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Thriving on Our Changing Planet: A Midterm Assessment of Progress Toward Implementation of the Decadal Survey

Study Co-Chairs:

Christian Kummerow, *Colorado State University*
Anna Michalak, *Carnegie Institution for Science*

Download the report and report resources:
nationalacademies.org/esas-midterm

Decadal Survey Priorities

The 2017 decadal survey in Earth Science and Applications from Space (released in early 2018) **identified key science questions and prioritized observational needs** to advance U.S. efforts in Earth science and support critical applications such as climate modeling and weather prediction.

As climate change accelerates, the need for better scientific information on Earth's interacting systems has increased in urgency.

This midterm assessment evaluates progress toward decadal survey goals.

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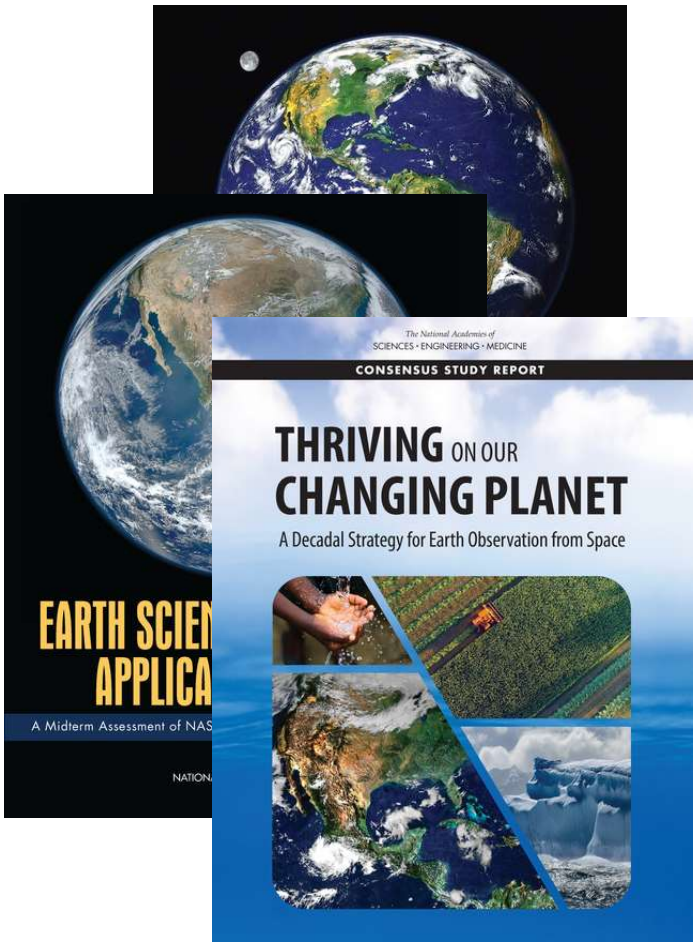

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Slide 2

BKL0 This is probably too wordy, but I took a stab at the type of context slide that might be helpful. You could also split this out into two slides, one on the decadal history and one on the need for more observations.
Bob, Kimberly L., 2024-07-10T03:02:15.787

Study Statement of Task (Abridged)

- Highlight the **most significant advances and relevant programmatic changes** since the publication of the decadal survey.
- Assess **whether NASA, NOAA, and USGS's programs address decadal survey priorities** and the progress toward realizing those priorities.
- Recommend actions that the agencies should undertake to **prepare for the next decadal survey**.
- For NASA in particular:
  - Assess impact and effectiveness of Earth science programs in implementing the decadal survey recommendations, synergies, and portfolio balance.
  - Recommend actions that could be taken to optimize the full breadth of NASA's Earth science programs during the remaining decadal interval.
  - Comment on NASA efforts to enhance the vitality and diversity of the scientists and engineers who work on ESD-sponsored programs and recommend actions that might be taken to enhance progress in these areas.
- ***The committee was asked not to revisit or redefine the scientific priorities or recommended targeted observables, unless indicated by superseding legislative or national policy directives.***

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Study Committee

- **Co-Chair: Christian D. Kummerow, Colorado State University***
- **Co-Chair: Anna M. Michalak, Carnegie Institution for Science**
- Stacey W. Boland, Jet Propulsion Laboratory*
- Francisco P. Chavez, Monterey Bay Aquarium Research Institute*
- William E. Dietrich (NAS), University of California, Berkeley*
- Deanna Hence, University of Illinois Urbana-Champaign
- Daniel J. Jacob, Harvard University*
- Dennis P. Lettenmaier (NAE), University of California, Los Angeles
- Kathleen (Kass) O'Neill Green, Kass Green and Associates
- Lesley E. Ott, NASA Goddard Space Flight Center*
- David T. Sandwell (NAS), Scripps Institution of Oceanography*
- Susan L. Ustin, University of California, Davis*
- Isabella Velicogna, University of California, Irvine
- Xubin Zeng, University of Arizona*

* Served on 2017 Decadal Survey

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Study Process

- First meeting on August 27, 2023
- Information gathering from August 2023 to January 2024
  - Had community RFI open from September to December 2023 (132 responses)
- Open Meetings:
  - September 28-29, 2023: Washington, DC
  - November 2-3, 2023: Irvine, CA
  - December 4, 2023: Virtual
  - January 25-26, 2024: Irvine, CA
- Briefings to NASA, NOAA, USGS, and Congressional Staffers: June 26 – July 9, 2024
- Report release: July 10, 2024

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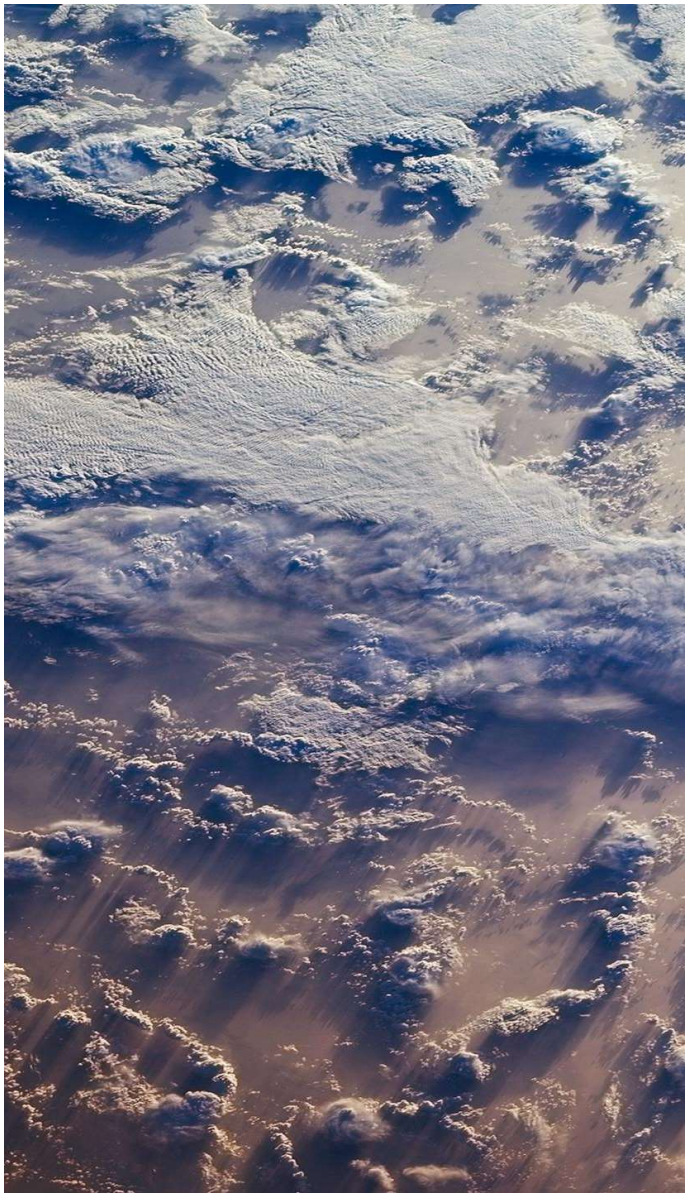
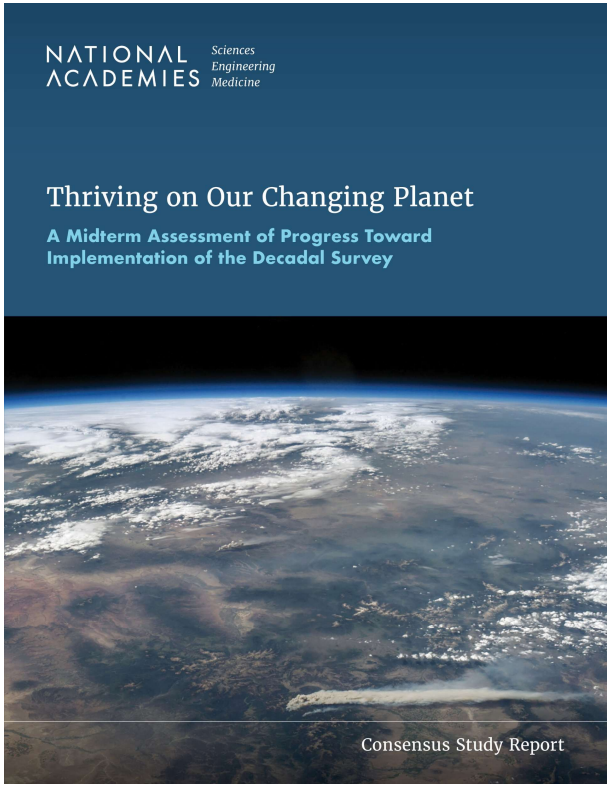


