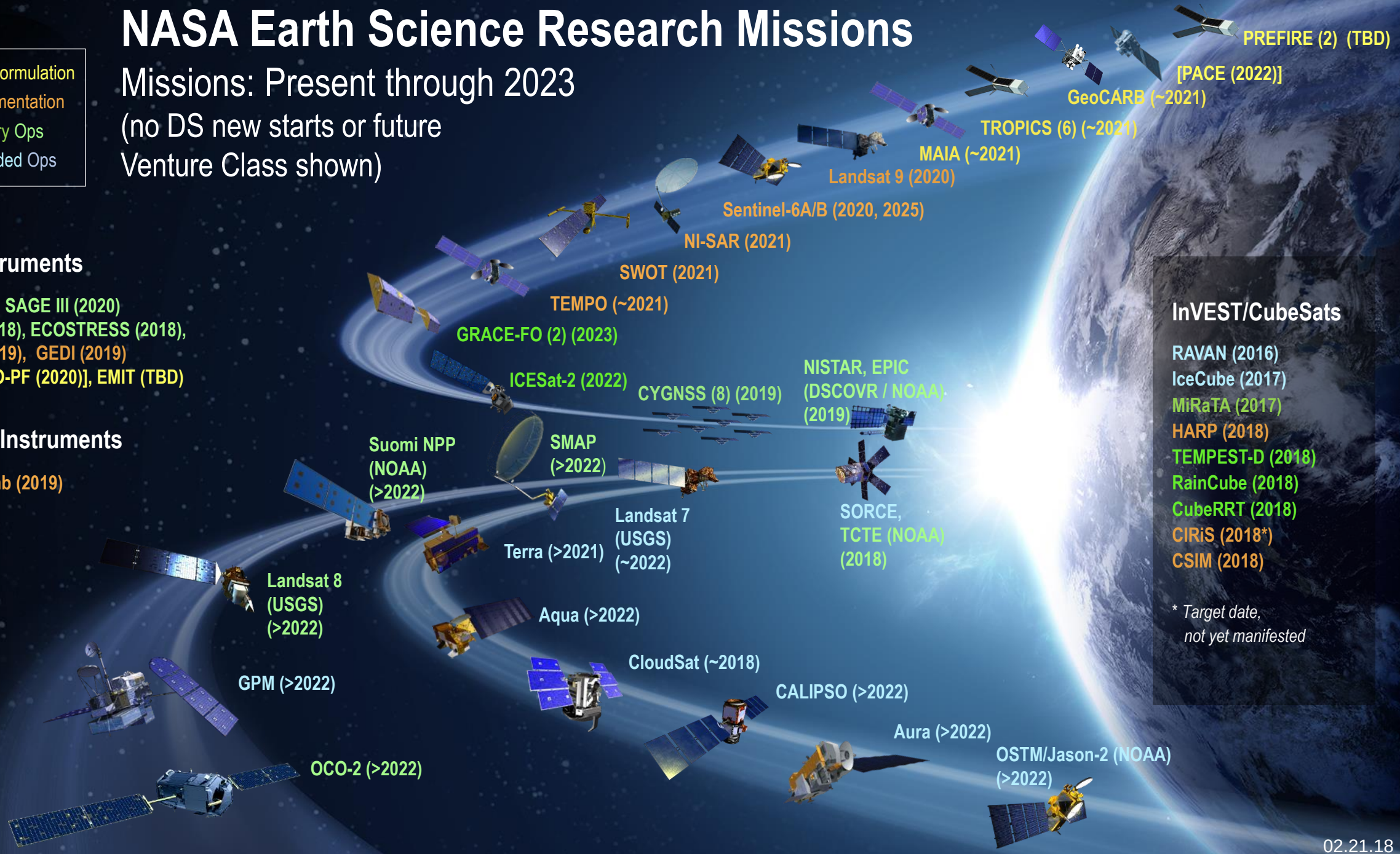
- (Pre)Formulation
- Implementation
- Primary Ops
- Extended Ops