About the Report – Key Takeaways

- NASA, USGS, and NOAA have **launched innovative science-driven missions** that have provided valuable new data and generated significant excitement from the research and applications community.
- Due to a variety of factors, however, **NASA has made limited progress** toward implementing the new missions recommended by the decadal survey.
- The report identifies potential strategies for managing the NASA ESD portfolio, with the goal of **maintaining programmatic balance and improving alignment with decadal survey priorities**.



Download the report and report resources:
nationalacademies.org/esas-midterm

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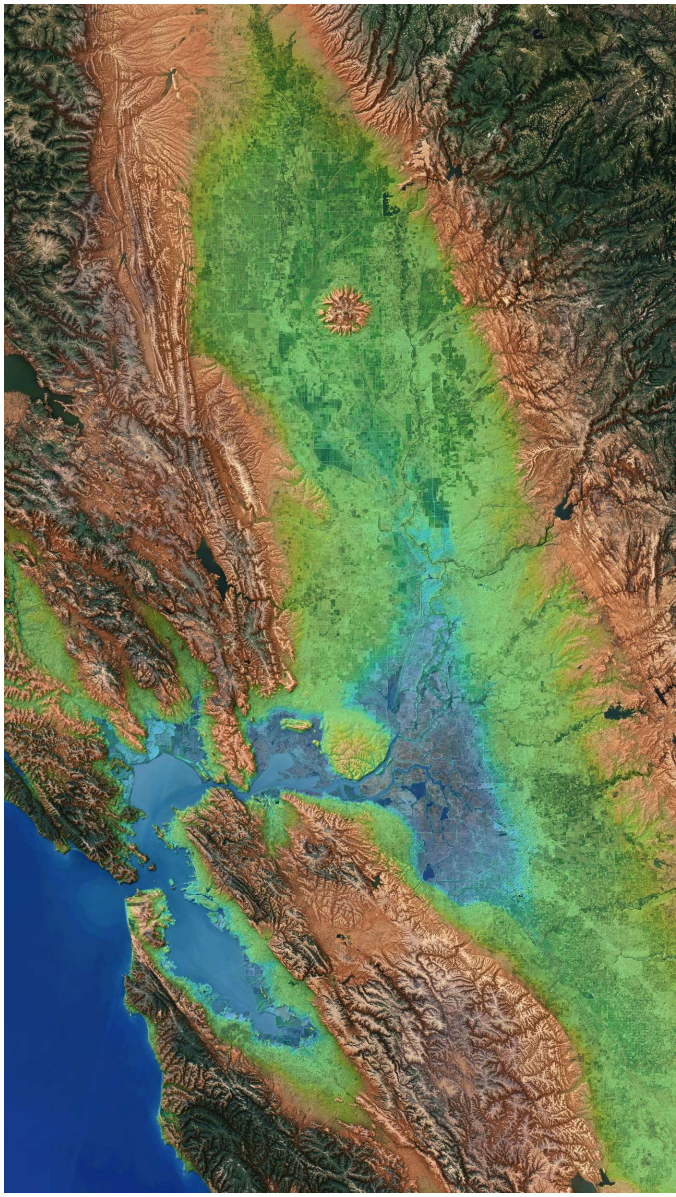
Science Successes

New Capabilities Are Supporting Both Research and Societal Needs

The decadal survey recommended a program that was implementable, balanced, and carefully considered to enable advances in Earth system science and applications from space with the resources that were stipulated to be available during the decade.

The broad scientific community surveyed as part of the current study is enthusiastic about new capabilities provided by Earth observing satellite missions.

The increased availability and variety of Earth observations has resulted in an exponential growth of their use to advance science and applications, support operational decisions, and address a broad myriad of societal needs.



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The fleet of existing and recently launched satellites and instruments has provided **new capabilities to track and understand**:

- methane leaks
- sea-level rise
- groundwater pumping
- deforestation
- wildfires
- ocean surface topography
- ocean primary productivity
- glacial outburst floods

These observations have helped **advance a variety of applications**, including:

- wildfire management
- conservation of water resources
- risk reduction of extreme heat, flooding, and landslides

Most Significant Advances since Decadal Survey

NASA ESM Program Element

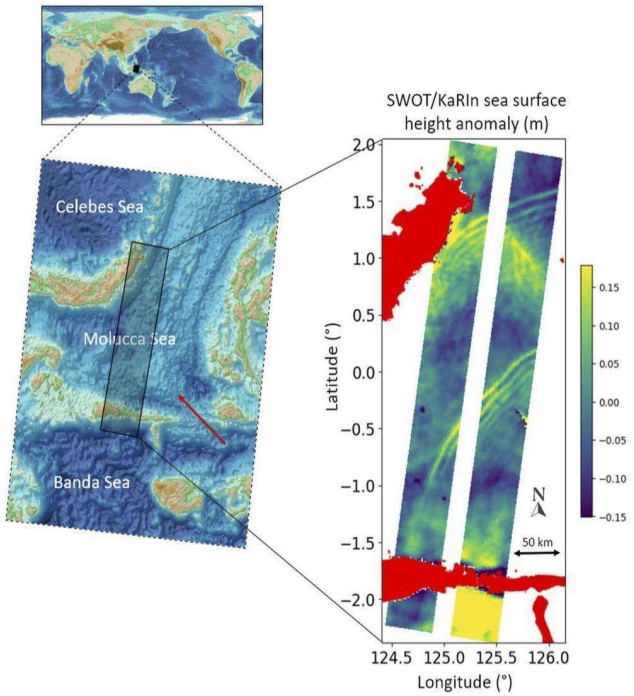
- GRACE-FO
- ICESAT-2
- Sentinel-6 MF
- Landsat 9 (w/ USGS)
- OMPS-L
- SWOT
- PACE

NASA ESSP & Ventures

- ECOSTRESS
- GEDI
- OCO-3
- EMIT
- TEMPO
- TROPICS

NOAA Program of Record

- GOES 17/18
- NOAA 20/21
- COSMIC-2



Surface Water and Ocean Topography (SWOT) observations of the surface elevations (in m) of internal solitary waves in the Molucca Sea in the western tropical Pacific. NOTE: Red areas are land. SOURCE: Fu et al. 2024.

Recurring Themes

- Challenges arising from budgetary constraints
- NASA's best way forward to preserve the enthusiasm of the scientific community
- The increasing tension between the need for continuing measurements vs innovation

Budget, Decision Processes, and Communication

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Investment in Decadal Survey Priorities is Vital

Findings:

- The need for **actionable information** based on Earth observations is increasing rapidly.
- However, NASA ESD has had an essentially **flat budget since 2015**, while mission costs are increasing.
- Priorities for science and technology **innovation directly compete with needs to continue observations of Earth's changing climate** which originally resulted from such innovation.

Recommendation: NASA should clearly **articulate the substantial societal value and urgency** of implementing the full set of 2017 Earth science and applications from space decadal survey priorities as well as its need for appropriate resources to do so. It is imperative that the NASA Earth Science Division **develop the framework to quickly assess and communicate what must be sacrificed** when requirements imposed by its other stakeholders supplant the science and applications community's priorities as expressed in the decadal survey.

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Expanding Collaboration Opportunities

Findings:

- At current levels of funding, **NASA cannot be expected to deliver on the needs for both providing long-term measurement continuity and new improved observation**s.
- The decadal survey outlined steps to be taken if budgets for recommended program elements grew beyond their allocated targets, but it **could not account for new requirements** levied upon the agencies by stakeholders other than the science and applications community.
- NASA has effectively leveraged collaboration with international agencies for the greater benefit of the scientific community and society at large.

Recommendation: NASA should expand funding opportunities for U.S. investigators to participate in and exploit data from international, interagency, and commercial endeavors.

NASA Should Pursue Funding for Landsat Next

Findings:

- **Communication of Landsat's importance and budget priority is not well-coordinated** with communication of the larger NASA Earth science program's importance or budget.
- This can significantly and negatively impact other elements within NASA's Earth science program when Landsat's budget is directed to increase without an increase in the NASA ESD top line budget.

Recommendation: NASA's Earth Science Division should pursue funding needed to cover the increase in Landsat Next's scope and budget that was not anticipated at the time of the 2017 Earth science and applications from space decadal survey. Otherwise, the increased Landsat Next budget substantially limits resources available to achieve the Earth science vision laid out in the 2017 decadal survey.

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Maintaining Alignment with Decadal Survey Priorities

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Findings:

- Lacking resources to implement the recommended program in its entirety, **NASA ESD has remained in analysis and evaluation mode** rather than having made timely decisions to enable progress on what is implementable.
- **Growth in individual program elements, without top line budget growth, does not support the healthy programmatic balance** called for in the decadal survey.

Recommendation: NASA ESD should take full advantage of its meetings with National Academies' Committee on Earth Science and Applications from Space (CESAS) to **seek feedback on its implementation plans to facilitate more timely decisions and maintain alignment** with decadal survey recommendations even as its budget fluctuates from year to year.

Recommendation: Consistent with the 2017 Earth science and applications from space decadal survey and the Earth System Observatory Independent Review Board (IRB) recommendations, NASA's Earth Science Division should **seek advice from the National Academies' CESAS prior to adding or substantially modifying individual program elements** to ensure appropriate consideration of program balance and decadal survey priorities.

Slide 16

BKL0 I combined the recs from these two slides because they seemed more on theme.
Bob, Kimberly L., 2024-07-10T12:19:09.441

Improving Communication with the Community

In the case of budget shortfalls, it is crucial to that NASA communicate expected program impacts to the community, particularly in the case of descoped mission plans, mission delays, and changes in solicitation schedules.

Recommendation: NASA's Earth Science Division should improve its communication with the community to provide the rationale for the decisions it makes particularly in the face of inadequate resources, including **providing timely information about program plans, budgets, and anticipated solicitation timelines** through town halls, webinars, and via the NASA website.

Slide 17

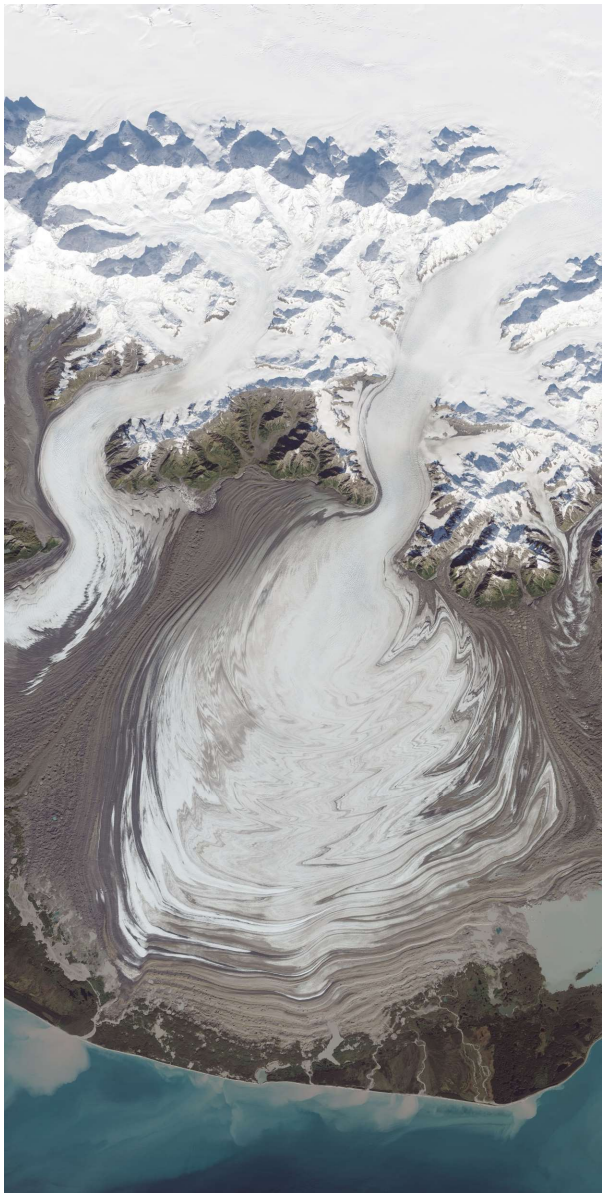
BKL0 I spun this out as it's own slide because it didn't quite fit with the other one. And added basically a sentence from the report highlights as an intro.
Bob, Kimberly L., 2024-07-10T13:01:53.242

Responding to Budgetary Pressures

Findings:

- NASA has been uneven in its response to decadal survey recommendations and has **not followed the decadal survey's decision rules regarding how to respond to budget pressures.**
- Neither the decadal survey nor the IRB recommendations have been consistently implemented across the Designated program element.

Recommendation: To address budgetary challenges, NASA should follow the guidance provided in the 2017 Earth science and applications from space decadal survey, **retaining competitive opportunities in the Earth System Explorer and Earth Venture lines, and implementing the Designated program element missions to the extent possible** within current constraints and consistent with the decadal survey's identified descopes.



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Program Elements

Timing of Committee Recommendations

- The last open Committee meeting was in January 2024, and most of the writing of the report was completed by February and March.
- During a March 13 online Townhall, NASA announced changes to the Designated program element to bring costs in line with a nearly $1.2 billion shortfall in the five-year (2025-2029) budget runout.
- Given the timing, the Committee proceeded with its existing recommendations, based on NASA ESD's plan as had been presented in open committee meetings in the fall of 2023.
- The final report compares its recommendations to the new NASA plan to highlight similarities and differences.

Surface Biology and Geology

Findings:

- The success of EMIT (VSWIR) and ECOSTRESS (Thermal Infrared [TIR]) onboard the International Space Station have demonstrated the promise of SBG.
- NASA is proceeding to address the decadal survey's SBG recommendation through two missions: SBG-VSWIR and SBG-TIR. The latter is to be implemented as a partnership with the Italian space agency (Agenzia Spaziale Italiana [ASI]). SBG-TIR is proceeding while SBG-VSWIR is being delayed.
- It would be more cost-effective and maximize science benefits to proceed with both SBG-VSWIR and SBG-TIR missions without further delay.

Recommendation: NASA's Earth Science Division should proceed with both the Surface Biology and Geology (SBG) - Visible to ShortWave InfraRed and SBG-Thermal Infrared missions without further delay in order to minimize cost and maximize achievable overlap.