ISS Instruments

LIS (2020), SAGE III (2020)
TSIS-1 (2018), ECOSTRESS (2018),
OCO-3 (2019), GEDI (2019)
[CLARREO-PF (2020)], EMIT (TBD)

JPSS-2 Instruments

OMPS-Limb (2019)



InVEST/CubeSats

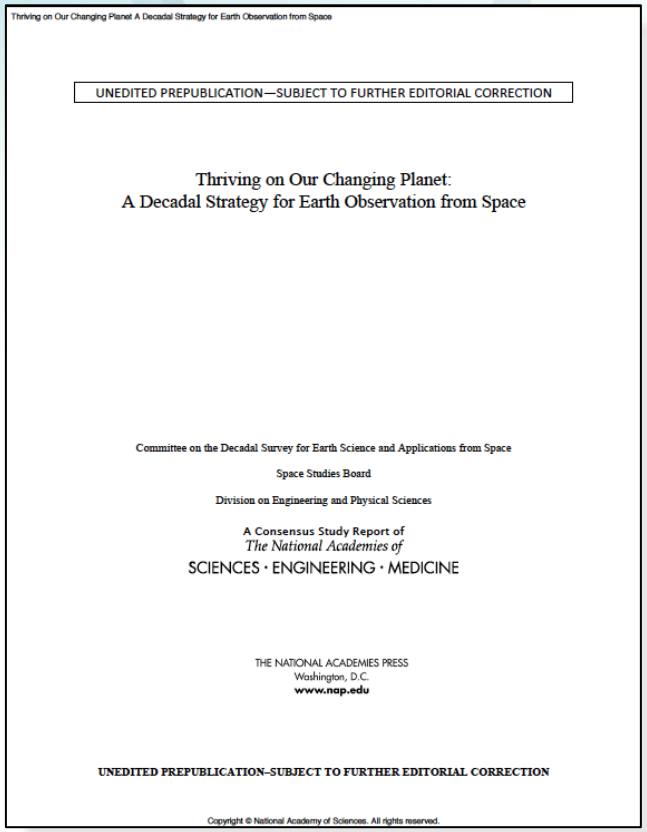
RAVAN (2016)
IceCube (2017)
MiRaTA (2017)
HARP (2018)
TEMPEST-D (2018)
RainCube (2018)
CubeRRT (2018)
CIRiS (2018*)
CSIM (2018)

** Target date, not yet manifested*

02.21.18

2017 Decadal Survey Snapshot

2017 DECADAL SURVEY


Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space

UNEDITED PREPUBLICATION—SUBJECT TO FURTHER EDITORIAL CORRECTION

Thriving on Our Changing Planet:
A Decadal Strategy for Earth Observation from Space

Committee on the Decadal Survey for Earth Science and Applications from Space

Space Studies Board

Division on Engineering and Physical Sciences

A Consensus Study Report of
The National Academies of
SCIENCES · ENGINEERING · MEDICINE