Atmospheric Observing System

Findings:

- The AOS baseline capabilities exceed those required to meet the decadal survey recommendations, resulting in higher costs to the program which could negatively impact other decadal survey priorities.

Recommendation: NASA should fully implement the 2017 Earth science and applications from space decadal survey's prescribed descopes for the Aerosols and Clouds, Convection, and Precipitation Targeted Observables, adding two Earth System Explorer solicitations to the program with Targeted Observable 1 (TO-1) and TO-2 eligible to compete and pursuing a simpler single band radar mission responsible to TO-5.

Gravity Recovery and Climate Experiment - Continuity

Findings:

- Costs for GRACE-C are higher than the maximum decadal survey recommended investment for the Mass Change Targeted Observable. Some cost growth was driven by increased performance demands from stakeholders owing to the missions' large number of applications and others by IRB recommendations to reduce risk.

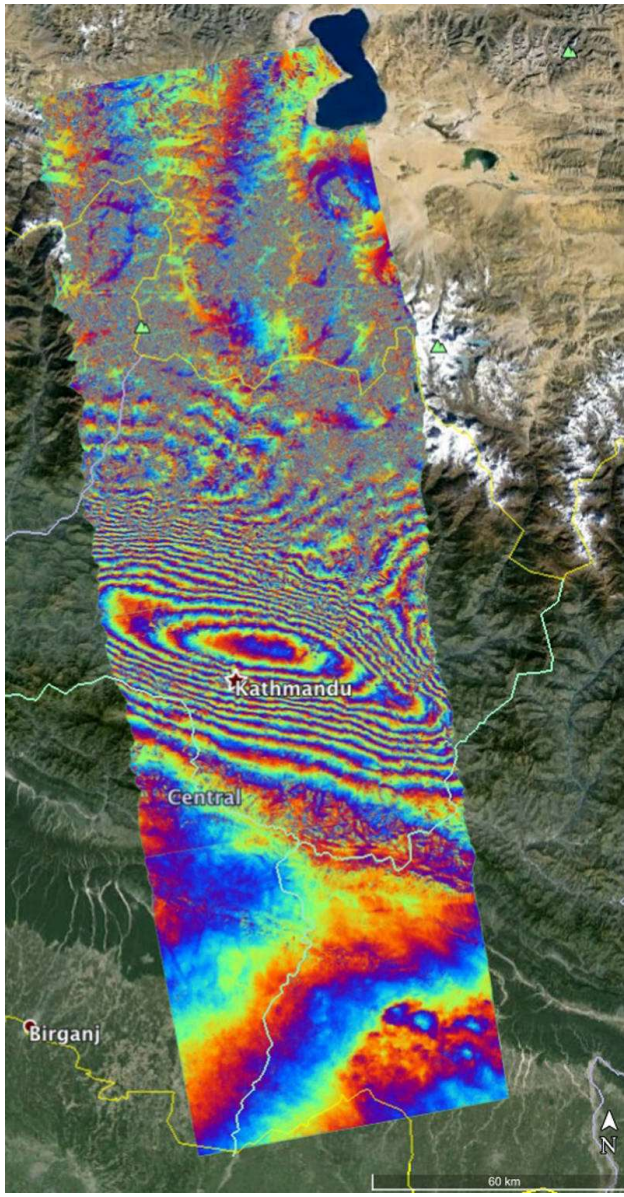
Recommendation: While it is appropriate to implement the GRACE-C (Gravity Recovery and Climate Experiment-Continuity) mission on its current timeline, **NASA should identify a long-term solution for achieving measurement continuity beyond GRACE-C at lower cost to the agency.**

Surface Deformation and Change

Findings:

- The mission architecture for addressing the SDC Targeted Observable following the NISAR mission remains undefined because no options identified to date meet the cost cap while also addressing the decadal survey's priority science and applications objectives.

Recommendation: NASA should engage with the European Copernicus program to explore ways to meet the science objectives tied to the Surface Deformation and Change Targeted Observable through a potential collaboration. Unmet science and continuity objectives should be re-evaluated once NISAR (NASA-IRSO [Indian Space Research Organization] Synthetic Aperture Radar) data becomes available.



Earth System Explorers, Venture Class and Incubation

Findings:

- The cadence of NASA's Earth System Explorer solicitation opportunities is not consistent with decadal survey recommendations. Instead of three solicitation spaced throughout the decade, NASA is planning to select two missions from a single solicitation.
- **Reducing the number of solicitation Earth Venture class missions and waiting to define them until closer to solicitation time provides programmatic flexibility but does not serve to provide the community with either routine, frequent open call opportunities, or an ability to plan ahead.** The lack of opportunity of competing for Earth Venture and Earth System Explorer missions in 2024 and 2025 also makes it difficult to sustain a culture of innovation and creativity among the Earth observations from the space community, as recommended in the decadal survey.
- Incubation programs for the PBL and STV Targeted Observables are worthwhile and working well overall.

Planning Ahead

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BKL0

Improving DEIA Across All Programs

Findings:

- NASA ESD has made substantial effort, yet shown limited progress, in enhancing workforce vitality and diversity, even relative to other divisions.
- The lack of competed mission opportunities, including the reduced cadence of Earth Venture solicitations and the reduction in number of Earth System Explorer calls, has limited opportunities to achieve or demonstrate progress on workforce development goals and DEIA objectives.

Recommendation: NASA's Earth Science Division (ESD) should **better coordinate systematic diversity, equity, inclusion, and accessibility plans across all of its program elements**, to provide holistic end-to-end support for underrepresented groups in Earth system science, and to ensure routine formal review. These plans should be supported by NASA's ESD with appropriate and sustainable budget allocations and include ongoing opportunities for training, principal investigator development, mission engagement at all career and leadership levels, and sharing best practices.

Slide 27

BKL0 Add cover images from diversity in competed space mission report; and the other 2022 report
Bob, Kimberly L., 2024-07-10T17:07:58.659

BKL0 0 Also make sure images have oceans/water theme
Bob, Kimberly L., 2024-07-10T17:08:46.116

BKL0 1 Phytoplankton bloom, clouds over oceans, islands
Bob, Kimberly L., 2024-07-10T17:09:10.701

BKL0 2 Also cryosphere, glaciers, snow, ice
Bob, Kimberly L., 2024-07-10T17:09:56.829

Preparing for the Next Decadal Survey

Recommendation (paraphrased): Prior to the next decadal review, NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey should engage a broader Earth sciences constituency by:

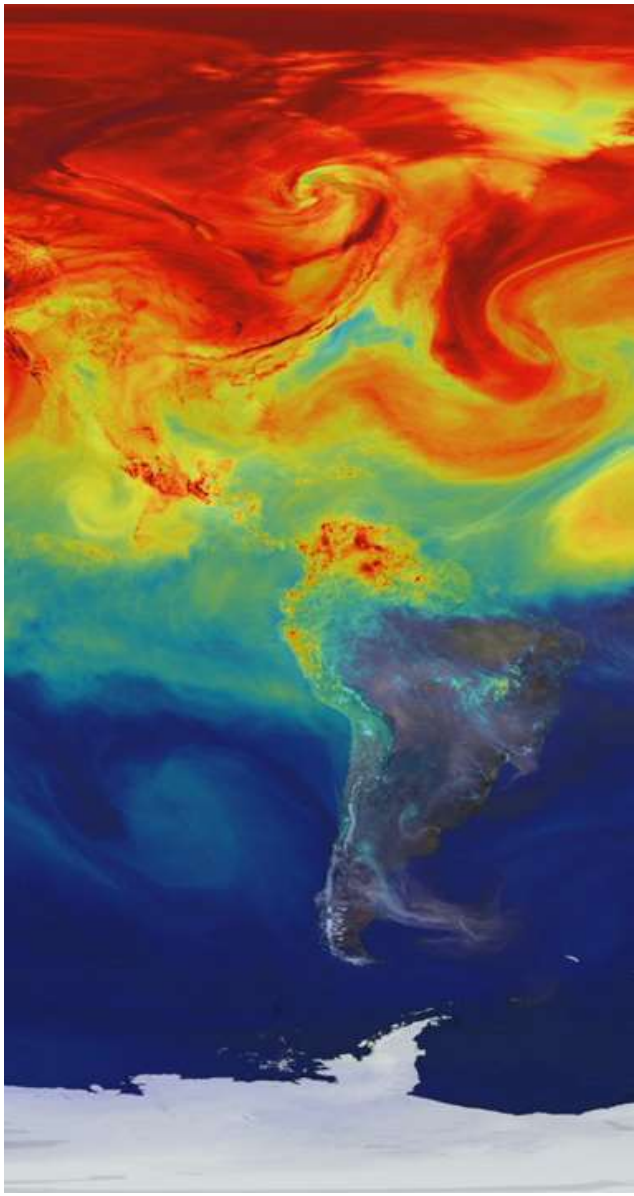
- Identifying Earth observation stakeholders, improving understanding of their short- and long-term needs and **encouraging participation of the community of stakeholders in the next decadal survey**. These stakeholder groups should include both the scientific community and communities impacted by climate change, including historically marginalized and underrepresented groups that are often disproportionately impacted.
- **Sponsoring workshops to engage the entire Earth system community** to better address observational needs for interdisciplinary and crosscutting issues.

Engaging the Modeling Community

Findings:

- Strengthening the interaction between the flight planning, satellite data analysis, and Earth system modeling communities would enhance the use of satellite data.
- Engagement of the Earth system modeling communities is needed to ensure that future satellite missions enable improvements in prediction across the range of time and space scales that are influenced by climate-related and natural hazards.

Recommendation: Through requests for information and workshops, NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey should **more actively engage the Earth system modeling community** to devise strategies to more fully exploit existing and potential Earth observations for advancing model parameterizations and predictions.



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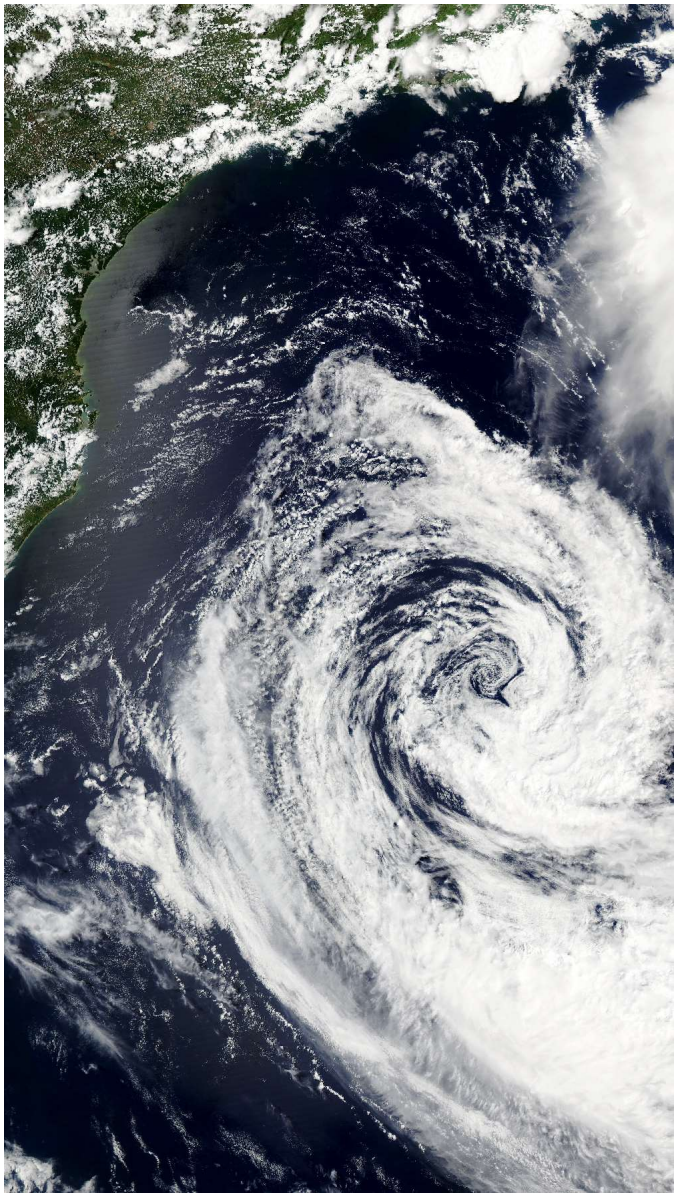
Developing Strategies for Observational Continuity

Findings:

- Despite the decadal survey's recommendation that NASA ESD lead development of a more formal continuity decision process, current ESD decisions with regard to observation continuity remain ad hoc and do not generally communicate what future observations will be prioritized or how budgets need to expand in order to accommodate new and sustained observations.

The committee reiterates the 2017 decadal survey recommendation that there is an urgent need to "ensure that no flight program element is compromised by overruns in any other element" and "**lead development of a more formal continuity decision process to determine which satellite measurements have the highest priority for continuation**, then work with U.S. and international partners to develop an international strategy for obtaining and sharing those measurements."



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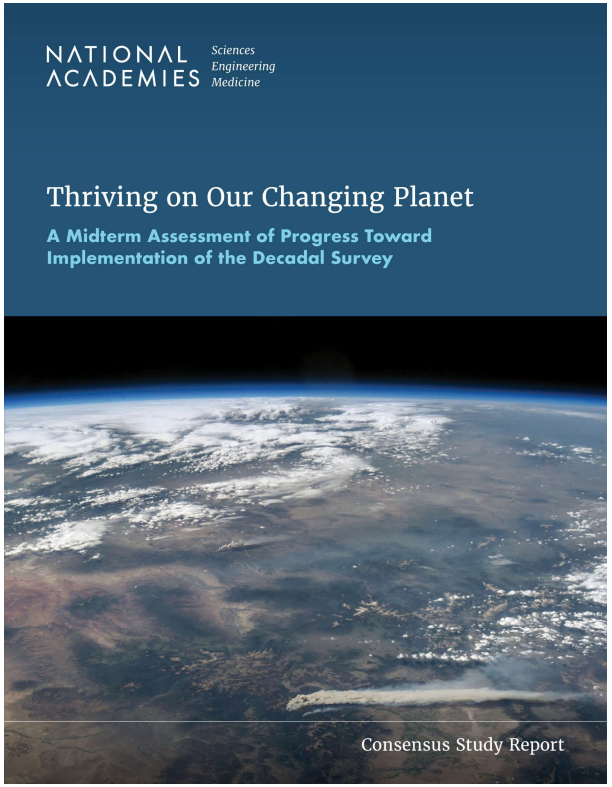
Key Takeaways

- NASA, USGS, and NOAA have **launched innovative science-driven missions** that have provided valuable new data and generated significant excitement from the research and applications community.
- Due to a variety of factors, however, **NASA has made limited progress** toward implementing the new missions recommended by the decadal survey.
- The report identifies potential strategies for managing the NASA ESD portfolio, with the goal of **maintaining programmatic balance and improving alignment with decadal survey priorities**.
- The increasing urgency of reliable climate information will require **increased levels of funding to ensure that NASA, NOAA and USGS can implement a balanced portfolio** that invests in new technology while maturing existing observations and eventually transitions them into the applications needed to adapt to a changing climate



Download the report and report resources:
nationalacademies.org/esas-midterm

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Agency Responses

Highlights from NASA Response

From October 22 presentation given at ESD town hall

NASA grouped the report findings/recommendations and their responses into **four themes**:

- Engaging [Their] Community and Stakeholders
- Developing the Earth System Observatory (ESO) Through Budget Constraints
- Strategic Approaches for Continuity
- Strategic Approaches for Modeling

NASA also shared some "key topics for ongoing CESAS engagement/future discussion:

- "Given that substantial additional funding is unlikely in the near future, [NASA's] strategy is to maximize the impact of the existing resources
- **"What observations are we talking about and what are the essential attributes?**
  - Observations to enable breakthroughs
  - Sustained observations for understanding Earth system processes and change
  - Measurements that have broad application
  - Observations for operational purposes are very important
- "Structured analysis of risks and opportunities"

For more information, go to
https://science.nasa.gov/earth-science/esd-community-forum/

Highlights from NOAA Response

From November 4 presentation given to CESAS

- **“Modeling Strategy:** NOAA’s 2024-2033 Modeling Strategy embraces unification, diversity, and open science to enhance Earth System Modeling. It emphasizes collaboration with NASA, USGS, and other partners, a unified approach to modeling for a range of timescales and spatial needs, and integration of emerging fields like AI and community-based science.”
- **“Earth Observations Connection:** NOAA is aligning Earth Observations with Earth System Modeling (ESM) needs. Regular collaborations and global meetings ensure that observing systems are tailored to ESM goals, helping NOAA provide critical decision-support information.”
- **“NOAA fully supports [recommendation to engage modeling community].** [NOAA is] advancing new observational tools, moving from R&D to demonstration missions that serve as proxies for future operational capabilities. Instruments like TEMPO, GOCI, GLIMR, and QuickSounder are already providing critical data for refining model accuracy, paving the way for future systems like GeoXO and NEON.”
- **“Innovative Approaches:** NESDIS has explored a fully disaggregated LEO constellation, allowing for flexible upgrades as technology advances. International partnerships, like EUMETSAT’s EPS-Sterna microsatellites, play a crucial role in modernizing this architecture.”
- **“Commercial Collaboration:** Through the Commercial Data Program, NESDIS is maximizing partnerships, with recent initiatives in microwave soundings, radio occultation, ocean surface winds, and space weather. This **hybrid “build-borrow-buy”** strategy is key to NOAA’s future.”

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For more information, go to the Fall 2024 meeting at
https://www.nationalacademies.org/cesas

Highlights from USGS Response

From November 4 presentation given to CESAS

- "…the language [in the recommendation beginning with, 'NASA should clearly articulate the substantial societal value…'] assumes the Decadal's own stated science priorities are the most valid source of user needs for the science and applications communities. While these needs are important, these science priorities alone undervalued the importance of continuous observations and operational land imaging. The user needs requirements for Landsat Next are very comprehensive and well validated across the public services and research communities, while those done via the Academy tend to focus more on cutting-edge research."
- "[Concurs] with NASA ESD pursuing the funding needed to cover the full scope of Landsat Next. The USGS is also requesting increased funding to meet this mission's ground system need. However, the USGS does not believe the increase in Landsat Next's scope and budget should have been unanticipated."
- "…the Mid-term Report seemed to take issue with the budget for the [program of record], and singled out Landsat Next in a budgetary graphic (next slide) with new decadal missions representing it as apparently outside the POR and implying it was a new mission unforeseen by the original 2017 Decadal. This represents how the Mid-term Report seemed to disregard the Decadal Survey's prioritization of operational, services-oriented remote sensing missions over other more research-focused missions."
- "Landsat Next supports the growing public services, research, and educational needs of the land imaging user community and continues Landsat's history of technology infusion and improvements in observing capabilities. Yet the Mid-term Report was critical of this approach and seemed to question why NASA and the USGS didn't settle for older, less capable technology. The Mid-term Report thus seemed to equate the concept of observational continuity with technological stasis."

Thank You

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Download the report and report resources:

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Backup Slides

BKL0

Recurring Themes

- Challenges arising from budgetary constraints
- NASA's best way forward to preserve the enthusiasm of the scientific community
- The increasing tension between the need for continuing measurements vs innovation

The increasing urgency of reliable climate information will require increased levels of funding to ensure that NASA, NOAA and USGS can implement a balanced portfolio that invests in new technology while maturing existing observations and eventually transitions them into the applications needed to adapt to a changing climate

Slide 38

BKL0 I'm not sure this slide quite works as a conclusion, but maybe you can rework it to be more forward looking? Maybe we can call it "Moving Forward" or somesuch?
Bob, Kimberly L., 2024-07-10T15:15:09.133

BKL0

Despite budget challenges, advancing existing observations and transitioning them into the applications needed to adapt to a changing climate is achievable. **A well-defined strategy by NASA, NOAA, and USGS that invests in new technology while maturing current observations is good for the research community, the nation, and the world.**

Slide 39

BKL0 I tried to streamline this a bit and break it up, since the original sentence was a bit hard to parse. Here is the original:

Despite budget challenges, a well defined strategy by NASA, NOAA and USGS that invests in new technology while maturing existing observations and eventually transitions them into the applications needed to adapt to a changing climate is good for the research community, the nation, and the world is achievable through the creative use of new technology and the right support

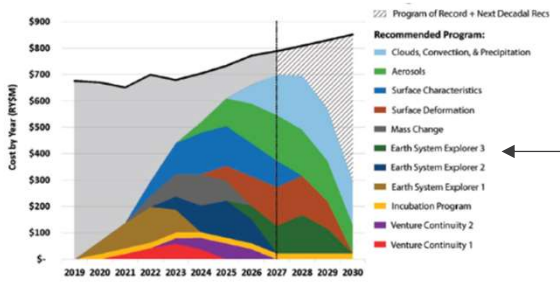
Bob, Kimberly L., 2024-07-10T15:15:09.133

BKL0 0 For now repaste recurring themes slide here

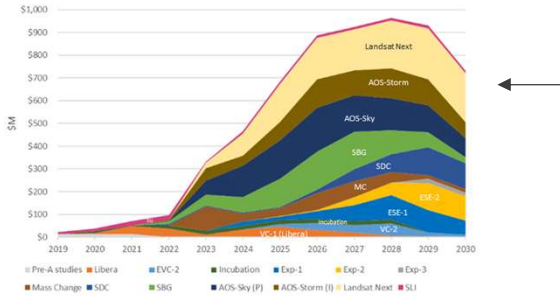
Bob, Kimberly L., 2024-07-10T17:14:44.095

Key Topics of Discussion

- The budget shortfalls



Working budget from decadal survey



Latest working budget presented to the committee, affected by:

- COVID-19
- Growth in Program of Record
- Landsat Next
- Delays in implementation

- NASA's best way forward to preserve the enthusiasm of the scientific community
- The increasing tension between the need for continuing measurements vs innovation

NATIONAL ACADEMIES Sciences Engineering Medicine

Finding: The decadal survey recommended a program that was implementable, balanced, and carefully considered to enable advances in Earth system science and applications from space within the resources that were stipulated to be available during the decade. (Chapter 1)

Finding: The broad scientific community surveyed as part of the current study is enthusiastic about new capabilities provided by Earth observing satellite missions. Among many scientific achievements, the fleet of existing and recently launched satellites and instruments has provided new capabilities to track and help understand methane leaks, sea-level rise, groundwater pumping, deforestation, wildfires, ocean surface topography, ocean primary productivity, and glacial outburst floods; and has enabled significant improvements in a variety of applications such as wildfire management, conservation of water resources, and risk reduction of extreme heat, flooding, and landslides. (Chapter 2)

Finding: The increased availability and variety of Earth observations has resulted in an exponential growth of their use to advance science and applications, support operational decisions, and address a broad myriad of societal needs. (Chapter 5)

Finding: Given the observed rapid pace of climate and environmental changes, the need for actionable information based on Earth observations is increasing rapidly, with a goal of informing society, assisting in the process of decision-making, and protecting society and human lives. (Chapter 2)

Finding: NASA ESD has had an essentially flat budget since 2015, despite the fact that mission costs are increasing. (Chapter 2)

Finding: NASA ESD's current funding level is inconsistent with societal needs and the urgency associated with widespread environmental changes and escalating cost of adaptation and mitigation efforts. It is evident that NASA ESD is being stretched as it attempts to address multiple competing priorities. In the context of a flat budget, priorities for science and technology innovation directly compete with needs to continue observations of Earth's changing climate which resulted from such innovation. (Chapter 2)