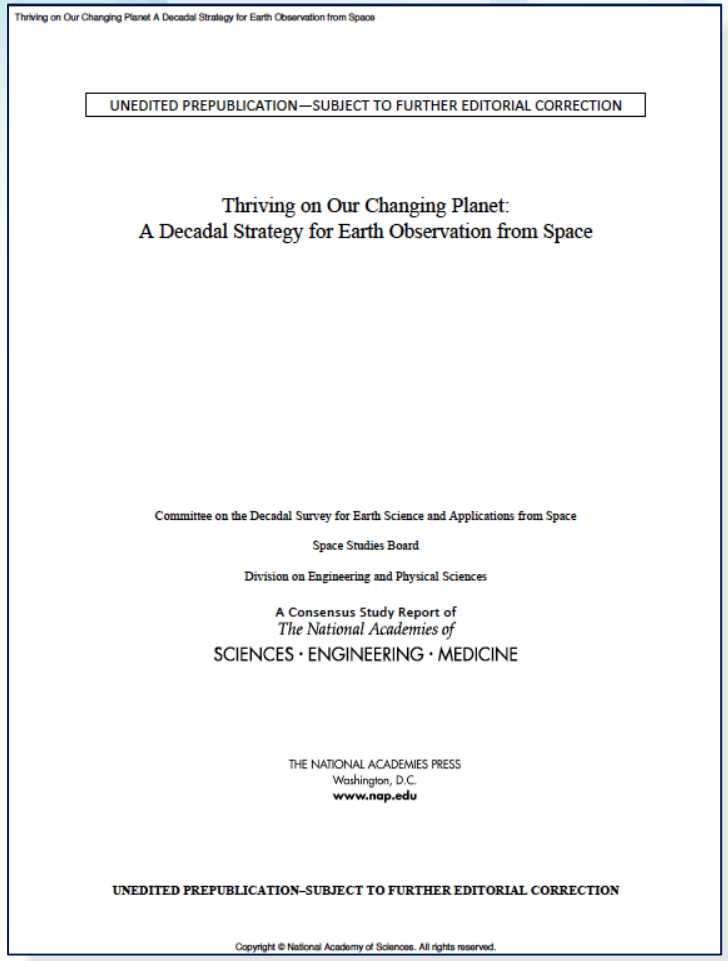
THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

UNEDITED PREPUBLICATION-SUBJECT TO FURTHER EDITORIAL CORRECTION

- Publicly released January 5, 2018
- Supports the ESD (and international) *Program of Record*
- Prioritizes *observations* rather than specific missions; explicitly allows *implementation flexibility*
- Emphasis on *competition* as cost-control method
- Explicitly encourages and notes value of *international partnerships*
- Endorses *existing balances* in ESD portfolio

2017 Decadal Survey Snapshot (cont.)

2017 DECADAL SURVEY


Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space

UNEDITED PREPUBLICATION—SUBJECT TO FURTHER EDITORIAL CORRECTION

Thriving on Our Changing Planet:
A Decadal Strategy for Earth Observation from Space

Committee on the Decadal Survey for Earth Science and Applications from Space

Space Studies Board

Division on Engineering and Physical Sciences

A Consensus Study Report of
The National Academies of
SCIENCES · ENGINEERING · MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

UNEDITED PREPUBLICATION–SUBJECT TO FURTHER EDITORIAL CORRECTION

- Calls for "cost-capping" essentially all missions
- Recommends "Continuity Measurement" strand ($150M full mission cost cap) as an addition to the existing Venture-class program
- Identifies 5 "Designated" observables (DO) for mandatory acquisition (*Aerosols; Clouds, Convection, & Precipitation; Mass Change*; *Surface Biology & Geology; Surface Deformation & Change)*
- Introduces a new competed "Explorer" flight line with $350M cost constraint, 3 observables to be chosen by ESD from among 7 identified
- Calls for "Incubator Program" between Technology, R&A, and Flight to mature specific technologies for important – but presently immature – measurements (preparation for next Decadal)

Designated Observables Summary (from DS)

Observable	Science/Applications Summary	Candidate Measurement Approach	ESAS maximum cost
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their effects on climate and air quality	Backscatter lidar and multichannel/multi-angle/polarization imaging radiometer flown together on the same platform	CATE Cap $800M
Clouds, Convection, And Precipitation (CCP)	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes including cloud feedback	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	CATE Cap $800M
Mass Change (MC)	**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	Est Cap $300M
Surface Biology and Geology (SBG)	**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	CATE Cap $650M
Surface Deformation and Change (SDC)	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	Est Cap $500M

Aerosol – Cloud, Convection and Precipitation (A-CCP) Designated Observable Study Plan

Objectives

- Refine Science Traceability Matrices (STM) from ACE and add STMs for aerosol air quality, convection and precipitation
- Engage NASA center, university, U.S. government agencies, commercial and international partners
- Use refined STMs as the scientific basis to design, develop and assess viable candidate architectures for making necessary observations utilizing satellite remote sensing, airborne measurements and surface-based sensors