Recommendation: NASA should clearly articulate the substantial societal value and urgency of implementing the full set of 2017 Earth science and applications from space decadal survey (NASEM 2018) priorities as well as its need for appropriate resources to do so. It is imperative that the NASA Earth Science Division develop the framework to quickly assess and communicate what must be sacrificed when requirements imposed by its other stakeholders supplant the science and applications community's priorities as expressed in the decadal survey. (Chapter 2)

Finding: At current levels of funding, NASA cannot be expected to deliver on the needs for both providing long-term measurement continuity and new improved observations. In addition, while the decadal survey outlined steps to be taken if budgets for specific recommended program elements grew beyond their allocated targets, it could not account for new requirements levied upon the agencies by stakeholders other than the science and applications community during the decade. (Chapter 2)

Finding: NASA has effectively leveraged collaboration with international agencies for the greater benefit of the scientific community and society at large. (Chapter 2)

Finding: Consistent with decadal survey recommendations, NASA has worked effectively with international partners to explore implementation of Designated program element priorities. (Chapter 3)

Recommendation: NASA should expand funding opportunities for U.S. investigators to participate in and exploit data from international, interagency, and commercial endeavors. (Chapter 2)

Finding: Lacking resources to implement the recommended program in its entirety, NASA ESD has remained in analysis and evaluation mode rather than having made timely decisions to enable progress on what is implementable. (Chapter 3)

Finding: Communication of Landsat's importance and budget priority is not well-coordinated with communication of the larger NASA Earth science program's importance or budget. This can significantly and negatively impact other elements within NASA's Earth science program when Landsat's budget is directed to increase without an increase in the NASA ESD top line budget. (Chapter 3)

Recommendation: NASA ESD should take full advantage of its meetings with National Academies' Committee on Earth Science and Applications from Space to seek feedback on its implementation plans to facilitate more timely decisions and maintain alignment with decadal survey recommendations even as its budget fluctuates from year to year. (Chapter 3)

Recommendation: NASA's Earth Science Division should pursue funding needed to cover the increase in Landsat Next's scope and budget that was not anticipated at the time of the 2017 Earth science and applications from space decadal survey (NASEM 2018). Otherwise, the increased Landsat Next budget substantially limits resources available to achieve the Earth science vision laid out in the 2017 decadal survey. (Chapter 3)

Finding: Growth in individual program elements, without top line budget growth, does not support the healthy programmatic balance called for in the decadal survey. (Chapter 3)

Recommendation: Consistent with the 2017 Earth science and applications from space decadal survey (NASEM 2018) and the Earth System Observatory Independent Review Board recommendations (ESO IRB 2022), NASA's Earth Science Division should seek advice from the National Academies' Committee on Earth Science and Applications from Space prior to adding or substantially modifying individual program elements to ensure appropriate consideration of program balance and decadal survey priorities. (Chapter 3)

Recommendation: NASA's Earth Science Division should improve its communication with the community to provide the rationale for the decisions it makes particularly in the face of inadequate resources, including providing timely information about program plans, budgets, and anticipated solicitation timelines through town halls, webinars, and via the NASA website. (Chapter 4)

Finding: NASA has been uneven in its response to decadal survey recommendations and has not followed the decadal survey's decision rules regarding how to respond to budget pressures. (Chapter 3)

Finding: Neither the decadal survey nor the IRB recommendations have been consistently implemented across the Designated program element. (Chapter 3)

Recommendation: To address budgetary challenges, NASA should follow the guidance provided in the 2017 Earth science and applications from space decadal survey (NASEM 2018), retaining competitive opportunities in the Earth System Explorer and Earth Venture lines, and implementing the Designated program element missions to the extent possible within current constraints and consistent with the decadal survey's identified descopes. (Chapter 4)

Finding: Recent National Academies of Sciences, Engineering, and Medicine reports *Advancing Diversity, Equity, Inclusion, and Accessibility in the Leadership of Competed Space Missions* (NASEM 2022a) and *Foundations of a Healthy and Vital Research Community for NASA Science* (NASEM 2022c) found that NASA ESD has made substantial effort, yet shown limited progress, in enhancing workforce vitality and diversity, even relative to other divisions. (Chapter 5)

Finding: The lack of competed mission opportunities, including the reduced cadence of Earth Venture solicitations and the delay and reduction in number of Earth System Explorer calls, has limited opportunities to achieve or demonstrate progress on workforce development goals and DEIA objectives. (Chapter 5)

Recommendation: NASA's Earth Science Division (ESD) should better coordinate systematic diversity, equity, inclusion, and accessibility plans across all of its program elements, to provide holistic end-to-end support for underrepresented groups in Earth system science, and to ensure routine formal review. These plans should be supported by NASA's ESD with appropriate and sustainable budget allocations and include ongoing opportunities for training, principal investigator development, mission engagement at all career and leadership levels, and sharing best practices. (Chapter 5).

(This is also related to the Recommendation to retain competitive opportunities in Chapter 4).

While through the Sustainable Land Imaging (SLI) program NASA and USGS partner to ensure continuity of the 50-year Landsat record, Landsat Next goes substantially beyond providing simple continuity of the existing Landsat observations.

This increase in performance, however, comes at significantly increased cost to NASA for mission development and to USGS owing to the associated increased demands on ground system development, impacting other program elements at NASA and USGS.

The committee acknowledges the significant challenge of balancing the needs and priorities of users of an operational Landsat program with the priorities of the Earth system science and applications community as a whole. When substantial increases to Landsat Next are not accompanied with an overall budget increase, the result is a significant impact on the rest of the program. NASA ESD should pursue funding needed to cover the increase in Landsat Next's scope and budget that was not anticipated at the time of decadal survey. Otherwise, the increased Landsat Next budget substantially limits resources available to achieve decadal survey priorities.

Finding: Progress on the SBG Targeted Observable has been promising overall. The success of EMIT (VSWIR) and ECOSTRESS (Thermal Infrared [TIR]) onboard the International Space Station have demonstrated the promise of SBG, and NASA is proceeding to address the decadal survey's SBG recommendation through two missions: SBG-VSWIR and SBG-TIR. The latter is to be implemented as a partnership with the Italian space agency (Agenzia Spaziale Italiana [ASI]). SBG-TIR is proceeding while SBG-VSWIR is being delayed. It would be more cost-effective and maximize science benefits to proceed with both SBG-VSWIR and SBG-TIR missions without further delay. (Chapter 3)

Finding: While the IRB noted the benefit of overlap between SBG and AOS-P and AOS-I and recommended that NASA investigate opportunities for aligning launch dates, an unnecessary delay in the launch of SBG-VSWIR will be detrimental to SBG objectives that need both VSWIR and TIR data. The relative benefit of aligning launch dates between AOS and SBG is insufficient to justify delay of SBG. (Chapter 3)

Finding: The SBG mission is in a position to deliver success within ESD's limited budget. Proceeding with both SBG-VSWIR and SBG-TIR missions without further delay will minimize cost and achieve maximum science benefit. (Chapter 4)

Recommendation: NASA's Earth Science Division should proceed with both the Surface Biology and Geology (SBG)-Visible to ShortWave InfraRed and SBG-Thermal Infrared missions without further delay in order to minimize cost and maximize achievable overlap. (Chapter 4)

Finding: The AOS baseline capabilities exceed those required to meet the decadal survey recommendations, resulting in higher costs to the program which could negatively impact other decadal survey priorities. (Chapter 3)

Recommendation: NASA should fully implement the 2017 Earth science and applications from space decadal survey's (NASEM 2018) prescribed descopes for the Aerosols and Clouds, Convection, and Precipitation Targeted Observables, adding two Earth System Explorer solicitations to the program with Targeted Observable 1 (TO-1) and TO-2 eligible to compete and pursuing a simpler single band radar mission responsible to TO-5. (Chapter 4)

Finding: Costs for GRACE-C are higher than the maximum decadal survey recommended investment for the Mass Change Targeted Observable. Some cost growth was driven by increased performance demands from stakeholders owing to the missions' large number of applications and others by IRB recommendations to reduce risk. (Chapter 3)