Scope/Implementation

- **Phase 1** – Develop Science Value Framework
- **Phase 2** – Refine and Develop STMs
- **Phase 3** – Develop A-CCP DO Architecture(s) including documentation for Mission Concept Review
- **Phase 4** – Preparation of Final Study Report

Timeline

- September 2018 – Start Development of Science Value Framework
- October 2018 – Initiate Science Group work on STMs
- January 2019 – Complete STMs
- January/February 2019 – Meeting of Full A-CCP Study Team
- March 2019 – Blue Sky Study
- April/May 2019 – Start Architecture Studies
- Early 2022 – Final Report, Mission Concept Review

Participants

- HQ – Maring, Jackson, Lefer, Dutta, Edwards, Haynes
- Study Coordinators – Cutlip (GSFC), Vane (JPL), Trepte (LaRC)
- NASA Centers - GSFC, JPL, LaRC, MSFC, ARC, GRC
- Other Expected U.S. Participants NOAA, EPA, Universities, Commercial
- Hoped-for International Partners – CNES, JAXA, ESA, SRON, …

Mass Change (MC) Designated Observables Study Plan

Objectives

- Identify and characterize a diverse set of high value MC observing architectures responsive to Decadal Survey, preserving the fundamental approach that MC is observed through gravitational forces acting on the spacecraft
- Assess the cost effectiveness of each of the studied architectures.
- Perform sufficient in-depth design of one or two select architectures to enable rapid initiation of a Phase A study

Scope/Implementation

- Examine (1) novel approaches considering emerging capabilities, such as industry spacecraft, launch vehicles, and “data buy” opportunities, and (2) innovative approaches and enabling techniques, such as small satellite buses, constellations using only positioning information, compact, low-power electronic accelerometers and drag compensation systems.
- Candidate Mission Architectures will maintain continuity of measurements and/or explore:
  - Ground water and water storage mass change
  - Land ice contributions to seal level rise
  - Ocean mass change & heat content (when combined w/altimetry)
  - Glacial isostatic adjustment
  - Earthquake mass movement.
  - Operational applications (drought, hazards, agriculture, etc.)

Timeline

- **Oct 2018 – Phase 1 – Develop Candidate Architectures:** Engage user communities to define requirements and establish capabilities, and create value framework
- **Oct 2019 – Phase 2 – Assessment of Candidate Architectures:** Evaluate science and applications value, down-select to top candidates for detailed evaluations
- **June 2020 – Phase 3 – Architecture Design of top candidate(s):** Phase A study leading to Mission Concept Review
- **Jan 2021 – Phase 4 – Develop final report and Preparation of Mission Concept Review**
- **Sept 2021 – Delivery of final report and end of Study:** includes required observational capabilities of mission concept that may be used for competitive procurement of mission components.

Participants

- NASA – L. Tsaoussi, MC HQ Lead
- JPL – Study Lead (B. Bienstock, Study Coordinator)
- ARC, GSFC, LaRC study partners
- Academia (U. of Texas, U. South Florida, U. Colorado)
- International (DLR, ESA)
- U.S. government (NOAA, USGS)
- Industry

Surface Biology and Geology (SBG) Designated Observable Study Plan

Objectives

- Establish research and applications questions for SBG looking to the Decadal Survey and prior HyspIRI questions
- Engage SBG end users and stakeholders in the above process
- Use a science and applications traceability framework to derive observing system desired capabilities from questions
- Explore domestic and international partnerships
- Develop, assess, and design candidate architectures

Scope/Implementation

- **Phase 1** – Development of Candidate Architectures
- **Phase 2** – Assessment of Potential Architectures for Cost-effective SBG Observations
- **Phase 3** – Design of Recommended SBG Architecture and Preparation of Mission Concept Review Material
- **Phase 4** – Preparation of End of Study Report