Recommendation: While it is appropriate to implement the GRACE-C (Gravity Recovery and Climate Experiment-Continuity) mission on its current timeline, NASA should identify a long-term solution for achieving measurement continuity beyond GRACE-C at lower cost to the agency. (Chapter 4)

Finding: The mission architecture for addressing the SDC Targeted Observable following the NISAR mission remains undefined because no options identified to date meet the cost cap while also addressing the decadal survey's priority science and applications objectives. (Chapter 3)

Recommendation: NASA should engage with the European Copernicus program to explore ways to meet the science objectives tied to the Surface Deformation and Change Targeted Observable through a potential collaboration. Unmet science and continuity objectives should be re-evaluated once NISAR (NASA-IRSO [Indian Space Research Organization] Synthetic Aperture Radar) data becomes available. (Chapter 4)

Finding: The cadence of NASA's Earth System Explorer solicitation opportunities is not consistent with decadal survey recommendations. Instead of three solicitation spaced throughout the decade, NASA is planning to select two missions from a single solicitation. (Chapter 3)

Finding: Incubation programs for the PBL and STV Targeted Observables are worthwhile and working well overall, facilitating coordination among the associated science and applications communities, improving understanding of related measurement and modeling needs and priorities, and advancing related technologies. (Chapter 3)

Finding: Reducing the number of solicitation and waiting to define them until closer to solicitation time provides programmatic flexibility but does not serve to provide the community with either routine, frequent open call opportunities, or an ability to plan ahead. The lack of opportunity of competing for Earth Venture and Earth System Explorer missions in 2024 and 2025 also makes it difficult to sustain a culture of innovation and creativity among the Earth observations from the space community, as recommended int eh decadal survey. (Chapter 3)

The following activities are seen as critical for organizing the community in advance of the next Decadal Survey

Recommendation: Prior to the next decadal review, NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey should engage a broader Earth sciences constituency by

- Identifying Earth observation stakeholders, improving understanding of their short- and long-term needs and encouraging participation of the community of stakeholders in the next decadal survey. These stakeholder groups should include both the scientific community and communities impacted by climate change, including historically marginalized and underrepresented groups that are often disproportionately impacted.
- Sponsoring workshops to engage the entire Earth system community to better address observational needs for interdisciplinary and crosscutting issues. The workshops should
  - Gather input on priorities,
  - Communicate expected program resource constraints to help set expectations,
  - Sensitize participants to the need for working within a holistic Earth system science rather than disciplinary framework when considering implementation options,
  - Support development of brief reports outlining community progress and expressing observation needs at discipline and crosscutting topic area levels (e.g., sea level, modeling), and
  - Ensure systematic representation of interdisciplinary topics to ensure they do not fall through the gaps in community organization. (Chapter 5)

Finding: Strengthening the interaction between the flight planning, satellite data analysis, and Earth system modeling communities would enhance the use of satellite data for model assimilation and evaluation, inform the improvement of model parameterizations, and facilitate the development of high resolution digital replicas of the Earth system to support applications. (Chapter 3)

Finding: Engagement of the Earth system modeling communities is needed to ensure that future satellite missions enable improvements in prediction across the range of time and space scales that are influenced by climate-related and natural hazards. (Chapter 5)

Recommendation: Through requests for information and workshops, NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey should more actively engage the Earth system modeling community to devise strategies to more fully exploit existing and potential Earth observations for advancing model parameterizations and predictions. (Chapter 5)

Finding: Despite the decadal survey's recommendation that NASA ESD lead development of a more formal continuity decision process, current ESD decisions with regard to observation continuity remain ad hoc and do not generally communicate what future observations will be prioritized or how budgets need to expand in order to accommodate new and sustained observations. (Chapter 5)

While there is no new recommendation based on this finding, there is an urgent need to follow Recommendation 4.6 from the Decadal Survey, including its call to "ensure that no flight program element is compromised by overruns in any other element" and "lead development of a more formal continuity decision process (as in NASEM, 2015) to determine which satellite measurements have the highest priority for continuation, then work with U.S. and international partners to develop an international strategy for obtaining and sharing those measurements."

Briefing Timeline

- June 26, 2024 - NASA Briefing
- July 8, 2024 - NOAA Briefing
- July 8, 2024 - USGS Briefing
- July 9, 2024 - Congressional Committees Briefing
- July 10, 2024 - Report is officially published
- July 11, 2024 - Public Briefing

Statement of Task

The National Academies of Sciences, Engineering, and Medicine (NASEM) shall convene an ad hoc committee to review the responses from NASA, NOAA, and the USGS earth observations programs to the 2017 decadal survey, "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space." The committee's review will include the following tasks:

1. Highlight the most significant scientific discoveries, technical advances, and relevant programmatic changes in Earth science and applications over the years since the publication of the decadal survey. Describe any significant changes in the scientific and operating environment specifically related to Earth Observations that should be considered as NASA, NOAA and the USGS move forward in implementing the decadal survey.
2. Assess the degree to which the programs of NASA, NOAA and the USGS address the strategies, goals, and priorities outlined in the 2017 decadal survey and other relevant National Academies reports, including the impact of legislative or national policy directives.
3. Assess the progress toward realizing these strategies, goals and priorities.

Statement of Task

4. Assess and provide guidance on impact and effectiveness of Earth science programs (including research, applications, data systems and technology) in implementing the decadal survey recommendations, synergies, and portfolio balance.
5. Recommend actions that could be taken to optimize the full breadth of NASA's Earth science programs during the remaining decadal interval. Consider current and forecasted resources, progress on decadal missions, coordination with entities external to NASA including other agencies, international partners, and science and technology advances from the study groups examining implementation of the survey-recommended "targeted observables".
6. Recommend any actions that NASA, NOAA and the USGS should undertake to prepare for the next decadal survey, including information, observables, pathfinders, or technology.
7. Comment on NASA efforts since the last survey to enhance the vitality and diversity of the scientists and engineers who work on programs sponsored by NASA Earth Science Division (ESD) and recommend actions that might be taken to enhance progress in these areas.

In conducting these tasks, the committee shall not revisit or redefine the scientific priorities or recommended targeted observables, unless indicated by superseding legislative or national policy directives.

Community RFI Questions

1. What do you consider to be the most significant recent scientific and applications-related discoveries and technical advances relevant to Earth science and applications from space that the committee should consider in its assessment?
2. What have the agencies done well in response to the 2017 decadal survey's recommendations, and where have there been challenges?
3. What changes in the operating environment have occurred since 2017 that would have impacted the decadal survey's recommendations?
4. What actions could be taken now (mid-term) to improve the agencies' implementation of the 2017 decadal survey's recommendations?
5. What actions might the agencies and/or community take to enhance the talent pool of scientists and engineers who will take leadership roles in the next generation of Earth science missions?
6. What specific actions or activities would you suggest the agencies undertake to prepare for the next decadal survey?

Open Meeting #1

- Karen St. Germain, NASA
- Waleed Abdalati, University of Colorado Boulder
- Scott Braun, NASA Goddard Space Flight Center
- Tim Newman, USGS
- Steve Volz, NOAA

Open Meeting #2

- Fran Bagenal, University of Colorado Boulder
- Wanda Ward, University of Illinois Urbana-Champaign
- Charlie Bolden, The Charles F. Bolden Group LLC
- Wanda Sigur, Lambent Engineering LLC
- Duane Waliser, Jet Propulsion Laboratory
- Dave Schimel, Jet Propulsion Laboratory
- Paul Rosen, Jet Propulsion Laboratory
- Frank Webb, Jet Propulsion Laboratory
- Tim Newman, USGS

Open Meeting #3

- Gerald Bawden, NASA
- Steven Hamburg, Environmental Defense Fund
- Joe Mascaro, Planet Labs PBC
- John Worden, Jet Propulsion Laboratory
- Mauro Facchini, European Commission

Open Meeting #4

- Karen St. Germain (NASA)