Timeline

- August 2018 – Final HyspIRI Workshop/Initial SBG Workshop
- September 2018 – HyspIRI Final Report
- October 2018 – Initiate SBG Study Plan Funding
- December 2018 – Parallel and connected activities of the Research and Applications, Architecture Formulation, and Cost Estimation technical teams
- January 2019 to September 2021 – Assessment of candidate architectures and design of SBG observing system concept
- December 2021(?) – Final Report, Mission Concept Review

Participants

- HQ – Turner, Phillips, Bontempi, Jarrett, Doorn – SBG Leads
- Study Coordinator – JPL/Jamie Nastal
- GSFC, ARC, LaRC, MSFC study partners
- USGS, USDA, NOAA, SI, etc. – Government Participants
- Academia
- Industry
- ESA, SRON, IAVCEI, etc. – International Participants

Surface Deformation and Change (SDC) Designated Observables Study Plan

Objectives

- Determine cost-effective SAR-based architecture to implement the Surface Deformation and Change Observable
- Keep other science and applications that SAR can enable in the trade space
- Engage emerging best and new practices in industry to maximize engagement and exploitation of commercial sector capabilities and interests, including small-sat constellations
- Explore international partnerships to leverage capability and reduce cost

Scope/Implementation

- Include SAR-based architectures that support broader science/applications observables beyond geodetics in trades
- **Phase 1 –** Engage user communities to define requirements and 5-6 candidate architectures; establish value framework
- **Phase 2 –** Evaluate science/applications value; down-select to 2 top candidates for detailed evaluation; down-select to concept
- **Phase 3 –** Phase A study leading to Mission Concept Review
- **Phase 4 –** Final Report and MCR prep

Timeline

- October 2018 – Study Kickoff
- October 2019 – Complete Performance Tool Development
- March 2020 – Complete Requirements Definition
- March 2021 – Begin assessment of candidate architectures
- March 2022 – Downselect to concept
- March 2023 – Complete design concept
- October 2023 – Deliver Final Report
- December 2023 – Conduct Mission Concept Review

Participants

- HQ Leads: PS–Bawden, Margolis: PE–Slonaker: PA– Green
- JPL – Study Lead (P. Rosen, Study Coordinator)
- ARC, GSFC, LaRC, MSFC study partners
- USGS, NOAA, NGA government participants
- Academia
- Industry

Communicating our plans and progress:

- ESD's Decadal Survey web page:
  https://science.nasa.gov/earth-science/decadal-surveys
- Monthly webex/calls with NASA Centers
- 3/year (every 4 months) open webex/calls with external communities (January 21 2019)
- Engagement with interagency and international partners
- Town halls at professional society meetings
- Use the web page to…
  - See meeting and telecon announcements
  - Ask questions
  - Find answers to questions, as they become available
  - View records of progress and decisions

Recent and Near-Term Planned ESD Launches (1 of 2)

TSIS-1: DEC 15, 2017

GRACE-FO: May 22, 2018

ECOSTRESS: June 29, 2018

TSIS-1 *The Total and Spectral Solar Irradiance Sensor (TSIS-1) is measuring the total amount of sunlight that falls on Earth, and how that light is distributed among the ultraviolet, visible and infrared wavelengths.*

GRACE-FO *Obtaining high resolution global models of Earth's gravity field, including how it varies over time*

ECOSTRESS *Providing insight into plant-water dynamics & how ecosystems change with climate via high spatiotemporal resolution thermal infrared radiometer measurements of evapotranspiration (ET)*

Recent and Near-Term Planned ESD Launches (2 of 2)

ICESat-2: Sep 15, 2018

GEDI

December 2018

OCO-3

February 2019

ICESat-2 *Quantifying polar ice-sheet contributions to sea-level change & measure vegetation canopy height as a basis for estimating large-scale biomass and biomass change*

GEDI *Characterize the effects of changing climate and land use on ecosystem structure and dynamics, providing the first global, high-resolution observations of forest vertical structure*

OCO-3 *Investigate important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion.*